HYBRID BREEDING IN OKRA

[*Abelmoschus esculentus* (L.) Moench]

THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Doctor of Philosophy

in

Horticulture

Supervisor
Prof. Anil Kumar Singh

by
Shashank Shekhar Solankey

DEPARTMENT OF HORTICULTURE
INSTITUTE OF AGRICULTURAL SCIENCES
BANARAS HINDU UNIVERSITY
VARANASI – 221 005
INDIA

I.D. No. PH-0621 2010 Enrolment No. 293163

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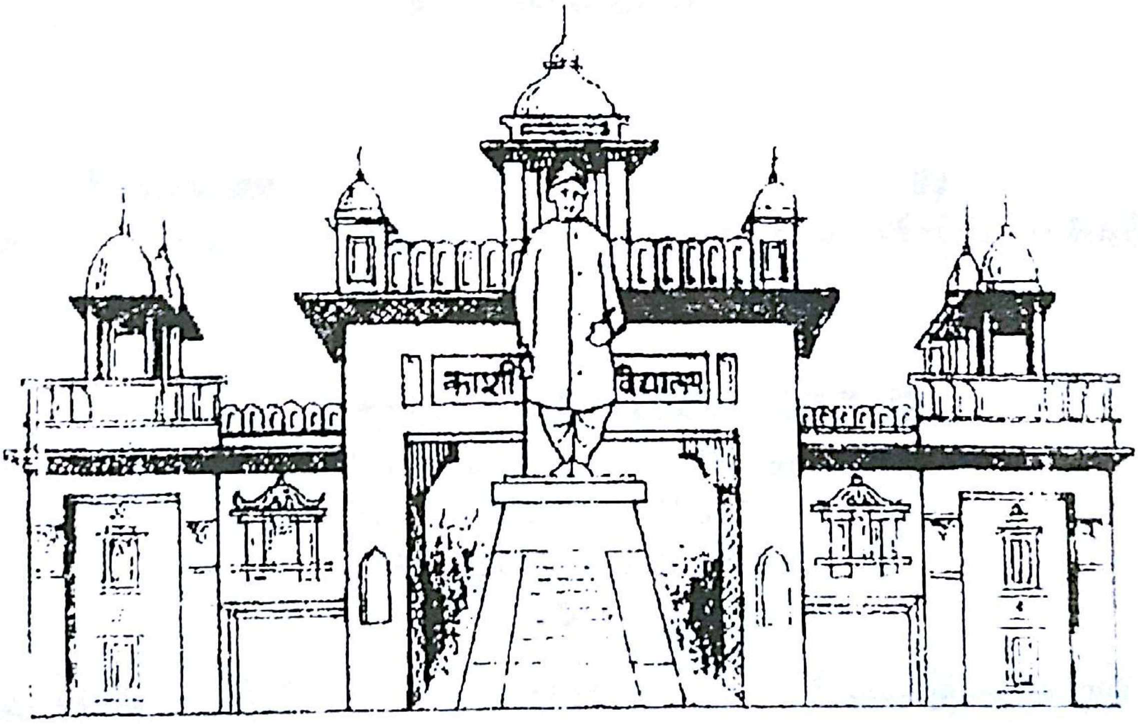

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I, Shashank Shekhar Solankey, research scholar under the supervision of Dr. Anil K. Singh (Professor), Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, give undertaking that the thesis entitled **"Hybrid breeding in okra [*Abelmoschus esculentus* (L.) Moench]"** submitted by me for the degree of Doctor of Philosophy is a record of first hand research work done by me during the period of study.

I avail myself to responsibility such as an act will be taken on behalf of me, mistakes, errors of fact and misinterpretations are of course entirely my own.

Date: 27th April, 2010
Place: Varanasi

Shashank Shekhar Solankey
(Shashank Shekhar Solankey)

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I, Shashank Shekhar Solankey, certify that the work embodied in this Ph.D thesis is my own bonafide work carried out by me under supervision of Dr. Anil K. Singh (Professor) for a period of July 2006 to April 2010 at Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University Varanasi. The matter embodied in this Ph.D. thesis has not been submitted for the award of any other degree/diploma.

I declare that I have faithfully acknowledged, given credit to and referred to the research workers wherever their works have been cited in the text and the body of the thesis. I further certify that I have not willfully lifted up some other's work, para, text, data, results, etc. reported in the journals, books, magazines, reports, dissertations, thesis, etc., or avail at web-sites and included them in this Ph.D. thesis and cited as my own work.

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Supervisor's Signature
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HYBRID BREEDING IN OKRA
[*Abelmoschus esculentus* (L.) Moench]

Thesis submitted in partial fulfillment of the requirements for the award of the degree of

Doctor of Philosophy
In
Horticulture

2010

by

Shashank Shekhar Solankey

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My ecstatic thanks are due to my respected teachers, Prof. B.P. Singh, Prof. B.K. Singh, Prof. M.M. Syamal and Dr. Anand K. Singh for their valuable suggestions and timely help.

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Lastly, I bow at the feet of "Lord Shiva" with whose omnipresent blessing today on the eve of completion of my thesis. This is a long adventurous journey to the unknown destination with a hope for future. I was not alone in this journey, to accomplish this Herculean task. Today is one of delightful moments of my life. I am in position to acknowledge all those, who helped me a lot to cross the way, in finishing the marathon work.

Shashank Shekhar Solankey

Date: 27/04 /2010
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(Shashank Shekhar Solankey)

Contents

ABBREVIATIONS

Abbreviation	Full form
%	Per cent
°C	Degree Centigrade
a.m.	Antemeridian
AA	Arka Anamika
BP	Better Parent
CV	Coefficient of variation
DF	Degree of freedom
e.g.	For example
et al.	Co-authors [et allii]
etc.	et cetera [and so on; and other]
F_1	First filial generation
g	Gram
GA	Genetic Advance
GCA	General combining ability
GCV	Genotypic coefficient variance
GN	Grand mean
Hrs.	Hours
i.e.	That is [id est.]
Kg.	Kilogram
m	Meter
Max.	Maximum
mg	Milligram
Mh.	Million hectare
Min.	Minimum
MS	Mean sum of square
MSE	Mean sum of square due to error
N	North
p. / pp.	Page(s)
p.m.	Postmeridian
PCV	Phenotypic coefficient variance
PK	Prabhani Kranti
PS	Pusa Sawani
PSS	Sum of square due parent
R	Rainy
RBD	Randomized Block Design
RSS	Sum of square due to replication
S	South
S	Summer
S.S.	Sum of square due to F_1 hybrid
SCA	Specific combining ability
SE	Standard error
SS(e)	Sum of square due to errors
SS(I)	Sum of square due to lines
SS(It)	Sum of square due to lines × tester
SS(t)	Sum of square due to tester
St.	Station
SV	Standard variety
t ha^{-1}	Tonnes $hectare^{-1}$
TSS	Total sum of square due to treatments
viz.	Videlicet; read as namely
Vs	Versus
YVMV	Yellow vein mosaic virus

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PREFACE

Since this thesis is written as the final thesis for doctorial degree in Horticulture and primarily aimed to understand the application of hybrid breeding in crop improvement and I hope it will be of interest of horticulturists and vegetable grower for boosting the vegetables on the whole vegetable seed industry too in the future. In hybrid breeding heterosis refers to the superiority of F_1 hybrid in one or more characters over its parents. Heterosis leads to superiority of F_1 in adaptation, yield, quality, disease resistance and general vigour over its parents. Generally, positive heterosis is considered as desirable, but in some cases of okra negative heterosis is important for characters like days to first flowering, days to 50 per cent flowering, first flowering node and disease reactions. The study of heterosis reveals the possibility of commercial exploitation of hybrid vigour. It is also help the breeders in eliminating them to concentrate their attention to the few but more productive crosses. Line × tester analysis is a modified form of top cross, provides information on general combining ability (GCA) and specific combining ability (SCA) effects and variance. This technique also provides information on heterosis, heritability and genetic advances. It is a good approach for screening the germplasm on the basis of general and specific combining ability effects; to understand the nature of gene action involved in the expression of various quantitative traits.

The work described in this thesis was carried out between March, 2007 to May, 2008 at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University under the supervision of Dr. Anil K. Singh (Professor) Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University Varanasi.

Chapter 1 the introduction part which provides much of the general background and an overview of current situation of vegetable production in the country. This chapter justifies the purpose for choosing this research topic, importance of vegetable like okra, combining ability, heterosis, heritability, genetic advance, gene action and genetics of resistance against yellow vein mosaic virus under field conditions and objectives of the research work.

Chapter 2 the review of literature deals with the findings of hybrid research related work done by scientists from time to time in the past.

Chapter 3 the materials and methods deals with the methodology employed for carrying the research work and the details of treatments and methods for statistical analysis.

Chapter 4 the experimental findings deals with the results of this research work illustrated with the help of tables.

Chapter 5 the discussion which explains the results obtained with appropriate reasons and support.

Chapter 6 the summary and conclusion gives brief description of the results of the investigation and the conclusion drawn from this investigation.

References deals with citation which has been consulted during the course of investigation.

Chapter I

INTRODUCTION

In Indian agriculture, vegetables are important components due to their productivity, use in diversification, nutritional and medicinal values, and export potential. In India largest number of vegetable crops grown as compared to any other country of the world, and as many as 61 annual and 4 perennial vegetable crops are commercially cultivated. Vegetables form the most nutritive menu of human diet and tone up energy and vigour because these are valuable source of carbohydrates, proteins, vitamins, minerals and have antioxidants property. They also contain varying proportion of crude fiber as well as a variety of flavours and odours.

According to ICMR about 300 g vegetables (125 g leafy vegetables, 100 g root and tuber vegetables and 75 g other vegetables) per capita per day required (Thamburaj and Singh, 2001). Vegetables and fruits are the only natural sources of protective food supplying all the nutrients especially minerals, vitamins and crude fiber. The regular consumption of vegetables consistently decreased the level of cholesterol, provides protection against respiratory diseases and intestinal disorders reduces accumulation of carcinogenic substances and slows down against of the human body.

Now, India has emerged as the second largest producer of vegetables after China. The total area covered under vegetable crops is about 7.8 million hectare and the total production of vegetables has gone up from 58.5 to 125.89 million tonnes, over a period of 17 years from the year 1991-92 to 2007-08. (Anonymous, 2008). Annual growth rate of vegetable production in the country is around 2.6 per cent. It is estimated that in 2020 the demand of vegetables would be around 220 million tonnes/annum (Singh, 2004). For coping with the future challenges, the primary need is to evolve high yielding and disease resistant varieties also with development of approximate production technology that will results to enhance the productivity is required.

India is the largest producer of okra in the world. In India, the total area covered under okra is 0.41 million hectare and production is 4.19 million tonnes green pods, whereas productivity of the crop is 10.3 metric tones per hectare. Among the vegetables, contribution of okra is 5.2 per cent in area and 3.3 per cent in production. West Bengal is leading state in area and production of okra, while Andhra Pradesh in productivity (Anonymous, 2008).

Okra, or lady's finger, is a flowering plant with small green pods in the malvaceae (from the genus Mallow, altered from the Greek, in allusion to the mucilaginous emollient qualities), originating somewhere near present day Ethiopia. The word okra is of West African origin and is cognate with "ókùrù" in Igbo (Bailey, 1963). It is an important vegetable crop in the tropics because of its easy cultivation, dependable yield, adaptability to varying moisture conditions and popular among consumers. This crop is suitable for cultivation as a garden crop as well as on large commercial farms. Yet another species, *A. manihot* (ssp. *manihot* 'Guinean' type), is cultivated for its green fruits in the humid tropics in West Africa. Okra is an often cross pollinated vegetable with a high chromosome number of 2n = 120 to 132 (Fryxell, 1957) which, appears to have originated in South Africa or Asia (Thompson and Kelly, 1957). About 40 species have been described by taxonomist under the genus *Abelmoschus.* Zeven and Zhukovasky (1975) also believe that okra originated from India. This view gets its strength from the Sanskrit words Tindisha and Gandhmula found to designate *Bhindi.* Thus it is likely that cultigens might have originated in Asia or it might originally have been present in Africa and India as a polyphyletic species (Joshi and Hardas, 1976).

Okra is extensively cultivates as a warm/Summer and Rainy season crop in North India and as winter crop in Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. It is basically a self pollinated crop but natural cross pollination (NCP) to an extent of 8.75 per cent may also occur so, it comes under often cross pollinated crop (Purewal and Randhawa, 1947).

The species is an annual, herbaceous, growing to 2 m tall. The leaves are 10-20 cm long and broad, palamately lobed with 5-7 lobes. The flowers are 4-8 cm diameters, with five white to yellow petals, often with a red or purple spot at the base of each petal. The fruit is a capsule up to 18 cm long, containing numerous seeds. Herbs, shrubs or trees, with alternate, simple, usually palmately veined leaves: flowers bisexual, regular; sepals 5, often united, valvate, frequently bracteolate at the base; petals 5, convolute, often adnate to the stamens; stamens very numerous, hypogynous, the filaments united into a tube (monadelphous), anthers 1-celled, pollen spiny; ovary superior, 2 to many-celled, rarely 1-celled; ovules in each cell 1 to many; styles and stigmas usually as many as the carpels: fruit a capsule or separating into drupelets, very rarely fleshy.

It is used in various preparations such as curries, stew, fried and cooked into soups (Tindall, 1986). It can also be canned and dried to be used in off-season. Matured fruits and stem contain crude fiber, which are used in paper industry and purifying cane juice in jaggery making. It is said to be very useful against genitor-urinary disorders, spermatorrhoes and chronic dysentery (Nandkarni, 1927). Okra is an economical source of calcium, iron, and proteins, vitamins i.e. A, B and C with other minerals. Fruit contains 6.60 to 10.40 per cent crude fiber, 84.60 to 90.50 per cent edible protein, 14.40 to 18.60 per cent protein and 8.20 to 9.16 per cent ash of the total weight. Among minerals, calcium ranges from 99.00 to 198.00 mg/100g, phosphorous from 34.50 to 56.00mg/100g and iron from 0.80 to 2.40 mg/100 g of edible portion (Singh *et al.*, 1974).

Okra specially valued for its tender and delicious fruit in different part of the country and are generally marked in the fresh state, but sometimes in canned or dehydrated from. Its fruit which are rich in vitamin-A (88 µ/100g), vitamin-C (13 mg/100g), calcium (66 mg/100g), potassium (103 mg/100g) and other minerals (Aykroyd, 1963) are cooked and consumed in a variety of ways. It is fried in butter or alone or with other vegetables for preparation of various dishes. Indian cooking, it is sautéed or added to gravy-based preparation and is very popular in South India. Okra leaves may be cooked in a similar manner as the green of beets or dandelions. Okra seeds may be roasted and ground to from a non-caffeinated substitute for coffee. Dry seeds of okra contain 18-20 per cent oil and 20-23 per cent crude protein. It has great medicinal values. It has been reported to have an average nutritive value (ANV) of 3.21which is higher than tomato, eggplant and most of cucurbits except bitter gourd (Grubben, 1977). Besides this it has a tremendous export potential as fresh vegetables and accounts for about 60 per cent exchange, other than potato, onion and garlic, from export of vegetables.

In okra so many varieties have been developed but substantial increase in productivity potential could not be realized probably due to genetic potential ceilings of the genotypes. Thus, there is an urgent need of genetic improvement of the crop for yield which can be done by exploitation of hybrid vigour (heterosis), breeding for efficient plant type and component breeding. The genetical studies revealed that yield and its components is most assessing in nature and magnitude of gene effect is important for increasing the yield potential. Exploitation of heterosis has been attempted and hybrid vigour has been reported with as much as 86 per cent increase yield (Elmaksoud *et al.,* 1986).

The main objectives of crop improvement include the development of early maturing, high yielding, insect and disease resistance varieties along with other desirable quality attributes like good fruit shape and size besides fresh texture. In most of the developed countries like U.S.A. and Japan mainly F_1 varieties are under cultivation on commercial scale instead of open pollinated varieties. Exploitation of hybrid vigour by inter varietal hybridization has been very promising attempt to increased the production of other vegetables in India, but good success has not been made so for in this crop. However, during past decades much work has been done on the study of hybrid vigour in okra and high heterosis has been reported by many workers (Ahmed *et al.*, 1999; Sood and Sharma, 2001; Mamidaw and Nandan, 2006 and Desai *et al.*, 2007). Some private seed companies of India are marketing the seeds of hybrid varieties of okra (Varsha, Vijay and Vishal from IAHS, Adhunic and Panchali from Century, H-7, H-8 and H-10 from MAHYCO and S-45 from Sungro) but these hybrids could not gain popularity among the farmers as well as consumers. Therefore, there is almost need to develop a hybrid variety possessing high heterosis over standard variety (economic heterosis), along with other desirable traits, to grow on commercial scale.

The heterosis breeding programme intended to develop a hybrid variety involves analysis of combining ability, identification of desirable parents producing F_1 hybrid having high level of economic heterosis and to determine nature and magnitude of gene action through the estimation of genetic components. Thus, it is helpful in the selection of suitable parent for hybridization and also choosing the appropriate breeding procedure for the crop improvement. So many mating design are adopted to evaluate the genotypes for their combining ability attributes but line × tester (L × T) has been found most suitable to test more number of genotypes at a time for the general and specific combining ability effects (Kempthorne, 1957).

The correlation coefficient measures the mutual relationship between two or more variable and gives an idea about the various associations existing between the yield and yield components. Correlation coefficient between a pair of characters is either positive or negative and it may be high or low. Estimation of correlation coefficient among the yield contributing variables is necessary to understand the direction of selection and to maximize yield in the shortest period of time. Genetic correlation indicates the relative importance of character(s) on which greater emphasis should be made in selection for yield. However, as the number of variables in the correlation study increases the direct and indirect association between yield and particular component character becomes complex. It only reveals the direction and magnitude of association between any two characters but the path coefficient analysis helps in partitioning the correlation into direct and indirect effects of various yield components on yield.

Wright (1921) gave the theory of path coefficient for statistical analysis of cause and effect, which gives a critical examination of specific forces to produce a correlation. Therefore, correlation studies coupled with path coefficient analysis are a powerful tool to study the character association and their final impact on yield, which help the selection procedure accordingly. Path coefficient analysis which determines the cause and effect relationship has been found useful in splitting the correlation into its direct and indirect effects contributing to yield.

The great extent of natural variation present in various characters among the varieties of okra suggests good scope of improvement in economic traits through conventional breeding techniques. During recent past, much breeding efforts have been put to develop promising okra varieties possessing high yield, better quality and resistance to diseases especially yellow vein mosaic virus. To break yield ceiling, exploitation of hybrid vigour and selection of parents on the basis of combining ability has been an important breeding approach in crop improvement. In okra although, several reports on the extent of heterosis and combining ability are available (Pratap *et al.,* 1981 and Poshiys and Shukla, 1986).

The study of heterosis reveals the possibility of commercial exploitation of hybrid vigour. It is also help the breeders in eliminating them to concentrate their attention to the few but more productive crosses.

An understanding of the nature and magnitude of the character associations in segregating and non-segregating generations is useful in achieving desire improvement through selection and also in determining the criteria of selection for developing most productive genotype.

In okra, yellow vein mosaic virus is very devastating disease, the total loss of vegetable on this account has been estimated up to 20 - 30 per cent but if the pathogens are allowed to develop, this loss may increase up to 80 - 90 per cent yield losses depending on the stage of crop growth at which infection occurs (Hamer and Thompson, 1957). In case of hybrids disease incidence ranged from 19.26 - 69.13 per cent, whereas, on parent plants, it ranged from 19.95 - 51.16 per cent (Choudhary *et al.,* 1992). Yellow vein mosaic virus is transmitted by white fly (*Bemisia tabaci*) belonging to order Hemiptera. Long back okra cultivar Pusa Sawani, was developed as a tolerant to YVMV by using a resistance gene from strain IC-1542 (Singh and Joshi, 1960) and now become susceptible. Most of our present day varieties are susceptible to YVMV. Thus a pressing demand for a developing a variety which not only possess high yield trait but also resistant to

YVMV as well. Therefore, it is necessary to evolve high yielding, disease and insect pest resistant varieties or hybrids to its high yield potential, earliness, quality and resistant attributes to meet the demand of increasing population. Study was also undertaken to transfer genes for tolerance to YVM from related wild species to susceptible cultivated varieties (Nerkar and Jambhale, 1985).

Keeping in view of the above, present investigation, "Hybrid breeding in okra [*Abelmoschus esculentus* (L.) Moench]" was planned and carried out using 20 parents (17 lines and 3 testers) and their 51 F_1's of okra. The genetic information about genetic variability, heritability, general and specific combining ability effects through line × tester analysis, heterosis over better and standard parent, correlation coefficient, path analysis, resistancy against YVMV and gene action for yield and yield attributing traits. The findings of this study would be helpful in the selection of promising F_1 hybrids for yield and other characters and to formulate appropriate breeding programme for achieving the desired genetic improvement in okra.

Objectives

1. To estimate general and specific combining ability variances their effects.
2. To estimate heterobeltiosis and standard heterosis for different characters.
3. To study the variability, heritability and genetic advance.
4. To estimate the correlation coefficient and path coefficient analysis among the different economic traits, under study.
5. To study the genetics of resistance against yellow vein mosaic virus.
6. To elucidate the nature of gene action for yield and yield attributing traits.

*****

Chapter II

REVIEW OF LITERATURE

Extensive studies on the genetic, cytogenetic and the breeding aspect have been made in the past in okra [*Abelmoschus esculentus* (L.) Moench]. A brief account of literatures available on okra pertinent to present investigation has been reviewed under the following sub-heads:

2.1 Combining ability

2.2 Hybrid vigour/heterosis

2.3 Variability, heritability and genetic advance

2.4 Correlation and path coefficient analysis

2.5 Genetics and inheritance pattern of yellow vein mosaic virus (YVMV)

2.6 Nature and magnitude of gene action for yield and its components

2.1 Combining ability

The combining ability analysis concept has been the most important and efficient tool for choosing the desirable parents. Identification of genetically superior parents is pre-requisite for the development of superior genotypes and the high yielding hybrids.

Several techniques have been evolved for the estimation of combining ability by different workers has used several methods. Among them polycross (Tysdal *et al.,* 1942), line × tester (Kempthorne and Curnow, 1961) and triallel cross (Rawling and Cockerham, 1962) have most commonly used.

Line × tester (L × T) approach is the second important bifactorial design for combining ability analysis the first being diallel. But under the former use can accommodate and screen out more number of parents with same amount of work.

The concept of general and specific combining ability was given by Sprague and Tatum (1942). They were first to define the performance of parents and crosses in terms of combining ability and coined the term general combining ability (gca) for average performance of the lines in a series of hybrid combinations while specific combining ability (sca) was referred to those cases in which certain crosses do relatively better or worse than would be expected on the basis of general combining ability of the parents involved. Further, they concluded that general combining ability is primarily due to additive effect of genes, while specific combining ability is the consequence of intra-allelic (dominance) and inter-allelic (epistasis) interactions.

Henderson (1952) also defined general combining ability as the average merit of large number of progenies of the individual line when mated with a random sample, whereas, specific combining ability was defined as little deviation from an average of an significantly large number of progenies of two individual or lines from the values expected on the basis of known general combining ability involves only dominance. He further remarked that specific combining ability is mainly a measure of dominance and epistatis in unselected and selected materials, respectively.

Griffing (1956a) reported that general combining ability contains for the most part additive effects as well as additive × additive type of epistasis, while specific combining ability involves both dominance and epistasis.

Arunachalam (1974) has opined that in line × tester analysis the combining ability of parental line (l) is judged by the performance of ‘S’ hybrids in which ‘t’ is the tester parent. The precision of estimation increases with the increase in‘t’ and ‘l’.

Sharma and Mahajan (1978) advocated that in a line × tester analysis of combining ability and heterosis in okra, the parents “Pusa Sawani” and “Clamson Spineless” exhibited the highest combining ability.

Singh and Singh (1979) reported that in a line × tester analysis in okra involving 12 varieties; high × high and high × low crosses seemed to be potential material for breeding work. The cross, 7107 × 6313 could be utilized for developing high yielding lines by selection and for exploiting hybrid vigour.

Pratap *et al.* (1981) evaluated the crosses through seven parents (IC-6653, IC-6316, Pusa Sawani, Natural Collection, Dwarf Green Smooth and Sel-2) half-diallel for yield, earliness and quality traits in okra. The variance of gca and sca were highly significant for all the characters except yellow vein mosaic virus disease incidence and fruits per plant.

Thaker *et al.* (1981) reported that general combining ability variance for some components of yield was high in EC-6875 (fruits length), IC-18960 (fruit length and weight) and IC-19974 (single fruit weight). The combination of IC-18960 × IC 18974 showed promise as initial material for breeding.

Poshiya and Shukla (1986) studied yield and 5 related characters in a diallel cross of 7 varieties of okra and they observed significant general and specific combining ability effects for days to 50 per cent flowering, fruit length, number of fruits per plant and nodes on the main stem.

Shukla *et al.* (1989) observed that out of 3 male parents (cvs. Pusa Sawani, Prabhani Kranti and P-7), Prabhani Kranti had high general combining ability for fruit yield/plant and length of fruit. Among sixteen elite liens of female parents, IC-52339 had the highest general combining ability for fruit yield per plant and days to flowering, cv. Punjab Padmini for length of fruit, KS-310 and Reshmi for number for fruits per plant. Estimates of specific combining ability showed that the best cross combination for yield was IC-122 × Prabhani Kranti.

Jawili and Rasco (1990) revealed the information provided from data on 19 characters in 6 parents and their 15 F_1 hybrids grown at Los Banos in 1989. The cultivar Smooth Green was the best combiner for almost all the traits.

Chaudhary *et al.* (1991) evaluated 15 F_1 hybrids along with 8 parents *viz.* Pusa Sawani. Selection 6-2, Selection-2, Pusa Makhmali and 67/82/26 as females P-7, Prabhani Kranti and Punjab Padmini as males. The line Pusa Makhmali and the tester, Punjab Padmini proved to be good general combiners for yield and yield components. The most promising F_1 hybrid was Pusa Sawani × P-7, because it had the highest sca for yield per plant, fruits per plant and days to first flowering.

Shukla *et al.* (1993) crossed 16 lines as females with three testers' *viz.* cv. Pusa Sawani, Prabhani Kranti, Punjab-7 as males. The estimates of gca indicated that among females, Sel-2 was the best general combiner for fruit yield per plant, cv. Reshmi for number of branches and 100 seed weight and IC-52392 for diameter of fruit, whereas, among males cv. Pusa Sawani was found best general combiner for fruit yield, diameter of fruit and P-7 for number of branches. The specific combining ability estimates indicated that crosses IC-12205 × Prabhani Kranti and KS-315 × Pusa Sawani for the number of branches were desirable and may be utilized for exploitation of hybrid vigour.

Patel *et al.* (1994) reported the GCA: SCA ratio had predominance of non-additive gene action for dry seed yield/plant, number and weight of seeds/pod and 1000-seed weight, and additive for the remaining characters. The cultivar Gujarat Bhindi was the best general combiner for dry seed yield/plant and 1000-seed weight.

Vasline and Ganesan (1995) noted that the 15 parents and 36 hybrids from a 12 line × tester cross of *Bhindi* (*Abelmochus esculentus*) were evaluated for fruit length, fruit circumstances and number of fruits/plant and weight of fruit/plant. Combining ability analysis indicated that there was no significant relationship between parental performance *per se* and general combining ability and specific combining ability effects. The parental lines AE-110 and AE-158 were good general combiners for a combination of traits. The hybrid Pusa Sawani × CO-2 was promising based on specific combining ability effect and *per se* performance.

Dhankar *et al.* (1996) observed combining ability in okra by crossing 10 line with 3 testes (cvs. Pusa Sawani, Prabhani Kranti and Punjab-7). They reported that the parent Raj-12 for fruit number, yield and number for branches per plant for earliness and diameter of fruit; cv. Prabhani Kranti for length of fruit and plant height exhibited high general combining ability effects. They advocated that cross Raj-12 × Prabhani Kranti yield be exploited through heterosis breeding.

Patil *et al.* (1996) studied GCA of 10 lines of okra (*Abelmochus esculentus*) and SCA of their 45 direct crosses for 10 characters. They observed GCA: SCA ratios were less than unity for the majority of characters, indicating non-additive gene action. Line PI-489782 was the best general combiner for marketable yield, total number of pods per plant and plant height while, high positive significant SCA effect for marketable yield was shown by the crosses IIHR-4 × PI-489782, Pusa Sawani × Smooth Green, Pusa Sawani × PI-496620 and IIHR-4 × Green Valvet.

Singh *et al.* (1996) investigated combining ability in *Abelmochus esculentus* for yield and 9 yield components in 8 lines (cvs. Pusa Makhmali, Pusa Sawani, Prabhani Kranti, Arka Anamika, EMS-8, Punjab Padmini, Punjab-7 and P-5) and their F_1 hybrids. Non-additive action was predominant for all the characters investigated. The best specific combinations were Punjab Padmini × Punjab-7, Punjab 7 × P-5 and Punjab Padmini × P-5 for total yield, plant height, fruit length and marketable yield.

Pathak *et al.* (1998) studied line × tester analysis for combining ability of 16 important characters in okra including 6 lines with 3 testers. They identified cv. Arka Abhay, Pusa Makhmali, Prabhani Kranti and Punjab Padmini were most promising parents for improving pod yield per plant. Crosses exhibiting significant positive SCA effects for pod yield/plant were IC-9275 × HB-55, Arka Abhay × Punjab Padmini, Arka Abhay × HB-55, Prabhani Kranti × HB-55, P-7 × Punjab Padmini, Pusa Makhmali × Punjab Padmini and Pusa Makhmali × EC-16511.

Pawar *et al.* (1999a) found combining ability was derived from data on 11 yield components in 10 parents and F_1 hybrids grown during Rainy season. The lines, HRB-55, Pusa Sawani, DL-1-87-5 and JO-5 were good general combiners for yield/plant.

Nichal *et al.* (2000) found the highest gca effects in Pusa A-4 for days to first flowering; in Arka Anamika for plant height and number of primary branches on main stem; and in AKO-16 for number of fruiting nodes on main stem, number of fruits per plant, average fruit weight, fruit length, and yield per plant. These parents were fond to be the best general combiners. Arka Abhay × Arka Anamika exhibited the highest *per se* performance for yield and showed significant sca effect for all characters. Based on *per se* performance, heterosis percentage, sca effects of crosses and gca effects of parents, Arka Abhay × Arka Anamika, AKO-16 × Pusa A-4, JNDO-5 × AKO-16, and Arka Abhay × Pusa A-4 were identified as the superior crosses that can be exploited for heterosis breeding programmes.

Pal and Hossain (2000) observed combining ability analysis for seed yield and some of its components and some quality traits for seed. Variety Punjab Padmini was the best general combiner for seed weight/plant and most of its components. Specific combining ability effect indicated that crosses like Vaishali Vadhu × Pusa Sel-1, Sel-171-14 × Punjab Padmini and BO-1 × Sel-71-14 might be utilized for further selection of superior progenies in respect of seed yield and seed quality.

Dhankhar and Dhankhar (2001) studied 20 lines (female) and 4 testers (male). The combining ability analysis revealed that variances due to treatments, crosses, lines, testers, and parents vs. crosses were significant for fruit yield, number of fruits per plant, days to 50 per cent flowering, number of branches per plant, plant height, and number of effective nodes on stem but not for internodal length of stem for tester. The line MR-15 and tester BB-1 proved to be the good general combiners for yield and its components. Estimated of specific combining ability and heterosis showed that best cross combination for yield was MR-10-1 × Varsha Uphar, followed by MR-12 × Raj-12-9.

Singh *et al.* (2001) reported the lines 7310 and 6313 were good general combiner for most of important traits. The crosses 6305 × 6308, 6305 × 6328, 6302 × 6308, 6325 × 7312, 6308 × 6325, 6313 × 7312 and 67308 × 7312 showed significant positive sca effect for fruit yield per plant.

Sood and Kalia (2001) study the combining ability for 10 characters, i.e. fruit yield, fruits per plant, days to 50 per cent flowering, days to first picking, fruit length, fruit diameter, ridges per fruit, plant height, nodes per plant and internodal length. The line IC-9856 was a good general combiner for early flowering, maturity, dwarfness and shorter internodal length. The cv. Prabhani Kranti, P-7, Harbhajan, Pusa Sawani, Arka Abhay and Arka Anamika were good general combiners for fruit yield and its components. The best specific combinations for fruit yield were P-7 × Arka Abhay and P-7 × Arka Anamika.

Ravisankar *et al.* (2002) found the variety AE-202 as best general combiner for plant height, days to flowering, number of fruits per plant, yield per plant and AE-264 for internodal length, fruits length and fruit girth. The best specific combinations were AE-264 × AE-211 for plant height AE-211 × AE-190 for internodal length; AE-280 × AE-190 for days to flowering and fruit girth, AE-285 × AE-190 for first fruiting node; AE-198 × AE-285 for fruit length.

Yadav *et al.* (2002) studied the combining ability in okra and reported that parents P-7 and BO-2 were good general combiners for fruit weight and average combiners for all the traits. The parents 6318 and 7309 were good general combiners for yield per plant and average for all the traits except days to flowering. They also observed that crosses involving high × high, high × average and average × average general, combiners and possessing high sca effects have been sorted out.

Rani and Arora (2003) estimated high gca effects were exhibited by Punjab-8, HRB 9-2 and Punjab Padmini for days to flowering, node at which the first flower appears, days to first picking, number of fruits per plant, total yield per plant and plant height; and VRO-3, Okra No.6, HRB 9-2, Punjab Padmini and Punjab-8 for YVM virus incidence. High estimates of sca effects were exhibited by HRB 9-2 × VB 9101, Okra No.6 × Punjab-8 and Pusa Makhmali × Punjab-8 for days to flowering; HRB 9-2 × Punjab-8 for node at which the first flower appears; VRO-3 × KS-404 and Okra No.6 × KS-404 for days to first picking; Pusa Makhmali × Punjab-8 for fruit weight; VRO-3 × KS-404, Pusa Makhmali × Punjab-8 and Pusa Makhmali × VRO-3 for marketable yield per plant, number of fruits per plant, total yield per plant and plant height.

Rewale *et al.* (2003) evaluated the 63 F1 hybrids, along with the 16 parents, were grown to estimate the general and specific combining abilities (GCA and SCA, respectively) for eight yield contributing characters (plant height, branches per plant, fruits per plant, fruit length, fruit weight, seeds per fruit, test weight and yield per plant). DVR-4 and SOH-02 among the lines, and Arka Anamika among the testers showed good GCA effects for yield and most of the yield attributes. Among the hybrids, NK-01 × Ankur-40 and JNDO-5 × Arka Anamika had the highest seed number per fruit, plant height and yield per plant (181.24 and 192.11 g, respectively).

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

Singh *et al.* (2004) reported 45 F_1s developed through 10 × 10 diallel set excluding reciprocals and found to be significant gca effect were shown by parent 7704, Pusa Makhamali, Prabhani Kranti, BO-2 and KS-353. More length of fruit has positive effect in yield per plant. On the basis of sca effect in plant height showed range of variation from -20.65 [KS-410 × 7704 (Red)] to 6.74 (KS-410 × KS-412) while the length of node was noted minimum 1.69 (Pusa Makhamali × KS-412).

Kumar *et al.* (2005) observed significant general and specific combining ability for 10 characters examined. Cultivar AB-2 was a good general combiner for number of days to flowering, number of fruits per plant and yield per plant. Cultivar AB-1 was a good general combiner for number of days to flowering, number of first fruiting node, number of fruits per plant and yield per plant. Cultivar BO-2 was a good general combiner for internode length, whereas Prabhani Kranti was a good general combiner for plant height and fruit length and width. Most of the superior specific combiners for different attributes also had a good *per se* performance.

Shekhawat *et al.* (2005) found that the analysis of variances due to gca and sca revealed that both additive and non-additive gene effects were important for plant height, branches per plant, fruit length, number of fruits per plant and yield per plant. Azad Bhindi-2, Azad Bhindi-1, P-7 and Arka Anamika were good general combiners for most characters. Seven superior heterotic crosses were selected due to high sca effects on yield and its components, i.e. Arka Anamika × Pusa Sawani, P-7 × VRO-6, Azad Bhindi-2 × Prabhani Kranti, Azad Bhindi-2 × KS-305, Azad Bhindi-1 × Pusa Sawani, Azad Bhindi-2 × KS-312 and KS312 × Pusa Sawani.

Dahake and Bangar (2006) found that the Arka Anamika, Hissar Unnat and Shagun were the best general combiners and could be used as a parent in exploiting heterosis for fruit yield while Prabhani Kranti × Arka Anamika, Hissar Unnat × Duptali 45, Duptali 45 × Ankur 40, which produced significantly high sca effects for yield and yield contributing characters including number of internodes, number of fruits per plant and plant height can be exploited directly for heterosis.

Kumar *et al.* (2006) reported experiment was conducted with 45 F_1's developed through diallel technique excluding reciprocals along with 10 parents *viz.*, Azad Bhindi-2, KS-305, Prabhani Kranti, KS-312 and P-7, in randomized block design with three replications. The study revealed that the significant general combining ability effects were shown by P-7, KS-312, KS-303, number of fruits per plant ranged from -1.16 to 2.61 in Pusa Sawani and KS-305, respectively.

Kumar *et al.* (2006) reported experiment was conducted with six lines (TCR-2056, TCR-2086, TCR-852, Gobi Local, Dharamapur local and Mohanoor local) and three testers (MDU-1, Prabhani Kranti and Punjab Padmini) to estimate the combining ability and variance effects. The combining ability and variances indicated the preponderance non-additive gene action testers Prabhani Kranti and Punjab Padmini were adjusted as the superior performance for seed yield per plant based on gca effects. The hybrid Mohanoor Local × Prabhani Kranti found to be superior when sca effects were considered for many of the traits.

Naphade *et al.* (2006) observed that the parent Tot-1494 and Tot-1502 proved to have good gca for weight of fruit, number of primary branches on main stem, number of seeds per fruit and yield per plant. Seven hybrids recorded significant sca effect for days to flower initiation, days to 50% flowering, fruit length, fruit weight, number of primary branches on the main stem and number of seeds per fruit. The best yielding crosses identified on the basis of sca and gca effects of parents were Prabhani Kranti × Tot-1494, AKO-73 × Tot-1502 and Prabhani Kranti × Tot-1502.

Singh *et al.* (2006) studied that the parent showing high gca for fruit yield/plant might be due to high gca for fruit weight, fruit length, fruit diameter, internodal length and number of fruits per plant. High sca effects were expressed for cross-combinations, BO-2 × IIVR-10, Pusa Makhmali × IIVR-10, EMS-8-1 × Prabhani Kranti, Punjab Padmini × IIVR-10, No.315 × IIVR-10 and Sel.4 × Prabhani Kranti for fruit yield per plant and also exhibited high or average sca effects for yield component traits.

Yadav *et al.* (2006) reported that data were recorded for twelve characters namely days to flowering, height of plant (cm), number of branches per plant, number of first node, length of fruit (cm), number of nodes per plant, length of internodes (cm), width of fruit (cm), tapering length of fruit (cm), number of fruits per plant and yield per plant (g). The study revealed that the significant sca effect were shown by parent KS-440 followed by KS-448, KS-427 and KS-455.

Adeniji and Kehinde (2007) studied the combining ability and genetic components of 7 parents and 21 F1 generations of *Abemoschus caillei* for length and width of pods. Results indicated that the mean squares due to gca and sca for length and width of pods were significant.

Eswaran *et al.* (2007) reported that Prabhani Kranti showed superior gca followed by EC-112112 and EC-305626. Among the crosses, Arka Anamika × Prabhani Kranti showed the greatest sca followed by Pusa Sawani × EC-112112. Standard heterosis for fruit yield per plant was most pronounced in Prabhani Kranti × Arka Anamika, followed by Arka Anamika × Prabhani Kranti and Prabhani Kranti × EC-305626.

Singh *et al.* (2007) observed the parent KS-375 showed highly gca effect for all the characteristics except length and width of fruit in F_1 and F_2 generations, days to flowering in F_1 and plant height and number of branches per plant in F_2 population. Parent KS-313 for days to flowering; Azad Ganga for KS-375, BO-2 and KS-313 for length of branches/plant, KS-410 for length of fruit, Azad Ganga for width of fruit; KS-375 for number of fruit/plant were found desirable on the basis of *per se* performance and general combining ability effect.

Singh *et al.* (2007) reported experiment was conducted with 21 F_1's developed through diallel technique excluding reciprocals along with 7 parents i.e. KS-312, KS-401, KS-404, KS-410, 6312, 7211 and Pusa Sawani. No. of fruits per plant have positive effect in yield per plant, gca effect for number of fruits per plant ranged from -0.355 to 1.825 in F_1 from -0.995 to 1.366 Pusa Sawani in F_2 generation.

Kushwaha *et al.* (2007) studied diallel cross of 8 parent *viz.*, AB-2, AB-1, KS-312, BO-2, P-7, VRO-3, VRO-5 and Prabhani Kranti. The study revealed that yield. On the basis of specific combining ability following superior heterotic crosses were selected for yield. These crosses *viz.*, VRO-3 × Prabhani Kranti, KS-312 × BO-2, AB-2 × BO-2, AB-2 × KS-312, P-7 × VRO-5 were found superior for commercial yield production.

Srivastava *et al.* (2008) observed that the parents, IC-73352, Okra No.-6, Pb-8, VB-9101 and Punjab Padmini for days to 50 per cent flowering; Punjab-8, IC-73352, BO-1, Okra No 6 and IC-69117 for plant height; BO-1, Okra No. 6, IC-73352, Pb-8, IC-69117, Arka Abhay and VRO-3 for number of branches/plant; Punjab-8, Punjab Padmini, IC-69117, IC-73352, Arka Abhay for number of fruits/plant; Punjab Padmini, VRO-3, Arka Abhay, and Punjab-8 and IC-69117 for pod yield/plant were found good general combiners. However, in specific combining ability study, the cross, VRO-3 × Arka Abhay and Punjab Padmini × Arka Abhay for pod yield/plant; VRO-3 × IC-69117 for plant height; Punjab-8 × BO-1 for number of branches/plant; IC-73352 × Punjab Padmini for number of pods/plant; VRO-3 × IC-73352 for pod length; Punjab-8 × IC-68364 for pod diameter; Punjab-8 × IC-69117 for pod weight; IC-73352 × VB-9101 for number of seeds/pod exhibit high sca.

Weerasekara *et al.* (2008) found that the parents KAO-52, KAO-61, KAO-10, KAO-25 and KAO-35 were good general combiners for days to 50 per cent flowering and parents KAO-16, KAO-61, KAO-52 and KAO-AA were good general combiners for the number of seeds per fruit with negative significant GCA effects, which was preferred. High gca was also observed in KAO-25, KAO-17, KAO-35 and KAO-23 for the number of branches per plant, KAO-25 for plant height, KAO-53 and KAO-18 for fruit diameter, KAO-17 and KAO-25 for fruit weight, and KAO-25, KAO-17, KAO-35, KAO-10 and KAO-23 for yield per plant. Crosses KAO-52 × KAO-23 for the number of branches per plant, KAO-16 × KAO-AA for plant height, KAO-53 × KAO-18 for the number of fruits per plant, KAO-61 × KAO-18 for fruit length, KAO-16 × KAO-23 for fruit diameter, KAO-10 × KAO-18 for fruit weight and KAO-53 × KAO-18, KAO-35 × KAO-AA and KAO-17 × KAO-AA for fruit yield per plant were the specific combinations showing favorable sca effects for the characters mentioned.

Singh *et al.* (2009) studied the combining ability for yield and yield components was studied in 12 cultivars of okra, i.e. Pusa Makhamali (P1), Pusa Sawani (P2), 7D2 (P3), Arka Abhay (P4), lC-901 77 (P5), IC-90202 (P6), Punjab Padmani (P7), HRB 9-2 (P8), P-7 (P9), KS 404 (P10), BO (P11) and BO-2 (P12), and their hybrids grown in Varanasi, Uttar Pradesh, India, during the Summer season. Plant height, number of primary branches, number of days to flowering, number of days to first picking, number of pods per plant, pod size, pod weight, yield per plant and number of seeds per pod were evaluated. The analysis of variance revealed that the general combining ability and specific combining ability (SCA) were highly significant for all characters. The specific combinations producing desirable effects were P9 × P11, P9 × P12, P7 × P12, P7 × P11 and P1 × P6 for plant height, and P4 × P8, P2 × P3 and P2 × P7 for number of branches. Desirable effects based on SCA were observed in P2 × P7, P2 × P4 and P2 × P10 for number of days to flowering. P1 × P9, which was the best combiner for yield per plant, showed the greatest positive SCA effect and a high degree of heterosis.

2.2 Hybrid vigour/heterosis

The term heterosis was first used by Shull (1914) to replace the phrase "special stimulus of heterozygosis." This term was used to highlight the effect of the stimulus of heterozygosis upon cell division, growth and other physiological activities of an organism. However, a more explicit and precise definition of heterosis is given by Shull in 1952 representing heterosis as the "increased vigour, size fruit fullness, speed of development, resistance of disease and pest manifested in cross-bred organism as compared to corresponding in bred, as the specific result unluckiness in the contribution of uniting parental gametes". Heterosis is common used is defined as the phenomenon in which the F_1 population obtained by mating of two homozygous genetically dissimilar individuals show increased of decreased vigour over the mid parent (relative heterosis) or better parent (heterobeltiosis) or standard variety (economic heterosis) in quantitative as well as qualitative traits. This increased productivity or superiority of the hybrid over parents is known as hybrid vigour and the genetic cause of this phenomenon is known as heterosis.

Through the vigour associated with hybrid was recognized in the pre-Mendelian time, yet it was Jones (1918) after his suggestion of double cross hybrid in maize for the practical utilization of hybrid vigour, used this term synonymous with 'heterosis' given by Shull (1914).

The first suggestion that heterosis can be exploited in vegetable crops was made by Hays and Jones (1916). Among the vegetables heterosis was reported first in cabbage by Pearson (1932).

Jalani and Graham (1973) studied four F_1 hybrids from crosses involving the Malaysian varieties Local-5 and Local-7 and the

American varieties Emerald (4885) and Gold Coast (4887) and exhibited heterosis for percentage germination, precocity of flowering plant height and yield performance as indicated by fresh weight of fruit per plant.

The exploitation of heterosis is considered an outstanding application of the principle of genetics to agriculture. Heterosis breeding has led to a break through in yield in several crop plants. For the exploitation of heterosis, it is imperative study the magnitude of genetic differences among parents involved in the crosses as well as genetic worth of crosses. The parents with optimal to intermediate genetic diversity are supposed to show maximum heterosis (Moll and Stuber, 1976). Manifestations of heterosis in respect of various characters in okra have been reported by a number of investigators:

Muthukrishnan and Irulappan (1981) reported earliness in F_1 hybrids of okra for 50 per cent flowering.

Thaker *et al.* (1982) studied 21 crosses of 7 varieties of *A. esculentus* and reported icrease in F1's over better parents with maximum for fruit yield per plant followed by number of fruits per plant and fruit length.

Singh (1983) observed that certain crosses in okra manifested positive and significant heterosis for number of pods per plant.

Changan and Shukla (1986) observed out of 30 cross combinations, 18 showed heterosis over the mid parental value and 12 over the better-parent.

Poshiya and Shukla (1986) studied heterosis for yield and 4 related characters in a 7 × 7 diallel cross of okra and they observed highest value of heterosis for number of pods per plant and yield per plant. The cross New selection × AE 91 showed the highest heterosis for yield 29.94 % over the mid parental value and 27.77% over the better parent.

Yadav (1986) found that F_1 hybrids of okra showed more plant height and spread than their parental means. They also noted increase in fruit weight in most of the hybrids over the parental means however, 3 hybrids were superior to their better-parent.

Korla and Sharma (1987) reported that three crosses *viz.*, Vaishali Vadhu × EC-168475, Pusa selection-62 × EC-68475 and Pusa Sawani × EC-68475 showed increase in yield per plant over better parents.

Singh and Sharma (1990) in an inter-varietal cross between Pusa Sawani × Ludhiana Selection-1 found that in comparison to Pusa Sawani, Ludhiana Sel-1, possessed less number of seeds, more number of fruits, more fruits weight, fruit length and marketable yield. Heterosis was observed for average fruit weight and marketable yield only.

Vichart (1990) studied heterosis and heterobeltiosis by considering F_1 generation means of crosses. Heterosis for mature plant height, branch number per plant, pod number per plant and yield per plant existed; while heterobeltiosis for pod number per plant and yield per plant were recorded.

Chaudhary *et al.* (1991) observed highest heterosis for yield and number of fruits per plant by Pusa Makhmali × Punjab Padmini from 6 yield components in 8 lines and their F_1 hybrids.

Mandal and Das (1991) studied an 8 × 8 diallel cross and their 28 F_1 hybrids (excluding reciprocals) and observed greatest heterosis over better parent (52.4%) for yield per plant followed by fruits per plant (36.5%). They noted that crosses Punjab, Padmini × Sel-10 and

EMS-8 × Sel-4 showed high heterosis for yield and most of its components.

Sivagamasundhari *et al.* (1992) estimated heterosis over mid, better and best parent for yield and 7 related components of 30 hybrids of okra. They found Pusa Sawani for length of fruit.

Kumbhani *et al.* (1993) reported that among 8 parents diallel cross in okra Padra 18-6 × KS-312 and Punjab selection × KS-312 showed high heterosis for yield. They further observed advocated that it resulted from the combined effect of heterosis for yield component characters such as number of pods per plant, pod length, plant height and internodal length.

Mohammed *et al.* (1994) studied 4 parental genotypes and their F_1s and reported that hybrid was manifested for plant height, flower earliness, number of pods per plant and total yield per plant.

Poshiya and Vashi (1995) reported highest heterosis of 27.32% for fruit yield over better parent. The hybrids exhibiting significant heterosis for fruit yield also exhibited heterosis for most of the characters studied.

Patil *et. al.* (1996) observed a high degree of heterosis for all the characters studied. The crosses IHR-4 × PI-489782 and Pusa Sawani × Smooth Green showed favorable heterosis for marketable yield (weight of good pods per plant), earliness and pod borer resistance, while Smooth Green × PI-489782 and Smooth Green × PI 496681 were excellent with respect to earliness, pod borer resistance and optimum pod length (8-10 cm).

Singh *et al.* (1996) studied heterosis for 11 yield related traits in 8 varieties of *Aesculentus* (Pusa Makhmali, Pusa Sawani, Prabhani Kranti, Arka Anamika, EMS 8, Punjab Padmini, Punjab-7 and P-5) and their hybrids. They observed best performing hybrids were Pusa

Makhmali × Prabhani Kranti, Pusa Sawani × Prabhani Kranti, Pusa Makhmali × P5 and Prabhani Kranti × Punjab 7, which gave 103.2, 88.1 and 84.1% higher marketable yield than the better parent (Punjab Padmini), respectively.

More and Patil (1997) observed heterosis both over mid and better parent was highest for fruit yield per plant, 5.65% and 28.94%, respectively.

Syamal and Pathak (1997) evaluated 18 crosses (6 lines and 3 testers) of okra for 16 yield and fruit quality parameters. They observed 13 crosses showed high heterosis of pod yield per plant and also of 6-10 other parameters depending on the genotypes.

Wankhade *et al.* (1997) observed heterosis over standard variety Pusa Sawani for yield and significant heterobeltiosis for all the characters including yield and contributing traits except quality attribute ascorbic acid content. They identified Vaishali Vadhu × Local Akola as an outstanding F_1 hybrid for fruits per plant, yield per plant and seven characters to be exploited commercially for higher gain.

Ahmed *et al.* (1999) estimated that number of pods per plant recorded maximum heterosis (74.77%) followed by average pod weight (62.59%), branch number per plant (52.50%), height of first fruiting node (44.83%), pod yield per plant (36.66%), node number per plant (36.41%), number of node of first pod appearance (-32.09%), plant height (26.75%), internodal length (-26.11%), pod length (17.92%), days to first fruit set (-12.12%) and fruit girth (1.12%).

Panda and Singh (1999) studied the heterosis effect of 6 characters in 20 crosses of Okra and they observed highest value of heterosis for pod yield (45.62%) and number of pods per plant (28.32%).

Pawar *et al.* (1999b) recorded high heterosis for number of branch per plant, yield/plant, number of fruits per plant and plant height; moderate for first fruiting node, fruit girth, fruit length and number of nodes per plant and low heterosis for days to 50% flowering and days to first picking.

Pitchaimuthu and Dutta (2002) observed heterosis for different characters in okra. They also observed that crosses MS-1 × IIHR-120, MS-2 × Arka Anamika and MS-5 × Prabhani Kranti were observed to be most promising hybrids for marketable fruit yield and earliness.

Ravisankar *et al.* (2002) reported maximum standard heterosis of 51.88% for plant height and -0.70% for days to flowering in AE × AE-285; -18.66% for internodal length in AE-283 × AE-285; -4.29% for first fruiting node in AE-250 × AE-190; 56.99% for fruit length in AE-264 × AE-190; 11.15% for fruit width in AE-219 × AE-385; 46.09% for number of fruits per plant and 70.69% for yield per plant in AE-219 × AE-190 over the Standard Check Prabhani Kranti.

Singh *et al.* (2002) recorded that the heterobeltiosis in okra ranged from – 141% for length of fruits (5709 × 6901) to 67.51% maximum beneficial heterobeltiosis for weight of fruits per plant (yield per plant) in 6302 × 6308.

Vishwakarma *et al.* (2002) noted that increase in chromosome number might be increased in the gene dose, which is definitely related to increase in hybrids vigour in the polyploidy nature of the hybrids in okra of the many combinations studied the best five hybrids, which proved their superiority, in phenotypic distinctness significant heterosis and heterobeltiosis for quantitative and qualitative characters, also excelled in diversified climatic zones.

Indu Rani *et al.* (2003) reported that the YVM percentage in parents ranged from 34.78 to 11.53% PA-4 × OHD-1 recorded minimum YVM incidence of 24.13%. Among hybrids, OHD-1 × PA-4 showed the highest heterosis over the best parent for yield and fruit number per plant, fruit length and fruit girth. Hybrid PA-4 × Varsha Uphar exhibited higher heterosis over the best parent.

Bendale *et al.* (2004) observed that in parental lines, the highest fruit yield/plant was observed in Ankur-40 (103.149 g) followed by D-40, Arka Abhay and Long Green Smooth Finger and among the hybrids cross Prabhani Kranti × God Finger (437.66 g) yielded the highest followed by Long Green Smooth Finger × Green Gold and Green Gold × Ankur-40. Prabhani Kranti × Gold Finger (44.86%), Long Green Smooth Finger × Green Gold (193.83%) and Local × Green Gold (172.08%) showed desirable heterosis for yield over better parent.

Bhalekar *et al.* (2004) reported the highest heterosis over better parent for yield was in A.A.D.F.1 × Arka Anamika (19.29%) followed by Arka Anamika × Lorm-1 (14.85%), Varsha Uphar × Lorm-1 (15.31%) and Arka Anamika × Prabhani Kranti (13.96%), which also had the best *per se* performance.

Kumar *et al.* (2004) estimated heterosis over better parent eight diverse lines of okra and found to be heterobeltiosis was 16.09% for pd length, 10.26% for pod girth, 14.39% for average pod weight, 44.32% for pod number -9.80% per earliness and 58% for pod yield.

Patel *et al.* (2004) revealed that heterosis and heterobeltiosis was observed for all the traits studied. The cross combination VRO-3 × JOL-5 showed maximum magnitude of heterosis for fruit yield over mid-parent and better parent.

Singh *et al.* (2004) studied the 10 parental diallel excluding reciprocals in okra and found to be heterosis ranged from 35.00 to 69.36 in IC-7704 (Red) × KS-404 and PS × P-7 parent in first parent - 38.96 to 108.24 (Pusa makhmali × KS-412) and PS × P-7 in parent in weight of fruit per plant.

Yadav *et al.* (2004) found that the Azad Bhindi-1, a new okra cultivar developed from Pusa Sawani × Prabhani Kranti, exhibits higher yield (100-125 q/ha), earlier fruiting (40-42 days) and more resistance to bhindi yellow vein mosaic virus than Pusa Sawani and Prabhani Kranti.

Borgaonkar *et al.* (2005) found that the degree of heterosis was higher for fruit length, internode length, leaf area and yield per plant; moderate for number of nodes on the main stem and plant height, and low for number of days to 50% flowering, number of days to picking and fruit girth. No. 129 × JMDO-5 exhibited the greatest heterobeltiosis (52.22%) for yield per plant, followed by No. 74 × JMDO-5 (40.45%) and No. 114 × JMDO-5 (37.96%).

Jindal and Ghai (2005) studied the parents and crosses for number of fruits per plant, total yield and marketable yield per plant have been identified and these can be accomplished both through pure line breeding as well as through heterosis breeding.

Mamidwar and Nandan (2006) to studied the heterobeltiosis for yield and yield components in 14 lines and 3 testers and 42 hybrids of okra. Among the hybrids, heterobeltiosis was greatest in Dattari-1 × Arka Abhay for number of days to first flowering and number of days to 50% flowering, VRO-6 × Prabhani Kranti for fruit weight and fruit yield per plant, VRO-5 × Arka Abhay for fruit length and plant height, OV × Arka Anamika for number of seeds per fruit and VRO-3 × Arka Anamika for 100-seed weight.

Singh and Syamal (2006) estimated that the manifestation of heterosis in F_1 hybrid over better parent ranged from 7.19% (Pusa Sawani × Arka Abhya) for plant height to 45.71% (Pusa Sawani × Punjab Padmini) for the number of primary branches. Some crosses showed negative heterosis over better parent ranging from -13.84% (Pusa Sawani × BO-2) to -26.36% (Pusa Sawani × HRB 9-2) for days to flowering, and -28.22% (Arka Abhay × Punjab Padmini) to -29.21% (IC-90202 × P-7) for days to first picking. Heterosis over better parents was to the extent of 53.28% (IC 90177 × IC-90202) for the number of pods per plant, 27.155 (7D2 × Arka Abhay) for pod size, 12.65% (Arka Abhay × BO-1) for pod weight and 54.54% (Arka Abhay × BO-1) for yield per plant, heterosis for the lowest number of seeds over better parents ranged from 40.78% (Pusa Makhamali × HRB 9-2) to 16.21% (Punjab Padmini × HRB 9-2).

Yadav *et al.* (2006) found the Azad Bhindi 1-2, derived from the cross Pusa Sawani × P-7 through pedigree method, is a new bhindi (*Abelmoschus esculentus*) cultivar released in Uttar Pradesh, India. This cultivar is characterized by its higher yield (110-140 q/ha) and earlier fruiting (38-41 days).

Desai *et al.* (2007) studied the 28 hybrids of okra and to observed the Prabhani Kranti × Gold Finger recorded superior performance for plant height, nodes per plant, fruit weight, fruit per plant and yield per plant. While the hybrid long green Smooth Finger × Green Gold also showed superior performance for these characters except fruit weight.

Senthikumar *et al.* (2007) observed standard heterosis up to 86.80% was recorded by the cross Punjab Padmini × Prabhani Kranti for fruit yield per plant by applying reciprocal recurrent selection method. The crosses Arka Anamika × Mohanur Local and Arka Anamika × Prabhani Kranti can be economic heterosis for fruit yield and traits of interest.

Singh *et al.* (2007) studied the heterobeltiosis in okra ranged from 141% for length of fruits (5709 × 6308) to 185% for number of fruit/plant (6305 × 6801). Maximum beneficial heterobeltiosis for weight of fruit/plant (yield/plant) was observed in 6302 × 6308

(67.51%). In general, hybrid showed a wide range of heterotic effect for each character.

Yadav *et al.* (2007) found that the cross 6313 × 6318 showed an outstanding performance in both the F1 and F2 generations for the character number of branches per plant. The parents of this cross could be exploited as a potential source for heterosis breeding.

Hosamani *et al.* (2008) evaluated 24 F_1 hybrids developed from 3 lines ('IC-111478', 'IC-90044' and 'Arka Anamika') and 8 testers ('EC-316046', 'IC-111479', 'IC-90203', 'IC-90273', 'IC-90263', 'Parbhani Kranti', 'VRO-65' and 'IC-89936') in a line × tester fashion. Out of the 24 hybrids, 'IC-90044' × 'Parbhani Kranti' can be exploited commercially as it exhibited earliness, high number of fruits and high yield per plant. On the basis of expression of heterosis for different traits among different cross combinations, this particular cross can be exploited for the improvement of these desirable characters. In comparison with the widely grown popular public bred cultivar 'Arka Anamika', this cross recorded significantly higher yield, i.e. 262.84% higher. It is a promising hybrid for further utilization.

Singh *et al.* (2008) evaluated sixty F_1's along with 15 lines and 4 testers were tested for heterosis. Negative heterosis which is desirable for days of 50 per cent flowering was common in most of the crosses, since this trait is negatively correlated with yield per plant. The result indicated that green pod weight, plant height, number of branches per plant, number of fruit per plant and fruit yield per plant were the most heterotic traits. High positive and significant heterosis over better parent and mid parent was found in crosses AAN × X-70 for green pod weight, X-71 × X-70 for plant height, Okra-2 × Okra-1 for number of branches per plant and X-2 × Pusa Mukhmali for number of fruits per plant and fruit yield per plant.

Singh *et al.* (2009) determined the heterobeltiosis and inbreeding depression in okra. Heterobeltiosis in okra ranged from-141 % for length of fruits (5709 × 6308) to 185 % for number of fruits per plant (6305 × 6901). Maximum beneficial heterobeltiosis for weight of fruits/ plant (yield/ plant) was observed in 6302 × 6308 (67.51 %). In general, hybrids showed a wide range of heterotic effects for each character.

2.3 Variability, heritability and genetic advance

Heritability is a useful measure for considering the ratio of genetic variance to the total variance and is generally represented in percentage. This is an index of transmibility of characters from the parents to their off springs and is a measure of genetic relationship between parents and progeny, hence changing the characteristics of the population through selection can be predicted only from knowledge of the degree of correspondence between phenotypic and breeding values.

Many workers have defined heritability, Lush (1948) defined broad sense heritability as the ratio of additive genetic variance and narrow-sense as the ratio of additive genetic variance to the total variance. Since additive genetic variance is the only fixable portion of total variance, narrow sense heritability is more practical importance than broad sense heritability. Robinson *et al.* (1949) defined heritability in both broad and narrow sense. In the broad sense it is "The ratio of the total genotypic variance to the total phenotypic variance" and in narrow sense, "the ratio of additive genetic variance to the total phenotypic variance." They also categorized heritability estimates (h^2n) as follows:

1. Low heritability (5 to 10%)
2. Medium heritability (10 to 30%)
3. High heritability (above 30%)

Several methods have been developed by several workers (Mather, 1949; Warner, 1952, Kempthorne, 1957; Kempthorne and Currow, 1961; Crumpacker and Allard, 1962; Mather and Jinks, 1971) for estimation of heritability in narrow sense genetic.

Genetic advance is most useful estimate as it is the improvement in the genotypic value in the new population is contrast to base population. According to Comstock and Robinson (1952) expected genetic advance depends upon:

1. The amount of genetic variability
2. The magnitude of masking effect of environmental and interaction components of variability on the genetic diversity.
3. The intensity of selection.

Expected genetic advance in percentage of mean is the product of:

1. Selection different measured in terms of phenotypic standard deviation.
2. The genetic co-efficient of variability and square root of heritability ratio (Johnson *et al.,* 1955).

Since the genetic gain in character is a product of the heritability and the selection differential expressed in the unit of standard deviation, the heritability alone dose not have much significance.

A brief review of work done earlier on the heritability and genetic advance in okra is presented below:

Singh and Singh (1979) reported that plant height and length of first fruiting nodes to have high heritability estimates together with high to moderate estimates for genetic advance. For fruit width estimates of heritability were high along with moderate to low genetic advance.

Gulshan and Lal (1986) studied that the greatest genetic advance in pod yield was predicted to occur through selection based discrimenent function sing he characters, number of primary branches per plant, 100 seed weight and number of nodes on the main stem.

Yadav (1986) estimated high genotypic coefficients of variation, heritability and expected genetic advance for plant height, yield per plant and number of seeds per pod. Number of pods per plant and length of pods gave moderately high genotypic coefficients of variation and high heritability.

Rath *et al.* (1991) reported high estimates of heritability ranging from 69.7% (number of branches per plant) to 99.7% (number of seeds per pod).

Patel and Dalal (1992) reported high heritability estimates for yield and its components in 7 *Abelmoschus esculentus* genotypes and their F_1 hybrids pod attributes were found to have moderate heritability.

Sood *et al.* (1995) observed high heritability and genetic advance for ridges per pod, whereas moderate heritability coupled with high to moderate genetic advance was recorded for the node at which the first fruits set, plant height and nodes per plant.

Patil *et al.* (1996) evaluated 171 okra genotypes for 11 characters and they observed relatively high genetic advance for characters such as plant height, number of good pods per plant and weight of good pod per plant.

Rai *et al.* (1996) reported heritability for the total number of branches followed by fiber weight and weed dry weight.

Paiva *et al.* (1998) conducted an experiment in 11 okra cultivars and estimated heritability fruit length, diameter and weight, plant height and number of branches per plant and fruits per plant in 22 genotypes of bhindi.

Yadav *et al.* (2002) studied 30 strains/varieties of okra and reported high heritability coupled with high genetic advance for yield per plant and height of plant. Moderate to high heritability coupled with low genetic advance observed for days to flowering number of branches per plant, number of nodes per plant, length of fruit, width of fruit and number of fruits per plant.

Bendale *et al.* (2003) estimated that the number of branches per plant, yield per plant and number of pods per plant showed high GCV and PCV estimates. All the characters recorded medium to high and high heritability. Pod length, pod weight, plant height, nodes per plant and number of pods per plant were positively correlated with the yield.

Indu Rani *et al.* (2003) evaluated 33 cross combinations of okra for yield and yield components like fruits per plant, individual fruit weight, fruit length and fruit girth. The varieties OHD-1 × Varsha Uphar and Varsha Uphar × Arka Anamika were adjudged to be the best among all crosses. These two hybrids were also resistant ti yellow vein mosaic virus in the field.

Singh *et al.* (2004) studied the 10 parental dialed excluding reciprocals in okra and found to be heritability varied from 0.137 to 0.95 in number of fruits, per branches and plant height in parent and in F_1 generation in varied from 0.319 to 0.923 in length of node and in genetic advance showed a range of variation from 0.96 to 79.62 in length of the fruit to weight of fruit per plant in parents and F_1 generation.

Indu Rani and Veerangavathatham (2005) studied genetic variability, heritability and genetic advance for 8 characters (plant height at first flower bud appearance, number of fruits per plant, fruit weight, fruit length, fruit girth, plant height at final harvest, number of branches per plant and yield per plant). High heritability coupled with high genetic advance was recorded for plant height at first flower bud appearance, number of fruits per plant, fruit weight and yield per plant, these characters should be given importance in selection programme.

Bello *et al.* (2006) observed that the characters, which showed high broad sense heritability and high genetic advance after selection respectively, included fruit diameter (18 % & 16 %) and number of branches per plant (96 % & 41 %). These characters are all under additive gene effects.

Bhargawa *et al.* (2006) reported the study was based on 12 characters namely, days to flowering, height of plant, number of branches per plant, length of internode, length of fruit, width of fruit, tapering length of fruit, number of fruit per plant and yield per plant. High heritability coupled with high genetic advance were observed for, number of branches per plant, number of fruits per plant and yield per plant indicating that most likely the heritability is due to additive gene effects and selection may be effective.

Mehta *et al.* (2006) studied that the values of phenotypic coefficients of variation (PCV) were higher than that of genotypic coefficients of variation (GCV) values for all the seven traits indicating the influence of environment in the expression of these traits. The GCV, heritability and genetic advance as percentage of mean were higher for fruit yield, average fruit weight, plant height and fruit length, which might be attributed to additive gene action resulting their inheritance.

Kumar *et al.* (2007) studied genetic variability, heritability and genetic advance for 8 parents *viz.*, AB-2, AB-1, KS-312, BO-2, P-7, VRO-3, VRO-5 and Prabhani Kranti and 10 characters days to flowering, plant height, number of fruit per plant, length of internode, fruit length, fruit width, number of fruit per plant, yield per plant. All the characters showed moderate to high heritability. The highest estimates of genetic advance in per cent of mean were observed for number of branches per plant.

Singh *et al.* (2007) studied 10 diverse genotypes of okra *viz.*, 6312, KS-312, KS-387, KS-401, KS-404, KS-410, 7211, Prabhani Kranti and Pusa Sawani and estimated a high magnitude of narrow sense heritability was observed for days to heading, length of just fruiting node and length of internode while genetic advance was high for all the characters under study.

Singh *et al.* (2008) found that the highest genotypic and phenotypic coefficients of variation for various traits in okra in which number of branches per plant, plant height, number of seeds per fruit, number of nodes per plant, fruit length, fruit yield and number of fruits per plant exhibited high heritability along with high genetic gain, which indicated that there were higher number of additive factors involved in the expression of these characters and further improvement could be brought about by their selection.

2.4 Correlation and path coefficient variance

Knowledge of the nature of correlation coefficients between fruit yields its components and between the various components is of great interest in plant breeding and horticulture. The statistics, which measures the relationship between two or more variables, is known as correlation coefficient. The extent of association is measured by correlation coefficients. Correlation studies provide information that selection for one character will result in progress for all positively correlated characters. Many of the character are correlated because of mutual association, positive or negative, with other characters.

The original of correlation was presented by Galton (1889), which elaborated later by Fisher (1918) and Wright (1921).

The technique of path coefficient was originally developed by Wright, (1921). He defined the path coefficient as the ratio of the standard deviation of the effect to the total standard deviation when all the causes are constant, except the one in question, the variability of which is kept unchanged.

Dewey and Lu (1959) applied this technique for the first time in plant breeding in crested wheat grass (*Agropyron cristatum*). Several studies of path coefficient techniques to establish the relative importance of seed size, fertility and plant size as the determinate of seed yield.

Dhall *et al.* (2000) studied the correlation and path coefficient analyses in 48 advanced generation lines of okra. Marketable yield per plant, fruit weight, fruit length, number of fruits per plant and plant height were positively and significantly correlated with the total yield per plant. Path analysis revealed that the marketable yield per plant, number of fruits per plant, fruit weight, fruit length and plant height had the highest direct effect on the total yield, indicating that emphasis should be given on such characters to improve the yield potential.

Yadav and Dhankhar (2001) studied the correlation between field parameters and seed yield and quality of okra cv. Varsha Uphar. Seed yield of okra cv. Varsha Uphar was positively and significantly correlated with plant height, number of branches, fruit set percentage, number of fruits per plant, fruit length and fruit girth. Seed yield was negatively correlated with days to 50% flowering and days to fruit maturity. Positive and significant correlations were observed between fruit set percentage and plant height and number of branches per plant. Number of fruits per plant showed significant and positive correlation with fruit set percentage.

Dhankhar and Dhankhar (2002) observed that fruit yield was significantly and positively correlated with the number of fruits and branches per plant, and plant height, but was negatively correlated with days to 50% flowering. The number of fruits per plant was positively associated with the number of branches per plant and plant height, and was negatively correlated with days to 50% flowering. Fruit yield can be improved through selection for higher number of fruits and branches, and medium plant height.

Singh and Singh (2002) found that in general, genotypic correlation coefficients were higher than phenotypic correlation coefficients. Phenotypic and genetic correlation indicated that plant height, fruit length, and fruit number were positively associated with fruit weight per plant in the F2 generation. Only one combination, first fruiting node and fruit weight per plant, exhibited significant positive correlation at the genetic level in the F1 generation.

Kamal *et al.* (2003) found that the calculated values of genotypic correlation coefficients were higher than phenotypic correlation coefficients for most of the characters. Yield per plant was positive and highly significantly correlated with number of nodes per plant, width of fruit and number of fruits per plant. Path coefficient analysis revealed that number of fruits per plant and width of fruit had high positive direct effect on yield per plant indicating that these characters may be given due weightage while making selection for crop yield improvement.

Niranjan and Mishra (2003) estimated that in general, the genotypic correlations were higher than the corresponding phenotypic correlations for all the character combinations. Fruit yield was positively and significantly correlated with edibility period of fruits, number of fruits per plant, fruit length, number of seeds per fruit, fruit weight, plant height and number of branches per plant at both genotypic and phenotypic levels. Associations were significant at the genotypic level only between edibility period of fruits and number of branches per plant. All characters had positive and significant association among each other at both levels. Fruit weight, number of seeds per fruit, fruit length, number of fruits per plant and number of branches per plant had high direct contribution towards yield. Fruit weight exerted the highest positive direct effect (0.507) and the highest genotypic correlation value (0.975) on fruit yield per plant.

Jaiprakashnarayan and Mulge (2004) found that the total yield per plant was positively and significantly correlated with number of fruits per plant, average fruit weight, number of nodes on main stem, fruit length, plant height at 60 and 100 days after sowing (DAS) and number of leaves at 45 and 100 DAS, but negatively and significantly correlated with number of locules per fruit, number of nodes at first flowering and first fruiting. Path analysis revealed that average fruit weight, number of nodes on main stem and number of fruits per plant had high direct effect on total yield per plant. Hence, direct selection for average fruit weight and number of fruits per plant is suggested to improve yield.

Patro and Sankar (2004) revealed that fruit yield per plant have significant and positive correlation with number of branches per plant, number of ridges per fruit, fruit length, fruit weight and ascorbic acid content. Significant negative correlation of fruit yield per plant was recorded with plant height, number of days taken for first pod setting, fruit volume, shape index, longevity of tenderness. Path analysis revealed high positive direct effect for fruit weight followed by fruit length, germination percentage, number of ridges, plant height, number of branches per plant, number of nodes per plant, fruit volume, ascorbic acid content. A maximum positive indirect effect was recorded between fruit weight (via) number of ridges, whereas a maximum negative direct effect was recorded in fruit weight (via) fruit length. Cluster analysis revealed a considerable variation among the genotypes.

Bali *et al.* (2005) studied correlation and path analysis for number of fruits per plant, number of nodes per plant, internodal distance and plant height had the highest significant correlation with total yield per plant. Path analysis showed that number of fruits per plant, average fruit weight, internodal distance and plant height had the highest positive direct effect on total yield per plant.

Chhatrola and Monpara (2005) found that the Yield had a high significant and positive genotypic and phenotypic correlation with plant height, nodes per plant, internodal length, fruits per plant and 10-fruit weight. Genotypic and phenotypic correlation were roughly equal for the character combination of days to 50% flowering with days to first picking and fruits per plant, plant height with 10-fruit weight, nodes per plant with fruits per plant and fruit length with 10-fruit weight, implying that these characters were less under the influence of environmental conditions. Character combinations like plant height with primary branches, fruits per plant with fruit yield per plant, and primary branches with nodes per plant and fruits per plant showed highly significant and positive correlations but the values of phenotypic correlation were higher than those of genotypic correlation. In path analysis, primary branches showed the highest direct contribution to fruit yield (0.62), followed by plant height (0.50) and nodes per plant (0.47). Internodal length also showed a considerable amount of direct effect (0.34). These were not only the important direct sharing characters but also were important indirect contributors through the characters among them. Although fruits per plant showed high correlation with yield, the direct contribution of this trait to fruit yield was negligible. Despite its large negative direct effect, plant height was significantly and positively correlated with fruit yield.

Shekhavat *et al.* (2005) evaluated the okra cultivars Azad Ganga, KS-313, KS-375, KS-405, KS-410, KS-412, P-7, BO-2, Prabhani Kranti and Pusa Sawani. Correlation studies were performed using 100 genotypes, i.e. 45 F1, 45 F2 and 10 parents. Data were recorded for days to flowering, plant height, number of branches per plant, length of first fruiting node, length and width of fruits, number of fruits per plant and weight of fruits per plant (yield per plant). The genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients, indicating an inherent association among characters. Similarly, the genotypic correlation coefficients were higher in the F1 generation than in the parental or F2 generation.

Yadav *et al.* (2005) studied that the phenotypic correlation coefficients for the different characters, indicating the heritable association among them. Highly significant and positive association was found between yield per plant and number of fruits per plant in parents and F_1's at both the phenotypic and genotypic levels. This indicates the select for number of fruits per plant may result in significant yield improvement in okra yield.

Akinyele and Osekita (2006) found seed yield per plant showed significant positive correlation with number of pods per plant, height at flowering, pod width and weight of hundred seeds. Path coefficient analysis revealed that number of pods per plant and height at flowering had the highest direct effect on seed yield. This suggests that the two attributes have a strong influence on seed yield. Hence, number of pods per plant and height at flowering are the main determines of seed yield per plant in the studied variety.

Bello *et al.* (2006) found that the genotypic correlation coefficient showed more significant relationship between the pairs of characters *viz.*, fruit diameter, number of branches per plant, days to 50 per cent flowering, days to 95 per cent maturity, days to 50 per cent flowering and number of fruits per plant meaning that, these characters are more related genotypically.

Patro and Sankar (2006) reported that yield per plant showed a highly significant and positive correlation with germination percentage, number of branches per plant, number of ridges per fruit, fruit weight, number of seeds per fruit, 100 seed weight and ascorbic acid content. Yield per plant was positively and directly affected at both phenotypic and genotypic levels by germination percentage, number of branches per plant, number of fruits per plant, fruit weight, number of seeds per fruit, 100 seed weight and ascorbic acid content, at the genotypic level by plant weight, fruit volume and longevity of tenderness, and at the phenotypic level by number of nodes per plant.

Singh *et al.* (2006) studied that the fruit yield per plant was positively and significantly correlated with fruit length, fruit diameter, fruit weight and number of fruits per plant.

Mohapatra *et al.* (2007) estimated biochemical constituents like crude fiber (per cent), vitamin - C (mg/100 g) carried out for each of the cultivars at marketable matured stage. The genotypes showed significant variability for all the characters. Character association among the different fruits indicated that total fresh yield per plant was having positive and significant phenotypic correlation with number of fruits per plant, fruit girth, fruit diameter, internodal length and fruit weight. The same set of characters expressed in a similar manner under genotypic correlation study. Most of the genotypes were highly variable based on individual traits as well as divergent based on character constellation.

Singh *et al.* (2007) found the genotypic correlation (GC) in general was higher in magnitude than the corresponding phenotypic correlation (PC), indicating that genotype is superior but its expression is lessened under the influence of environment. Fruit yield (FY) had significant positive GC and PC with number of fruits per plant (NF), fruit length (FL) and plant height (PH). NF also showed significant positive genotypic and phenotypic associations with PH and FL. NF turned to be the major contributor to yield having the highest genotypic and phenotypic direct effects, followed by PH. Thus, FY in okra could be improved by selecting for more NF and number of branches per plant (NB), and short internodal length (IL).

Yadav *et al.* (2007) evaluated eight parents, i.e. Azad Bhindi-1, Azad Bhindi-2, KS-305, KS-312, BO-2, Arka Anamika, Pusa Sawani and IIHR-4, were used. Different characters such as days to flowering, plant height, number of nodes per plant, number of first fruiting node, length of internode, length of fruit, width of fruit, tapering length of fruit, number of fruits per plant and yield per plant, were studied. The phenotypic and genotypic correlation coefficients were worked out to measure the association among the quantitative traits. Highly significant positive associations were found between yield per plant and number of nodes per plant and yield per plant with number of fruits per plant in the F1 at both genotypic and phenotypic levels.

Shazia Ali *et al.* (2008) found that the correlation coefficients were consistently significant and positive in all the three population between fruit yield per plant and number of fruits per plant at both genotypic and phenotypic levels. The consistency was also observed in F_1 and F_2 generations between fruit yield per plant and plant height at both genotypic and phenotypic levels. Fruit yield per plant showed significant and positive correlation between length of fruit and width of fruit at genotypic level in both F_1 and F_2 generations.

2.5 Yellow vein mosaic virus (YVMV)

Only limited studied have been carried out to understand the mechanism of resistant to this virus. Singh *et al.* (1962) reported that four recessive alleles at two loci conferred resistance to yellow vein mosaic virus. However, Thakur (1976) advocated that resistance in an interspecific cross involving. An *esculaents* cv. Pusa Sawani and *A. manihot* ssp. *maniho*t cv. 'Ghana' was conditioned by the complementary dominants genes. On the other hand Jambhale and Nerkar (1981) and Nerker and Nerker and Jambhale (1985) advocated that YVMV disease resistance in *A. manihot* and *A. manihot* ssp. *manihot* is controlled by a single dominant gene in each taxon.

Sharma and Dhillon (1983) observed that some of the plants in F_1 hybrids and in resistant parent 'Ghana' as well not completely resistance and the characteristics symptoms of virus appeared either on the top or on the new shoot growth quite late in the season especially when the temperature started falling, this was also true in the some resistant segregants in the back crosses. They suggested that the gene responsible for resistant to virus or sensitive to the environmental changes particularly the low temperature. Therefore, the possibility that the resistant to yellow vein mosaic virus in *A. manihot spp.* is controlled by polygene can not be ruled out, which was again reported by Sharma *et al.* (1987) Veeraragavathatham and Irulappam (1990) observed that genetic variance was important for the virus incidence.

Mohapatra *et al.* (1995) noted that the disease was compared with severity index and a minimum variation in the severity index was observed among the varieties, Pusa Sawani was the most susceptible and recorded 100% infection while varieties like HRB-9-2, DOV-91-4 and Pashupati showed tolerance at least under field conditions.

Sagar (1997) tested eight varieties of okra YVMV and reported that Arka Anamika was highly resistant, Arka Abhay resistant and Prabhani Kranti and V-6 were moderately resistant to the disease. The other varieties tested were either susceptible or highly susceptible to YVMV.

Sannigrahi and Choudhary (1998) found that Arka Anamika and Arka Abhay was the most suitable yellow vein mosaic virus (YVMV) resistant to okra cultivars for commercial cultivation in Assam compared with Pusa Sawani a popular, but highly YVMV susceptible cultivar.

Chakraborty *et al.* (1999) reported the disease was characterized by the presence of conspicuous enations on the undersurface of the levels and leaf curling. The disease incidence varied from 2 to 83% in susceptible varieties grown in the field. Electron microscopic observation revealed geminated particles in infected sample.

Fugro and Rajput (1999) indicated that the progenies belonging to Sel.4 × Sel. 10, Sel. 4 × P-7 and P-7 × Sel.10 were free from YVMV. The progenies belonging to family EMS8 × BO-1 and PS × P-7 were highly susceptible. The progenies belonging to Sel. 4 × Sel. 10 were superior for yield, pod quality and disease resistance.

Ali *et al.* (2000) found the okra variety IPSA Okra-1, tolerant of YVMV [bhendi yellow vein mosaic virus] was crossed to 3 susceptible genotypes, *viz.* Prabhani Kranti, SL-44 and SL-46, to determine the nature of inheritance of tolerance of IPSA Okra-1.

Batra and Singh (2000) found that okras No.-6 LORM-1, VRO-3 and P-7 were free from disease reaction. Whereas, VRO-4 showed mile reaction. Okra hybrids DVR-1 and DVR-2 were found free disease. However, okra No.-6 among open pollinated and AROH-8 among hybrids gave the highest yield.

Bhagat (2000) reported a quantitative assessment of plant height, number of leaves, fruit/plant, fruit length, fruit girth, fruit weight and fruit weight/plant was made on healthy and diseased plants. The data reveal that the yield and other growth parameters were less affected in the resistant cultivar Prabhani Kranti in comparison with Vaishali Vadhu (susceptible) and Pusa Sawani (highly susceptible) cultivars.

Kumawat *et al.* (2000) studied the infestation of jassids and whiteflies started in the fourth week of July and reached peaks in the second and fourth weeks of September, respectively. Correlation of these insect-pests with abiotic factors *viz.*, minimum and maximum temperature, relative humidity and rainfall was also assessed. Maximum temperature was significantly correlated with whitefly density.

Ragupathi *et al.* (2000) evaluated 12 okra cultivars, including the highly-susceptible Pusa Sawani and MDU-1 for yield and resistance against BYVMV. The disease was absent in the highly-resistant cultivars BO.1 and HRB 55. Resistant cultivars were KS 404, HRB 9-2, Hy.8, P 7, Prabhani Kranti, Sel.10 and Sel.4, with a disease incidence of 0.51, 0.82, 1.26, 1.68, 2.87, 3.63 and 8.69%, respectively. BO.2 was susceptible (19.55%), and MDU-1 and Pusa Sawani recorded a disease incidence of 90.83 and 91.53%, respectively. The highest yield (103.09 q/ha) was obtained with HRB9-2.

Ratan and Bindal (2000) tested 25 lines of okra and observed that lines 407, 409, 417 and 430 were completely resistant to disease. The F_1 hybrid between the resistant was resistant, while susceptible from derived from parents. The studies indicated that resistance to disease monogenic and dominant. Maximum number of fruits and yield and yield per plant was recorded by hybrid 410 × 407 followed by 409 × 421 and 409 × 408 involving resistant × resistant and resistant × susceptible crosses, respectively.

Singh (2000) conducted a Field experiments during the Rainy seasons to identify varieties of okra suitable for western Uttar Pradesh conditions. Variety Prabhani Kranti gave higher yield and pod weight than the other varieties studied for all three years; in addition, Prabhani Kranti was also resistant to yellow vein mosaic virus.

Bhagat *et al.* (2001) studied the okra yellow vein mosaic virus (OYVMV) in okra cultivars Pusa Sawani (highly susceptible), Vaishali Vadhu (susceptible) and Prabhani Kranti (resistant) in Pusa, Bihar, India during the two Rainy seasons. The rate of infection was higher in Vaishali Vadhu and Pusa Sawani compared to Prabhani Kranti. The infection was almost five times in Pusa Sawani 40-day-old plants. The maximum rate of disease development was between 35 and 45 days after sowing (DAS), irrespective of cultivars in both years. Based on the results, it may be recommended that okra cv. Prabhani Kranti should be sown during the Rainy season.

Debnath and Nath (2002) studied to determine an environmentally safe management of yellow vein mosaic disease of okra through the use of tolerant cultivars (Prabhani Kranti, Arka Abhoy, Arka Pankaj, Sevendhari Green and an F1 hybrid). Among the varieties tested, F_1 hybrid (ECL) produced highest fruit yield with lower degree of virus infestation followed by the open pollinated variety, Arka Abhay.

Rashid *et al.* (2002) studied Twelve okra germplasm were screened for resistance to okra yellow vein mosaic virus (YVMV) under field conditions. Lines OK-292 and OK-285 showed resistant to YVMV in both season and OK-315, OK-316 and OK-317 were found tolerant.

Singh *et al.* (2002) evaluated 12 okra cultivars in which Pusa Sawani served as the susceptible control. The average YVMV disease incidence varied from 0.7% (Arka Abhay) to 57.4% (Chhindwada Local) in Rainy , from 1.4% (Arka Abhay) to 53.8% (Pusa Sawani) in Summer, and 7.4 % (Arka Abhay) to 51.2% (Prabhani Kranti) during Rainy in next year. Arka Abhay showed the lowest average YVMV incidence (1.2%), followed by Ambica Local (7.5%), Ratna Raj (9.6%) and Green Gold (9.7%). These were classified as resistant. Arka Anamika was moderately resistant to YVMV. Disease severity was lowest in Arka Abhay (9.4%), followed by Arka Anamika (32.2%) and Green Gold (44.2%).

Debnath and Nath (2003) found that the AM-4-5 showed complete tolerance of YVMV (0%) during 1999 and 2000, while Arka Abhoy showed mild infection (4.44%) in 1999 and tolerance of YVMV in 2000 (0%).

Singh *et al.* (2003) evaluated the performance of 5 okra hybrids (DVR-1, DVR-2, Shree, HIHBO-83 and HIHBO-90). DVR-2 recorded the longest pods and highest number of pods, plant height, stem diameter, whereas DVR-1 recorded the highest pod weight per plant and total pod yield/ha. The hybrids HIHBO-90, DVR-1 and DVR-2 were free from YVMV infection.

Ahmed and Patil (2004a) studied on disease incidence when the crops were 1-2 months old. Pusa Sawani recorded the highest disease incidence during Rainy season (15.08%) and Summer (58.14%). Arka Anamika recorded the lowest disease incidence during Rainy season (0.07%) and Summer (20.47%).

Ahmed and Patil (2004b) reported that the cultivar Arka Anamika recorded the lowest disease incidence (0.80%) and the highest yield (23.00 t/ha), while the susceptible control Pusa Sawani recorded the highest disease incidence (74.99%). None of the genotypes were immune to the disease. Arka Anamika, Hybrid 8 and Hybrid 10 were resistant, while Soumya F_1 and Reshma were moderately resistant.

Neeraja *et al.* (2004) studied the pooled data of two years revealed that the incidence of YVMV was minimum (9.7) in Varsha Uphar which was on par with HYOH-1 (9.9), KOH-1 (10.4), JNDOH-1 ((10.6), AROH-47 (11.2) and MBORH-913 (11.3). Though the incidence of YVMV was less in MBORH-913, the fruit yield was also not much due to fewer number of fruits/plant anti loss of fruit weight. NOH-15 and JNDOH-1 hybrids can be recommended for the areas where the incidence of YVMV is higher as they were found to be resistant to YVMV with good fruit yield (74.8 and 74.7 q/ha respectively).

Vijaya (2004) found that VRO-5 and VRO-6 from the Indian Institute of Vegetable Research recorded the lowest mean disease incidence (4.1 and 6.8%). The mean yields of VRO-5 and VRO-6 were 59.59 and 50.94 q/ha, respectively.

Dhankhar *et al.* (2005) observed the nature of inheritance for resistance to yellow vein mosaic virus of okra [*Abelmoschus esculentus* (L.) Moench] in an interspecific cross of 'Hisar Unnat' *Abelmoschus esculentus* × *Abelmoschus manihot* (L.) Medikus ssp *manihot*. The cross-compatibility was one way, i.e. when 'Hisar Unnat' *A. esculentus* was used as a female parent. The F_1 fruits were generally seedless, however, back crosses could be attempted with partial success.

Debnath *et al.* (2006) evaluated the resistance of okra cultivars Prabhani Kanti, Seven Dhari Green, Punjab Seven, Arka Abhay, AM-4-5, JNDO-5, VRO-5, VRO-6, VRO-3, VRO-4, KS-410, Lorm 1 and D-1-87-5 to Okra yellow vein mosaic virus. Punjab Seven and Arka

Abhoy were tolerant of the disease, whereas AM-4-5 was resistant. All the other cultivars tested were susceptible to the disease.

Anand *et al.* (2007) study the performance of 14 okra varieties for resistance to Yellow vein mosaic virus (YVMV) for yield and quality parameters. Based on the *per se* performance, the varieties MDO-6, TC-17 and OKHO 1016 were selected as promising ones with respect to growth and yield parameters. Screening for resistance to YVMV incidence indicated that the varieties MDO-6, Varsha Uphar and TC-17 were found to be moderately resistant to YVMV disease.

Prabu and Warade (2007) reported the *A. caillei* cultivar Susthira was found to be highly resistant to the virus during both the seasons while only one *A. esculentus* cultivar Varsha Uphar showed highly resistant reaction during Rainy season only. However, the *A. esculentus* cultivars GKIV-3-4-4 and JNDO-5 expressed resistant reaction to the virus during Rainy season. While rest of the varieties were susceptible during both the seasons.

Bhattiprolu and Rahman (2008) reported that the mean disease incidence (PDI) of bhendi yellow vein mosaic virus disease during the three years of trial ranged from 3.63 to 75.09 per cent. Among the 12 entries evaluated, the entry VRO-4 showed minimum disease (3.63%) followed by P-7 (4.24%), LORM-1 (4.49%) and VRO-3 (4.63%) respectively, while the control, Pusa Sawani, recorded the maximum of 75.09 per cent PDI, 100 per cent disease incidence was recorded in the control. No disease was recorded in KS-410 and Arka Abhaya. Performance of different entries over three years revealed that disease reduction in all the entries was significantly higher than in the control. Mean yield ranged from 47.93 q/ha in KS-410 to 80.93 q/ha in HIGH-068. HIGH-068 recorded the maximum yield increase of 55.28 per cent, followed by Arka Abhaya (45.52%), VRO-6 (37.74%) and VRO-5 (36.91%). Disease reduction ranged from 84.75 per cent in

Arka Anamika to 95.17 per cent in VRO-4. However, resistance was not correlated with increase in yield. High-yielding entry, HIGH-068, recorded 91.54 per cent reduction in disease compared to VRO-4 with 95.17 per cent disease reduction but only 6.41 per cent increase in yield.

Biswas *et al.* (2008) found that the disease incidence varied from 18.25 to 64.96 per cent. Disease incidence was lowest in ZOH-3002 (18.25%) and highest in VB-9801 (64.96%). The population of whitefly (*Bemisia tabaci*) was lowest in ZOH-3002, followed by BO-13 and US-7109, and highest in VB-9801. ZOH-3002 had the highest yield (85.43 q/ha). The lowest yield was registered for VB-9801 (13.20 q/ha). Of the 14 cultivars/ lines evaluated, ZOH-3002, US-7109 and BO-13 were moderately resistant; NOH-147, HRB-108-2 and AROH-113 were moderately susceptible; HRB-107-4, P-7, Arka Abhay, IIVR-11, Prabhani Kranti, Pant Bhendi and Local were susceptible; and VB-9801 was highly susceptible.

2.6 Nature and magnitude of gene action

Several biometrical designs were developed to partition statistic nature of gene action. Among them Line × tester analysis (Kempthorne, 1957) diallel cross analysis (Jinks and Hayman, 1953), partial diallel analysis (Kempthorne and Curnow, 1961) have been extensively used by the breeders of self, often cross and cross pollinated crops.

The majorities of economically important plant characteristic are quantitative in nature and show continuous gradation of expression between extremes.

In okra, varying magnitude of different forms of gene action governing yield and other traits related to the productivity has been reported in a number of studies.

Although, Fisher (1918) was the first to show the epistasis as a separate component of genetic variation. No studies were made on this aspect for a long time. Additional reports dealing with portioning of epistatic variance into additive × additive, additive × dominance and dominance × dominance interaction variations have been presented by Wright (1935). Anderson and Kempthorne (1954), Hayman and Mather (1955) and Cockerharn (1961).

In order to test the presence of epistatis in crosses, Mather (1949) and Hayman and Mather (1955) developed scaling testes (A, B, C & D). The significant deviation of any these scales from zero indicted the presence of epistasis. In these tests, only a few combinations of the generations are used as a time. The sets of such scaling tests can, however, are devised to cover any combination of the types of generations that may be available (Mather and Jink, 1982). These scaling tests only test the presence of epistasis and not the magnitude of various components.

Hayman and Mather (1955) developed models to describe the genetic variation present into inbred lines and their descendant families, Anderson and Kempthorne (1954) showed that all the information about additive, dominance and epistatic variation available in the means of generations described from two inbred lines is contained in just 6 parameters.

Hayman (1957) and Jinks and Jones (1958) advocated six parameter model for estimation of various genetic component i.e. mean (m), additive (d), dominance (h), additive × dominance (h), additive × additive (i), dominance × dominance (j) and additive × dominance (l).

Hayman (1958) found that the means of the families or generations are influenced by epistasis, often to as great as by additive or dominance variation. He further observed that various form of epistasis may occur with varying signs. The presence of non-allelic interactions i.e., epistasis has been complex problem faced by the breeder in studying the inheritance of quantitative characters. In general, the earlier statistical approaches in quantitative genetical studies have ignored epistasis or assumed it to be unimportant (Gamble, 1962).

Gardner (1963) found same importance parameters which have great utility to plant breeding as given below:

1. Additive variance, which arises due to the additive effect of genes at all segregation loci.
2. Dominance variance, which arises from the intra-allelic interaction of genes at all segregating loci.
3. Epistatic variance which is associated with inter-allelic interactions of genes at one or more segregating loci consists of:
    a. Additive × additive
    b. Additive × dominance
    c. Dominance × dominance.
4. Average degree of dominance.
5. Genotype × Environment interaction
    a. Additive gene effect × Environment.
    b. Non-additive gene effect × Environment.
    c. Genotypic correlation.

Stuber and Moll (1969) reported that the amount of total variation that could be attributed to epistasis was on an average less than 10 per cent in some specific crosses of maize. The implications of genetic variance in a breeding programme have been discussed by Cockerharn (1961) and Dudley and Moll (1969). They have indicated the presence of epistasis, particularly of duplicate type (*h* and *l* with dissimilar types of sign) slows down the breeding programme and hinders the isolation of desired types in the early segregating generations. In okra, varying magnitude of different forms of gene effects for yield and other morphological traits related to the productivity have been reported in a number of studies.

Thaker *et al.* (1981) advocated that the additive component was the chief determinant of genetic advance for fruit yield per plant, fruit weight and fruit length while number of fruits per plants was governed by non-additive gene actions.

Das *et al.* (1996) studied a 10 × 10 diallel analysis in okra *(Abelmoschus esculentus)* for 11 biometric characters, suggested the presence of additive and non-additive gene action in 6 traits. Dominant gene action with asymmetrical distribution of genes and overdominance was predominant for almost all the characteristics. It is suggested that recurrent selection and heterosis breeding could prove effective for *A. esculentus* improvement.

Hoque and Hazarika (1996) evaluated the progenies of diallel crosses of 6 okra cultivars were evaluated for 11 quantitative traits during Rainy season. Days to flowering, branches/plant and ridges/fruit were controlled by additive components, while the remaining traits were controlled by non-additive gene action.

Sood (2001) found that the non-additive components (H1 and H2) were significant and larger in magnitude than additive (D) components in both generations. The graphical analysis also revealed the preponderance of non-additive gene action for this trait. The combining ability analysis revealed the importance of non-additive gene action. Prabhani Kranti, P-7 and Arka Abhay were observed as good general combiners for the number of pods.

Prakash *et al.* (2002) observed the estimates of general and specific (GCA) combining ability and their ratio indicated the predominance of non-additive gene action for all traits. Pusa Makhmali, Arka Anamika, Punjab Padmini, and Dharmapuri local, the best general combiners for fruit yield per plant, as well as Punjab Padmini × Pusa Makhmali and Dharmapuri local × Prabhani Kranti, which exhibited favourable SCA effects for the majority of the characters, can be exploited in breeding for improved yield.

Vishwakarma *et al.* (2002) studied the 50 cultivated form of *Abelmoschus esculentus* germplasm for qualitative and quantitative parameters as plant height, 50 per cent flowering, fruit length, fruit weight, number of fruits per plant and yield per acre. The gene action was observed to be complementary.

Yadav *et al.* (2002) reported high heritability accompanied with high genetic advance was observed for yield per plant and plant height. Moderate to high heritability coupled with low to moderate genetic advance was observed for number of days to flowering, number of branched per plant, number of nodes per plant, fruit length, fruit width, tapering length of fruit and number of fruits per plant indicating the prevalence of the non additive type of gene action for these traits. Yield per plant, plant height, number of nodes per plant, number of days to flowering, fruit length and number of fruits per plant comprised the major yield contributing characters.

Adeniji and Kehinde (2003) found the ratio (H/D) 1/2=2.30 implied an overdominance situation across loci for the mean degree of dominance for pod yield. A positive F_1 estimate indicated that there were in general more dominant genes than recessive genes in the parents. Narrow sense heritability was 0.48, suggesting that a response to genetic improvement may be rapid.

Adeniji and Kehinde (2004) studied diallel analysis of earliness along with eight accessions and 28 F_1 generations. The mean squares due to general combining ability were greater than the mean squares for specific combining ability, suggesting the preponderance of additive gene effects in relation to other gene action. The component analysis indicated that the magnitude of additive gene estimates (D) was higher than the estimate of dominance (H-1 and H-2) for earliness. The ratio (H/D)(1/2) for early flowering showed a partial or incomplete dominance situation across loci. A negative estimate of F1 suggests that there were in general, more dominant decreasing alleles than there are dominant increasing alleles for earliness.

Kumar *et al.* (2006) studied line × tester (6 × 3) in okra and reported preponderance of non-additive gene action for plant height, number of branches per plant, capsule weight, capsules length, number of seed per capsule, 100 seed weight, number of capsule per plant, capsule yield per plant and seed yield per plant.

Kumar *et al.* (2006) studied line × tester analysis in okra with 6 line TCR 2056, TCR 2086, TCR 852, Gobi local, Dharmapuri local and Monhanoor Local and three testers MDU-1, Prabhani Kranti and Punjab Padmini. The combining ability and variances indicating the preponderance of non-additive gene action for all the characters.

Adeniji and Kehinde (2007) estimated variance due to SCA was greater than GCA variance for length and width of pods at edible stage and vice versa for length and width of pods at maturity. The study identified parents 7, 6, 4 and 5 as best combiners for edible pod length and width and mature pod length and width. Component analysis indicated that the dominant genetic action predominate other genetic effects in the inheritance of length and width of pods.

Arora and Ghai (2007) observed that in general all the traits were governed by additive, dominance and digenic non-allelic gene interactions. The non-additive gene effects were more pronounced than additive ones for most of the traits in both the environments.

Eswaran *et al.* (2007) fruit yield per plant was controlled by partial dominance. Among the parents involved in cross combinations characterized by high standard heterosis for fruit yield per plant, Prabhani Kranti had the highest number of recessive genes, whereas Arka Anamika and EC-305626 had equal numbers of dominant and recessive genes. This indicated that dominant or recessive genes are not the cause of heterosis. Heterosis might be due to epistatic gene action.

Singh *et al.* (2007) studied heterobeltiosis in okra and observed a most part of heterobeltiosis was accounted for dominance and dominance × dominance type of epistatic interactions and less for additive dominance type of gene effect for all the 3 characters *viz.*, length of fruits, number of fruits/plant and weight of fruit/plant.

Yadav *et al.* (2007) studied genetic components of variance in a diallel cross analysis involving 8 parents, (excluding reciprocals) for 10 traits *viz.* days to flowering, plant height, number of branches per plant, number of first fruiting nodes, number for nodes per plant, length of internode, fruit length, fruit width, number of fruit per plant, yield per plant. They observed that additive genetic variance (D) was observed highly significant for all the characters excepts plant height, number of branches per plant and number of nodes per plant, which indicated partial dominance.

Weerasekara *et al.* (2008) observed that the non-additive gene action was an integral component of the genetic architecture of the evaluated traits.

Udengwu (2008) found that the fruit skin colour in okra is monogenically controlled and the recessive genes involved form a multiple allelic series. The genotypes of the genes involved are suggested as well as their dominance hierarchy. Therefore transferring the deep green colour from Awgu Early, an elite cultivar, to other identified cultivars will be quite easy and fast. The results also failed to agree with some of the reports on the inheritance of okra fruit skin colour involving some exotic okra cultivars, thereby contributing to the resolution of some of the existing controversies on the pattern of inheritance of this trait.

Vachhani and Shekhat (2008) revealed that estimation of variance due to additive (D) and dominance (H) both were involved in the inheritance of most of the traits studied with preponderance of non-additive gene actions for all the characters in both the generations. These findings were also confirmed by the values of average degree of dominance estimates $(H_1/D)^{1/2}$, which was found in the range of over dominance for all the traits in both the generations except for number of branches per plant in F_1 generation.

Singh *et al.* (2009) reported that most part of heterobeltiosis accounted for dominance and dominance × dominance type of epistatic interactions and less for additive × dominance type of gene effects.

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Chapter III

MATERIAL AND METHODS

The present research work **"Hybrid breeding in okra [*Abelmoschus esculentus* (L.) Moench]"** was undertaken to study the heterosis, combining ability, heritability and genetics advance, correlation and path coefficient analysis, incidence of yellow vein mosaic virus (YVMV) and nature and magnitude of gene actions, using line × tester mating design.

A brief note on the materials used and the methodology adopted for the study is given below.

3.1 Experiment location

The experiment was carried out at the Vegetable Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. This farm is located at the latitude of 25.1^0 north and longitude of 83.03^0 east. The attitude is about 123.23 meters from mean sea level and it is located in the centre of Indo-Gangetic belt.

3.2 Climatic condition

The climate of this area is semi-arid to semi-humid and is often subject to extremes of weather conditions. The average rainfall in this area is about 1000 to 1100 mm annually, most of which generally occur during Rainy season (Middle of June to Middle of October). Some times, continuous cloudy weather with heavy rains for a longer period drastically affect the local agricultural system. Occasional showers are also very common in winter season, but this period in usually cool and dry. The hot period of Summer season generally starts some where in middle of April and continuous till the middle of

June, when the presence of monsoon in the sky becomes clearly visible. The weather data at meteorological observatory of the Institute of Agricultural Science for the period which experiment were conducted have been given below.

Table 3.2a: Weekly average meteorological data for the cropping period, during Rainy season (2007)

Week no.	Month & date	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Sun-shine (hrs.)	Evaporation (mm)
			Max.	Min.	Max.	Min.		
24	June 11 -17	84.2	34.2	25.2	58	63	4.1	5.2
25	18 -24	0.0	37.2	26.8	75	50	10.0	6.8
26	25 -01	105.4	36.2	22.7	78	55	7.8	5.3
27	July 02-08	8.0	35.6	26.7	78	59	7.4	5.2
28	09-15	24.2	35.2	25.7	78	62	7.1	4.7
29	16-22	158.6	32.8	25.4	82	66	2.8	4.1
30	23-29	38.0	30.9	24.9	80	51	1.6	2.7
31	30-05	37.0	33.5	25.0	66	46	4.0	3.9
32	Aug.06-12	0.0	34.1	26.6	80	68	8.5	4.8
33	13-19	33.2	29.9	25.1	78	83	0.2	2.6
34	20-26	3.2	33.4	25.6	84	68	6.3	3.7
35	27-02	44.2	33.1	25.4	89	72	4.1	3.2

Table 3.2b: Weekly average meteorological data for the cropping period, during Summer season (2008)

Week no.	Month & date	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Sun-shine (hrs.)	Evaporation (mm)
			Max.	Min.	Max.	Min.		
11	March 12-18	0.0	32.8	16.1	59	32	7.7	5.0
12	19-25	0.0	35.5	18.9	64	32	9.1	5.9
13	26-01	0.0	37.2	18.7	49	16	8.9	7.0
14	April 02-08	1.8	34.3	19.2	59	25	8.2	5.8
15	09-15	0.0	40.5	22.2	38	17	10.1	9.0
16	16-22	0.0	41.4	23.6	40	12	10.4	9.2
17	23-29	0.0	43.9	22.4	28	09	10.4	9.2
18	30-06	0.0	42.5	25.2	49	12	9.5	9.8
19	May 07-13	2.0	41.1	25.6	41	19	9.4	9.3
20	14-20	6.0	40.8	26.7	44	23	9.0	8.6
21	21-27	7.6	37	24.6	64	36	7.7	7.2
22	28-03	0.0	41.6	22.8	42	20	10.4	9.0

3.3 Experimental materials

The experimental materials consist of 51 crosses involving 17 lines and 3 testers. The details of lines and testers are as follows:

Table 3.3.1: Name and source of lines and testers

S. No.	Name of lines/testers	Source
Lines (Female)		
1.	IC - 128883	IIHR, Bangalore
2.	VRO-5	IIVR, Varanasi
3.	VRO-6*	IIVR, Varanasi
4.	AC-108	IIVR, Varanasi
5.	IC - 45806	IIVR, Varanasi
6.	IC - 218877	IIVR, Varanasi
7.	IC - 218844	IIVR, Varanasi
8.	Arka Abhay	IIHR, Bangalore
9.	IC - 43720	IIVR, Varanasi
10.	IIVR - 342	IIVR, Varanasi
11.	IC - 140906	IIVR, Varanasi
12.	IIVR - 198	IIVR, Varanasi
13.	EC - 305612	IIVR, Varanasi
14.	IIVR - 435	IIVR, Varanasi
15.	IIVR - 401	IIVR, Varanasi
16.	SA - 2	IIVR, Varanasi
17.	IC - 140934	IIVR, Varanasi
Testers (Male)		
1.	Arka Anamika	IIHR, Bangalore
2.	Pusa Sawani	IARI, New Delhi
3.	Parbhani Kranti	MPKV, Rahuri

* Standard variety VRO – 6.

3.4 Methods

3.4.1 Selfing technique

The parents were maintained by selfing for six generations. The flower buds likely to open on the following day were bagged.

3.4.2 Crossing technique

The flower buds likely to open on the following day were selected both in lines and testers. In the lines the selected flower buds emasculated in the evening of the previous day. For the emasculation a slight ring cut at the base of the flower bud with the help of a blade. Petals along with calyx sheath are removed and stamina column and stigma are exposed. The undehised another's are removed with a pair of forceps. The emasculated buds were covered by small tissue paper bags. In the tester also the selected buds were bagged to prevent from the contamination of the foreign pollen. On the following day, the pollen collected from the bagged flowers was dusted between 7.00 and 9.30 a.m. on the stigmatic surface. The flower was them rebagged and labeled. The bags were removed on the fourth day after crossing when the development of ovary was perceptible.

3.4.3 Experimental design

The experiment was carried out in a Randomized Block Design with three replications of assess the performance of 20 parental lines (17 lines and 3 testers) and their 51 F_1 hybrids. The seeds of the parents and F_1's were dibbled on the sides of the ridges formed 60 cm apart given a spacing of 30 cm between plants. A fertilizer schedule of 100 kg N, 60 kg P_2O_5 and 50 kg K_2O per hectare was adopted. Recommended agronomic package of practices and plant protection measures were followed to raise a good crop. Randomly ten plants were tagged for each hybrid and five plants were tagged for each line and tester in each replication for observation. The parents and their progenies in each cross were evaluated for the various characters.

3.5 Observations recorded

The observations were recorded on the basis of ten randomly selected plants in parents and hybrid in each replication for various characters as follows:

3.5.1 Plant height (cm): It was measured from the base of the plant to the top of the plant at maturity in centimeter.

3.5.2 Stem diameter (cm): The diameter of the main stem at a constant point i.e. 2 cm above the ground level was measured with the help of Vernier Calipers.

3.5.3 Number of branches/plant: Number of branches/plant on main shoot was recorded at the time of maturity.

3.5.4 Number of nodes/plant: The total number of nodes was counted at the time of final picking of fruit.

3.5.5 Internodal length (cm): The distance of internode is taken from 3 places in each plant and than mean is measured in centimeter.

3.5.6 Days to first flowering: Number of days from the date of sowing to the emergence of first flower was considered as days to first flower appearance.

3.5.7 Days to 50 per cent flowering: The days to 50 per cent flowering were recorded as number of days taken from the date of sowing to 50 per cent flowering of tagged plants.

3.5.8 Number of fruits/plant: The number of fruits/plant were recorded for all picking and counted.

3.5.9 Single fruit weight (g): The weight of edible fruit was recorded in gram at the time of each picking (5^{th} days from anthesis) from each plant.

3.5.10 Fruit length (cm): The length of each fruit was measured in centimeter (cm) from the base of the fruit to the tip of the fruit at the time of first picking of 15 randomly selected pods in each replication and average was worked out.

3.5.11 Fruit diameter (cm): The diameter of pod was measured in centimeter with the help of Vernier Calipers at the time of first picking of 15 randomly selected pods in each replication and average was worked out.

3.5.12 Fruit yield/plant (g): The total fruit yield was recorded per plant in gram.

3.5.13 Number of seeds/fruit: Number of seeds from 15 dried pods of parents and F_1's in each replication was extracted and average was worked out.

3.5.14 Number of ridges/fruit: The number of ridges per fruit was recorded at fruit maturity stage.

3.5.15 Colour of pod: The colour of pod was visually measured.

3.5.16 Reaction to yellow vein mosaic virus disease: The days to appearance of symptoms of yellow vein mosaic was recorded at 30 days intervals from sowing to pod maturity stage and average was worked out.

3.5.17 Ascorbic acid content (mg/100g):

Ascorbic acid was determined by the usual titration method, using 2, 6-dicholoro indophenol solution (AOAC, 1990).

Ascorbic acid, otherwise known as vitamin C is an antiscorbic compound. Generally it is present in all the fresh vegetables and fruits. It is a water soluble and heat-labile vitamin. It can be estimated by volumetric as well as colourimetric procedures.

In the volumetric procedure described below, ascorbic acid reduces the dye, 2, 6-dichlorophenol indophenol to a colourless leuco-base. During the process, ascorbic acid gets oxidized to dehydroascorbic acid. The dye, which is blue in colour, becomes pink in acid medium which is the end-point of the titration.

Reagents

1. Oxalic acid

Dissolve 4 g of oxalic acid in distilled water and make upto 100 ml with distilled water.

2. Dye solution

Weight 42 mg of sodium bicarbonate in distilled water, add 52 mg of 2, 6-dichlorophenol indophenols and make upto 200 ml with distilled water.

3. Stock standard solution

Dissolve 100 mg of ascorbic acid in oxalic acid solution and make upto 100 ml in a volumetric flask with oxalic acid. This solution contains 1 mg per ml.

4. Working standard solution

Dilute 10 ml of the stock standard solution to 100 ml with oxalic acid solution. This solution contains 100 mg ascorbic acid per ml.

Procedure

1. To 5 ml of working standard in a 100 ml conical flask, add 5 ml of oxalic acid and titrate against the dye (V_1) from the burette to a pink end point which persists for a few minutes. The amount of dye consumed is equivalent to the amount of ascorbic acid present in the conical flask.
2. Extract the sample (5 g) in oxalic acid, filter through muslin cloth and make upto a known volume (e.g. 100 ml) with oxalic acid.

3. Pipette out a known volume of the filterate (e.g. 5 ml) in the conical flask, add 5 ml of oxalic acid and titrate against the dye (V_2) to the pink end point.

4. Calculate the amount of ascorbic acid (mg/100 g) in the sample as follows:

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Ascorbic acid (mg) content in standard}}{\text{ml of aliquot}} \times \frac{V_2}{V_1} \times \frac{\text{Total sample volume (ml)}}{\text{Wt. of the sample (g)}} \times 100$$

3.6. Statistical analysis

The experimental data recorded for different characters were subjected to following biometrical analysis. Data were analyzed at Computer Center, BHU, Varanasi.

3.6.1 Analysis of variance: The mean values were subjected to statistical analysis as per the methods of Kempthorne (1957). ANOVA is detailed below (Table 3.6.1)

Table 3.6.1: Analysis of variance for heterosis

Source of variation	d.f.	Expectation of mean square
Replication	(r-1)	$\sigma^2 r + t\sigma^2 r$
Treatments	(t-1)	$\sigma^2 r + r\sigma^2 rt$
Parents	(p-1)	$\sigma^2 e + t\sigma^2 p$
Parents vs. crosses	1	$\sigma^2 e + \frac{r}{h+p} p\sigma^2 h^2 + h\sigma^2 p^2$
Crosses	(h-1)	$\sigma^2 e + r\sigma^2 h$
Lines	(f-1)	$\sigma^2 e + r\sigma^2 f$
Testers	(m-1)	$\sigma^2 e + r\sigma^2 m$
Line × testers	(f-1) (m-1)	
Error	(r-1) (t-1)	$\sigma^2 e$

Where;
r = Replications, h = Hybrid, m = Male parents (testers),
p = Parents, f = Female parents, t = Treatments

The replication, treatments, parents, parents vs. crosses and crosses mean square were tested against error M.S. by 'F' test, whereas, line and testers were tested against M.S. line × tester.

3.6.2 Estimation of heterosis

The magnitude of heterosis was estimated with the help of the following formula. Heterosis, the increase of F_1 mean over the better parental value and mid parental value, was calculated as follows:

Per cent heterosis over better parent = $\frac{\overline{F}_1 - \overline{BP}}{BP} \times 100$

Per cent heterosis over standard parent = $\frac{\overline{F}_1 - \overline{SP}}{SP} \times 100$

Where,

F_1 = Mean value of F_1's $\overline{BP}$ = Better parent value,

$\overline{SP}$ = Standard parent value.

Standard error of difference and critical difference for heterosis over better and mod parents were calculated as follows and where same as used for comparing any two genotyping means S.E. (d) = $\sqrt{\frac{2Me}{r}}$

C.D. = S.E. (d) × 't' at 5% error degree of freedom.

3.6.3 Combining ability analysis

Combining ability analysis in line × tester design was carried out by Kempthorne (1957). The following model was used for estimating the general combining ability and specific combining ability effects in combining ability analysis.

X_{ikj}	=	$\mu + g_1 + g_1 + S_{ij} + e_{ijk}$
μ	=	general mean
g_1	=	GCA effect of i^{th} line
i	=	1, 2, 3 9
g_j	=	GCA effect of j^{th} tester
j	=	1, 2, 3 ....
s_{ij}	=	SCA effect of i_{th} combination and
c_{ijk}	=	error associated with the observation
k	=	1, 2 ....r

3.6.3.1 Analysis of variance for combining ability

In the analysis of variance for combining ability, the component due to line, tester and line × tester was calculated by splitting the cross sum of squares (Table-3.6.3.1)

Table 3.6.3.1: Analysis of variance for combining ability

Sources	d.f.	S.S.	M.S.
Replication	(r-1)	$\sum_{k=1} \frac{X^2..k}{lt} - \frac{X^2}{ltr}$	
Treatment (cross)	(lt-1)	$\sum_{i=1}\sum_{j=1} \frac{X^2(ij)}{r} - \frac{X^2}{ltr}$	M_0
Line	(1-1)	$\sum_{i=1} \frac{X^2...}{tr} - \frac{X^2}{ltr}$	M_1
Tester	(t-1)	$\sum_{j=1} \frac{X^2...j}{lt} - \frac{X^2}{ltr}$	M_2
Line × Tester	(1-1) (t-1)	$\sum_{i=1}\sum_{j=1} \frac{X^2(ij)}{r} - \frac{X^2...j}{lr} + \frac{X^2}{ltr}$	M_3
Error	(lt-1) (r-1)	By differences	
Total	(ltr-1)	$\sum_{i=1}\sum_{j=1}\sum_{k=1} X^2ijk - \frac{X^2}{ltr}$	

3.6.3.2 Estimation of GCA and SCA effects

The individual effects were estimated as follows.

3.6.3.2.1 Estimation of GCA effects

a) For lines gi = $\frac{Xi}{tr} - \frac{X}{tr}$

Where, gi = general combining ability of i^{th} line.

Xi = total of i^{th} line over testers and replication.

b) For testers gi = $\frac{Xj}{lr} - \frac{X}{ltr}$

Where, gi = general combining ability of i^{th} tester.

Xj = total of j^{th} line over testers and replication.

3.6.3.2.2 Estimation of SCA effects

$$Sji = \frac{Xij..}{r} - \frac{Xi...}{tr} - \frac{Xj}{lr} + \frac{X...}{ltr}$$

Where,

Sij = specific combining ability of the cross between i^{th} line and j^{th} tester.

Xij = total of i^{th} combination overall replications.

3.6.3.2.3 Analysis of variance for combining ability

Expectations of mean squares in the above table for the analysis of variance of combining ability are presented below:

Table 3.6.3.2.3.1: Expectations of mean squares

m.s.	Expected mean squares
M_1	σ^2 e+r [Cov. (F.S.)-2Cov. (H.S.)] + tr Cov. (H.S.)
M_2	σ^2+r[Cov. (F.S.)-2Cov. (H.S.)]+lr Cov.
M_3	σ^2+r[Cov. (F.S.)-2Cov. (H.S.)]
M_4	σ^2e

Where,

r = number of replication, 1 = number of lines, t = number of testers, X.....K = sum of all the (l × t) crosses in k^{th} replication, X....= sum of all the (l × t) crosses over all replications, Xij = sum of $(ij)^{th}$ cross combination overall replication, Xi = sum of i^{th} line overall testers and replication , Xj = sum of j^{th} tester overall the lines and replications, Xijk = $(ij)^{th}$ observation in k^{th} replication, M_1= mean square due to lines, M_2 = mean square due to tester, M_3 = mean square due to line × tester interaction and M_4 = mean square due to error.

3.6.3.2.4 Standard error for combining ability effects and their differences

(i) SE (m) (gi) for line = $\left[\frac{l-1}{ltr}.Me\right]^{1/2}$

(ii) SE (m) (gi) for tester = $\left[\frac{t-1}{ltr}.Me\right]^{1/2}$

(iii) SE (d) (gi - gi) for line = $\left[\frac{(l-1)(t-1)}{ltr}Me\right]^{1/2}$

(iv) SE (d) (gi - gi) for tester = $\left[\frac{l-1}{ltr}.2Me\right]^{1/2}$

(v) SE (d) (gi - gi) for tester = $\left[\frac{t-1}{ltr}.2Me\right]^{1/2}$

(vi) SE (d) (Sij - Skj) for hybrid of same line = $\left[\frac{t-1}{rl}.2Me\right]^{1/2}$

Where,

S.E. (m)	=	standard error of mean
S.E. (d)	=	standard error of difference between two values
Me	=	error mean square

Critical differences (C.D.) = SED × 't' at 5% error d.f.

3.6.3.3. Testing the significance of GCA and SCA effects

Significance of GCA and SCA was tested by 't' test as follows:

t = $\frac{gi}{Se(m)gi}$ and $t = \frac{gi}{SE(m)gi}$

t = $\frac{Sij}{SE(m)Sij}$

Where,

gi = GCA of i^{th} line, gi = GCA of j^{th} tester, SE (m) gi = standard error of lines, SE(m) gj = standard error of testers, Sij = SCA of cross between i^{th} line j^{th} tester, SE(m) Sij = Standard error of crosses.

Calculated value of 't' tested against value in the 't' table at error d.f. at 5 and 1 per cent levels of probability.

3.7 Component of variance

Treatment and error mean squares were taken as estimates of phenotypic (σ^2p) and environmental (σ^2e) variance, respectively. The phenotypic variance being the summation of genotypic and environmental variance. Genotypic variance (σ^2g) was calculated by subtracting the mean squares at treatment level as propose by Burton and de Vane (1953).

$$\sigma^2 p = \frac{Mv - Me}{r}$$

$$\sigma^2p = \sigma^2g + \sigma^2 e$$

$$\sigma^2e = Me$$

Where,

Mv = Treatment mean square.

Me = Error mean square.

r = Number of replication.

3.7.1 Coefficient of variation (CV)

Phenotypic, genotypic and environmental coefficients of variation for different characters were estimated as suggested by Burton and de Vene (1953).

Phenotypic coefficient of variation (P.C.V.)

$$\text{PCV \%} = \frac{\sqrt{Phenotypic\ variance}}{\overline{X}} X\ 100$$

Genotypic coefficient of variation (G.C.V.)

$$\text{PCV \%} = \frac{\sqrt{Genotypic\ variance}}{\overline{X}} X\ 100$$

Environmental coefficient of variation (E.C.V.)

$$\text{PCV \%} = \frac{\sqrt{Environmental\ variance}}{\overline{X}} X\ 100$$

$\overline{X}$ = Grand mean of the character.

3.7.2 Heritability

Heritability in broad sense (h^2b) was calculated by following formula as suggested by Hanson *et al.* (1956).

$$h^2b\ (\%) = \frac{\sigma^2 g}{\sigma_2 p} X\ 100$$

Where, $\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

3.7.3 Genetic advance

The expected genetics advance (GA) was estimated using the formula as suggested by Robinson (1966).

$$GA = (h^2b)\ (\sigma^2 p)\ K$$

Where,

h^2b	=	Heritability in broad sense.
$\sigma^2 p$	=	Phenotypic standard deviation of given character.
K	=	Standardized selection differential (2.06) a constant at 5% selection intensity.

Genetic advance as per cent of mean was worked out as:

$$GA\ (\%) = \frac{GS}{\overline{X}} X\ 100$$

Where,

GA	=	Genetic advance.
$\overline{X}$	=	Grand mean of the character.

3.8 Estimation of correlation and path coefficients

3.8.1 Correlation coefficients

Phenotypic and genotypic correlation coefficients were worked out to study the inter-relationship between various pairs of characters as suggested by Al-Jibouri *et al.* (1958).

(a) Phenotypic Cov. Of xy

$$(rp) = \frac{\text{Phenotypic Cov. of } xy}{\sqrt{\text{Phenotypic } \sigma^2{}_x \,.\, \text{phenotypic } \sigma^2{}_y}}$$

(b) Genotypic correlation coefficients (rg):

$$(rg) = \frac{\text{Genotypic Cov. of } xy}{\sqrt{\text{Genotypic } \sigma^2{}_x \,.\, \text{phenotypic } \sigma^2{}_y}}$$

The significance of 'r' values was tested at 5% and 1% from 'r' table at (V-2) degrees of freedom.

Where,

'V' is number of genotypes on which the observations were recorded.

3.8.2 Path coefficient analysis

Path coefficients were obtained according to the procedure suggested by Dewey and Lu (1959) using phenotypic and genotypic correlation coefficients.

Different characters were included in the path coefficient analysis to find out their direct and indirect effect upon sweet potato yield per plot.

Residual factor was also included in the casual system representing all other factors, which might affect the end products. The correlations of 'cause' with effect were calculated by solving the following simultaneous equation.

$$\begin{cases} rmp = pmp + rmp\ pnp + rmo\ pop\ (1) \\ rnp = rnm\ pmp + pnp + rno\ pop\ (2) \\ rop = rom\ pmp + ron\ pnp + pop\ (3) \end{cases}$$

Where,

Pmp, pnp and pop are direct 'effects' of mn and on 'cause' p and rmp, pnp, rmo, pop .... are indirect effect on 'cause'.

This simultaneous equation was solved by matrix method and is expressed as:

$$\begin{pmatrix} rmp \\ rnp \\ rop \end{pmatrix} = \begin{pmatrix} rmn\ rmn\ rmo \\ rnm\ rnn\ rno \\ rom\ ron\ roo \end{pmatrix} \begin{pmatrix} pmp \\ pnp \\ pop \end{pmatrix} \qquad or\ A = BC$$

Here,

A and B vectors are known for calculated vector, the formula used as,

$C = B^{-1} A$

B^{-1} is the inverse matrix of B vector,

Residual factor was calculated as follows:

$P \times Y = \sqrt{1 - R^2}$

Where,

$R^2 = \sum_j P_{iy} \quad r_{iy}$

The r_{ij}; i.e. r 1.1 to r 9.10 denote correlation between all possible combinations of independent characters and P_{iy} i.e. P1y to P9y denote direct effect of various characters on character Y.

r_{iy} = Correlation coefficient between i^{th} and y characters.

P_{iy} = Direct effect of i^{th} character on y.

3.9 Screening for incidence of yellow vein mosaic virus disease in okra

For assessing the okra yellow vein virus in okra, the intensity of YVMV, disease was calculated following the grading system of Banerjee and Kalloo (1987) in the case of chilli leaf curl virus individual plants were evaluated for leaf curl virus reaction on the basis of 3 observations, taken at 15 days interval. The per cent severity grade was calculated by using following formula.

The coefficient of infection (C.I.) was calculated by multiplying the percentage of disease by the 'response value' assigned to each severity grade. Thus, the coefficient combined the per cent of infection and its severity. Thus overall disease reaction was assigned according to the infection range as stated below:

$$\text{PDI} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Where, PDI = per cent disease infection.

Table 3.9.1 Scale for classifying disease reaction in okra to YVMV disease

Symptoms	Severity grade	Response value	Coefficient of infection	Reaction
Symptoms absent	0	0	0 – 4	HR
Very mild symptoms up to 25% leaves	1	0.25	4.1 – 9	R
Appearance of disease between 26-50% leaves	2	0.50	9.1 – 19	MR
Symptom between 51-75% leaves	3	0.75	19.1 – 39	MS
Severe disease infection at 75% leaves	4	1.00	39.1 – 69	S
Above 75% leaves	>4	>1.00	69.1 – 100	HS

Whereas,
R = Resistant, S = Susceptible, H.R. = Highly resistant, H.S. = Highly susceptible, M.R. = Moderately resistant, M.S. = Moderately susceptible.

3.10 Estimation of gene action/genetic components

Griffing (1956) and Gardner (1963) suggested an analytical technique for the estimation of genetic component. Variance due to GCA effect and SCA effect were made free from environmental variation. This was done using the following equation.

1. Estimation variance due to GCA = $\dfrac{\sum_{i=1}^{P} gi^2}{p-1} = \dfrac{Mg - Me}{P+2}$

2. Estimation variance due to SCA = $\dfrac{\sum_{i}^{P}\sum_{j}^{P}}{P(P-1)/2} S^2 ij = Ms - Me$

The allied genetic parameters like degree of dominance (√Variance SCA/Variance GCA) and the ratio of additive to total genotypic variance $\left(Rg = \dfrac{2\sigma^2\ GCA}{2\sigma^2\ GCA + \sigma^2\ SCA} \right)$ were estimated as suggested by Kempthorne and Curnow (1961).

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Chapter IV

EXPERIMENTAL FINDINGS

The experimental results of the present investigation "Hybrid breeding in Okra [*Abelmoschus esculentus* (L.) Moench]" have been presented under the following heads:

4.1 Analysis of variance of Line × Tester (17 female and 3 male) for 15 characters comprising parents and F_1 progenies.

4.2 Combining ability analysis.

4.3 Heterosis over better parent and standard variety.

4.4 Variability, heritability and expected genetic advance.

4.5 Correlation and path coefficient analysis.

4.6 Incidence of yellow vein mosaic virus (YVMV).

4.7 Nature of gene action for yield and yield attributing traits.

4.8 Pod colour of parents and hybrids (F_1's).

4.1 Analysis of Variance

The analysis of variance for the fifteen characters has been analysed. The variance for different characters were partitioned into replications, treatments, parents, hybrids and error, variance due to parents were further partitioned into females, males and female vs. males, variance due to parents and hybrids were also worked out.

4.1.1 Analysis of Variance for Fifteen Characters in Parents

The analysis of variance 15 characters for 20 parental lines the difference due to treatments were highly significant for all the characters during both the seasons i.e. Rainy season (Table 4.1.1a) and Summer season (Table 4.1.1b), respectively.

Table 4.1.1a: Analysis of variance (mean square) for parents for 15 characters in okra during Rainy season.

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/ plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/ 100g)
Replication	2	10.281	0.009	0.023	0.048	0.084	0.516	1.117	0.421	0.633	0.038	0.041	262.000	33.742	0.000	0.037
Treatments	19	219.806**	0.199**	1.982**	12.006**	6.729**	17.389**	15.554**	7.505**	2.873**	1.907**	0.029**	1327.342**	242.542**	0.126**	9.268**
Error	38	34.199	0.043	0.091	1.215	1.345	1.166	2.011	1.410	0.329	0.035	0.009	164.317	25.744	0.000	0.185

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

Table 4.1.1b: Analysis of variance (mean square) for parents for 15 characters in okra during Summer season

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes /plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/plant (g)	Number of seeds/fruit	Number of ridges/fruit	Ascorbic acid (mg/100g)
Replication	2	63.187	0.013**	0.009**	1.026**	0.467	0.813	1.320	0.632	1.176	0.250	0.037	49.773	13.977	0.000	0.421
Treatments	19	337.054**	0.174**	1.417**	30.107**	7.220**	7.663**	6.361**	7.981**	4.189**	1.110**	0.027**	902.017**	284.794**	0.150**	9.063**
Error	38	72.635	0.031	0.039	1.742	0.498	1.150	1.334	0.434	0.247	0.155	0.009	40.491	16.564	0.000	0.339

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

4.1.2 Analysis of Variance for Fifteen Characters in F_1's

Among all the traits the difference due to treatments were highly significant for all the traits during both the season i.e. Rainy season (Table 4.1.2a) and Summer season (Table 4.1.2b), respectively.

4.1.3 Analysis of Variance for line × tester

In Rainy season (Table 4.1.3a) the mean square due to parents, females, males and hybrids were highly significant for most of the characters under study. The variance due to female vs. male were significant for all the characters except for plant height (cm), internodal length (cm), days to 50 per cent flowering, number of fruits per plant, single fruit weight (cm), fruit diameter and fruit yield per plant (g). Whereas, variances due to parents vs. hybrids were highly significant for number of branches per plant, days to first flowering, days to 50 per cent flowering, single fruit weight (g), fruit length (cm) fruit yield per plant (g) and significant for ascorbic acid content (mg/100g). The remaining characters were non-significant under study.

In Summer season crop (Table 4.1.3b), the mean square due to parents, females, males and hybrids were highly significant for most of the character under study. The variance due female vs. male were significant for all the characters except number of nodes per plant, days to 50 per cent flowering, fruit length (cm) and fruit diameter (cm). Whereas, variance due to parents vs. hybrids were highly significant for plant height (cm), number of branches per plant, days to first flowering, weight (g), fruit yield per plant (g) and number of seeds per fruit and significant for stem diameter (cm) and ascorbic acid content (mg/100g). The remaining characters were non-significant under study.

Table 4.1.2a: Analysis of variance (mean square) for hybrids (F_1) for 15 characters in okra during Rainy season.

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/ plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50% flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield /plant (g)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)
Replication	2	69.500	0.043	0.003	5.512	1.076	5.672	2.438	3.856	0.847	0.221	0.000	696.875	92.031	0.000	0.933
Treatments	50	476.950**	0.193**	0.972**	23.998**	6.821**	17.624**	22.723**	5.894**	3.644**	1.384**	0.026**	1300.073**	171.783**	0.103**	6.027**
Error	100	35.670	0.037	0.122	1.233	1.129	1.147	1.531	1.016	0.405	0.027	0.010	143.973	17.700	0.001	0.703

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

Table 4.1.2b: Analysis of variance (mean square) for F1's for 15 characters in okra during Summer season.

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/ plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/plant (g)	Number of seeds/fruit	Number of ridges /fruit	Ascorbic acid (mg/100g)
Replication	2	115.688	0.059	0.060	1.828	0.036	0.141	0.047	1.958	0.165	0.091	0.018	250.938	27.750	0.002	1.129
Treatments	50	222.360**	0.089**	0.612**	20.878**	3.048**	24.672**	16.094**	4.286**	3.269**	1.468**	0.032**	615.593**	178.426**	0.102**	5.597**
Error	100	38.364	0.023	0.047	2.199	0.172	1.311	1.659	0.236	0.269	0.108	0.009	38.660	17.211	0.001	0.744

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

Table 4.1.3a: Analysis of variance (mean squares) for parents and hybrids for 15 characters in okra in Rainy season.

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/plant (g)	Number of seeds/fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)
Replication	2	132.225	0.059	0.031	1.157	0.083	0.225	0.516	0.752	0.212	0.222	0.043	106.272	36.592	0.002	1.331
Parents	19	337.031**	0.175**	1.417**	30.107**	7.220**	7.663**	6.361**	7.981**	4.189**	1.110**	0.027**	902.009**	284.812**	0.150**	9.063**
Females	16	382.362**	0.149**	1.500**	34.080**	7.936**	8.292**	6.375**	8.995**	2.421**	1.045**	0.030**	958.048**	238.195**	0.177**	10.000**
Males	2	10.944	0.324**	1.301**	11.923**	3.308**	3.444	9.000**	3.103**	11.034**	2.175**	0.010	112.501	403.254**	0.000	2.943*
Female Vs Male	1	263.945*	0.281**	0.320**	2.899	3.589**	6.038*	0.852	1.502*	18.808**	0.023	0.001	1584.410**	793.781**	0.026**	6.304**
Hybrids (F_1)	50	222.370**	0.089**	0.612**	20.878**	3.048**	24.672**	16.094*	4.286**	3.269**	1.468**	0.032**	615.589**	178.421**	0.102**	5.597**
Parents vs Hybrids	1	346.062**	0.098*	0.569**	0.237	0.296	349.352**	66.000**	32.337**	43.276**	0.058	0.010	9309.938**	201.969**	0.001	3.641*
Error	140	47.786	0.025	0.045	2.068	0.264	1.259	1.559	0.312	0.276	0.120	0.009	41.384	16.864	0.001	0.627

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

Table 4.1.3b: Analysis of variance (mean squares) for parents and hybrids for 15 characters in okra in Summer season.

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/ plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/ 100g)
Replication	2	62.723	0.048	0.002	4.431	0.852	3.925	1.127	2.518	0.963	0.244	0.017	724.732	116.085	0.000	0.689
Parents	19	219.862**	0.199**	1.982**	12.006**	6.729**	17.389**	15.554**	7.503**	2.973**	1.907**	0.029**	1327.299**	242.523**	0.126**	9.268**
Females	16	254.497**	0.124**	2.004**	12.141**	6.937**	13.689**	18.245**	8.168**	2.979**	1.875**	0.029**	1425.660**	241.526**	0.148**	10.343**
Males	2	44.406	0.654**	0.314	11.498**	6.504**	38.111**	0.444	4.853*	3.368**	1.083**	0.040*	1151.311**	162.413**	0.000	2.590*
Female Vs Male	1	16.625	0.492**	4.952**	10.861**	3.853	35.158**	2.711	2.176	0.191	4.070**	0.007	105.492	418.688**	0.022**	5.413**
Hybrids (F_1)	50	476.932**	0.193**	0.972**	23.999**	6.821**	17.624**	22.723**	5.895**	3.644**	1.384**	0.026**	1300.064**	171.786**	0.103**	6.027**
Parents vs Hybrids	1	41.625	0.012	13.606**	2.096	1.476	98.922**	187.750**	0.405	16.606**	9.423**	0.011	1458.938**	0.016	0.000	2.379*
Error	140	35.003	0.038	0.112	1.227	1.177	1.168	1.674	1.134	0.386	0.029	0.010	150.794	19.796	0.001	0.556

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

4.2 Combining ability variances and their effects

The details of combining ability analysis 20 parents (17 lines and 3 testers) and their 51 crosses are being furnished as under.

4.2.1 Analysis of variance for combining ability

The analysis of variance for combining ability was carried out for all the 15 characters under study. The results are presented in Table 4.2.1a for Rainy season and Table 4.2.1b for Summer season crop, respectively. The mean squares due to crosses were partitioned into mean square due to lines, testers and line × tester interaction components.

In Rainy season crop, variances due to lines was highly significant for all the characters. Variance due to testers was also highly significant for all the characters except stem diameter (cm), number of branches per plant, days to 50 per cent flowering and number of fruits per plant. Whereas, significant for stem diameter and number of branches per plant. The line × tester component was highly significant for all the characters. Crosses also exhibited significant differences for all the characters taken into account.

In Summer season crop variance due to testers was highly significant for all characters. Variance due to tester was also highly significant for all the characters. The line × tester component was highly significant for all the characters.

4.2.2 Combining ability effects

The estimation of both general combining ability (gca) effects of 17 lines and 3 testers and specific combining ability (sca) effects of 51 hybrids in Rainy and Summer season for all the characters studied except YVMV and pod colour, have been presented in Table 4.2.2a (Rainy season parents), Table 4.2.4a (Rainy season F_1's), Table 4.2.2b (Summer season parents) and Table 4.2.4b (Summer season F_1's).

Table 4.2.1a: Analysis of variance (mean square) for combining ability for 15 characters in okra during Rainy season.

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges / fruit	Ascorbic acid (mg/ 100g)
Replication	2	69.150	0.042	0.002	5.516	1.075	5.676	2.431	3.864	0.850	0.221	0.000	696.811	92.098	0.000	0.939
Females	16	441.477**	0.198**	1.391**	18.252**	5.139**	18.923**	43.202**	12.167**	3.961**	1.494**	0.024**	2245.409**	215.134**	0.301**	12.513**
Males	2	615.453**	0.121*	0.512*	84.522**	24.246**	17.923**	1.494	1.849	10.916**	0.286**	0.078**	2491.898**	230.256**	0.009**	12.654**
Female × Male	32	468.006**	0.194**	0.791**	23.089**	6.573**	16.956**	13.809**	3.012**	3.032**	1.397**	0.024**	752.913**	146.457**	0.009**	2.370**
Error	100	35.677	0.037	0.122	1.233	1.129	1.146	1.531	1.016	0.404	0.027	0.010	143.975	17.699	0.001	0.702

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

Table 4.2.1b: Analysis of variance (mean square) for combining ability for 15 characters in okra during Summer season.

Source of variation	d.f.	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges / fruit	Ascorbic acid (mg/ 100g)
Replication	2	115.922	0.059	0.060	1.833	0.037	0.137	0.039	1.956	0.169	0.092	0.018	250.849	27.595	0.02	1.129
Females	16	231.688**	0.077**	0.636**	19.705**	2.127**	45.225**	28.862**	3.874**	5.251**	1.806**	0.023**	715.669**	286.691**	0.311**	12.652**
Males	2	70.824	0.053	0.843**	47.106**	8.761**	26.841**	25.138**	5.469**	1.833**	0.021	0.039*	1179.589**	582.964**	0.004*	6.573**
Female × Male	32	227.183**	0.097**	0.585**	19.825**	3.152**	14.259**	9.144**	4.418**	2.368**	1.390**	0.036**	530.300**	99.003**	0.004*	2.008**
Error	100	38.359	0.023	0.047	2.199	0.172	1.311	1.659	0.236	0.269	0.108	0.010	38.662	17.214	0.001	0.744

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

Table 4.2.2a: Estimates of general combining ability effects of parents (lines and testers) for 15 characters in okra during Rainy season.

Parents	Plant height (cm)	Stem diameter (cm)	Number of branches/ plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges /fruit	Ascorbic acid (mg/100g)
IC - 128883	-2.42	-0.22**	0.10	-1.06**	0.54	1.42**	0.53	1.79**	-0.74**	0.06	0.06*	8.37*	2.87*	-0.04**	-0.01
VRO-5	-14.36**	-0.01	0.35**	0.14	-0.67*	1.42**	1.20**	1.53**	1.50**	0.73**	0.03	26.12**	3.56**	-0.04**	2.80**
VRO-6	4.06*	0.02	-0.10	0.86**	-0.29	-1.25**	-1.14**	0.60*	0.51**	0.25**	-0.04	19.28**	-0.79	-0.04**	1.68**
AC-108	-3.06	-0.03	-0.30**	-0.12	-0.36	1.20**	-0.14	0.99**	0.54**	0.08	0.06*	14.63**	-7.79**	-0.04**	-1.00**
IC-45806	-7.33**	-0.13*	-0.19	-0.29	-0.73*	1.20**	-1.03**	0.60*	0.24	0.05	-0.01	9.51**	1.30	-0.04**	0.15
IC-218877	-0.29	-0.03	0.32**	-0.89**	0.46	0.42	-1.79**	-1.21**	-0.92**	-0.21**	0.06*	-21.15**	6.37**	-0.04**	-0.62**
IC-218844	1.76	0.13*	-0.52**	-1.27**	-0.14	-1.47**	-3.25**	-2.61**	0.32	0.62**	0.06*	-24.05**	-7.05**	-0.04**	-0.09
Arka Abhay	-0.41	-0.07	-0.44**	0.04	0.05	0.75*	-1.80**	1.28**	0.17	-0.19**	0.03	14.81**	2.98*	-0.04**	0.62**
IC-43720	-0.31	-0.10	0.09	-0.72*	0.49	-3.25**	-4.47**	-0.73*	-0.63**	-0.14**	-0.01	-14.13**	-1.58	0.71**	-0.95**
IIVR-342	8.36**	0.11*	0.09	-0.34	1.19**	-0.36	0.08	-0.42	-0.29	-0.21**	-0.07*	-7.12*	8.21**	-0.04**	-1.78**
IC-140906	1.67	0.02	-0.59**	-1.24**	1.07**	1.08**	1.86**	-1.45**	-0.63**	-0.22**	-0.07*	-21.08**	1.29	-0.04**	-0.64**
IIVR-198.00	8.12**	0.21**	-0.33**	4.82**	-1.66**	0.75*	0.20	-0.97**	-0.96**	-0.69**	0.06*	-19.94**	2.83*	-0.04**	0.51*
EC - 305612	6.42**	0.22**	0.17	0.33	0.58*	0.31	1.42**	0.73*	0.49**	-0.50**	-0.01	13.79**	0.77	-0.04**	0.46*
IIVR-435	1.38	-0.09*	1.02**	-0.14	0.04	-0.80**	1.20**	-0.01	-0.32	-0.41**	-0.11*	-4.34	-4.72**	-0.04**	-2.02**
IIVR-401	12.63**	0.28**	0.17	1.03**	0.03	-1.25**	0.42	-0.35	0.70**	0.01	-0.01	4.01	-5.11**	-0.04**	0.79**
SA-2	-5.21**	-0.13*	0.23*	-1.20**	0.54	-2.03**	1.64**	0.09	0.02	0.01	-0.01	0.29	-7.31**	-0.04**	0.30
IC-140934	-11.03**	-0.20**	-0.08	0.04	-1.12**	1.86**	5.08**	0.15	-0.01	0.76**	-0.01	1.01	4.17**	-0.04**	-0.21
SE ± F	1.64	0.05	0.10	0.30	0.29	0.29	0.34	0.28	0.17	0.05	0.03	3.29	1.15	0.01	0.23
Arka Anamika	3.84**	0.05*	0.10**	1.41**	-0.75**	-0.23*	-0.20	-0.15	0.10	0.05*	0.02*	-1.23	-0.47	-0.01**	-0.32**
Pusa Sawani	-2.94**	-0.04*	-0.01	-1.11**	0.61**	0.67**	0.12	-0.07	0.41**	0.03	0.03**	7.52**	-1.85**	0.00	-0.26**
Prabhani Kranti	-0.90	-0.01	-0.10**	-0.29**	0.14	-0.44**	0.08	0.22*	-0.50**	-0.09**	-0.05**	-6.29**	2.32**	0.01**	0.57**
SE ± M	0.58	0.02	0.03	0.11	0.10	0.10	0.12	0.10	0.06	0.02	0.01	1.16	0.41	0.00	0.08

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

Table 4.2.3a: Ranking of three desirable parents on the basis of performance and GCA effects for 14 characters in okra during Rainy season.

S.No.	Characters	Best general combiner	Desirable parents based on *per se* performance	Best parent based on *per se* performance and GCA effects
1	Plant height (cm)	IIVR – 401 IIVR – 342 IIVR – 198	IIVR – 401 IC – 140934 IIVR – 342	IIVR – 401 IIVR – 342
2	Stem diameter (cm)	IIVR – 401 EC – 305612 IIVR – 98	EC – 305612 IIVR – 342 Arka Anamika	EC – 305612
3	Number of branches / plant	IIVR – 435 VRO – 5 IC – 218877	IIVR – 435 Pusa Sawani Arka Anamika	IIVR – 435
4	Number of nodes / plant	IIVR – 198 IIVR – 401 VRO – 6	VRO – 6 IIVR – 435 Arka Abhay	VRO – 6
5	Internodal length (cm)	IIVR – 198 IC – 140934 IC – 45806	VRO – 5 AC – 108 IIVR – 435	
6	Days to first flowering	IC – 43720 SA – 2 IC – 218844	IC – 218877 AC – 108 IC – 218844	IC – 218844
7	Days to 50 % flowering	IC – 43720 IC – 218844 Arka Abhay	IC – 218877 AC – 108 IC – 218844	IC – 218844
8	Number of fruits / plant	IC – 128883 VRO – 5 Arka Abhay	VRO – 6 IC – 128883 Arka Anamika	IC – 128883
9	Single fruit weight (g)	VRO – 5 IIVR – 401 AC – 108	VRO – 5 VRO – 6 Pusa Sawani	VRO -5
10	Fruit length (cm)	IC – 140934 VRO – 5 IC – 218844	Arka Abhay VRO – 6 IIVR – 198	
11	Fruit diameter (cm)	IC – 218844 IIVR – 198 IC – 128883	IC – 140926 IIVR – 435 AC – 108	
12	Fruit yield / plant (g)	VRO – 5 VRO – 6 Arka Abhay	VRO – 6 VRO – 5 Prabhani Kranti	VRO – 6 VRO – 5
13	Number of seeds / fruit	AC – 108 SA – 2 IC – 218844	IC – 218844 Arka Abhay IC – 45806	IC – 218844
14	Ascorbic acid (mg / 100 g)	VRO – 5 VRO – 6 IIVR – 401	VRO – 5 VRO – 6 IC – 128883	VRO – 5 VRO - 6

Table 4.2.4a: Estimates of specific combining ability effects of hybrids (F_1s) for 15 characters in okra during Rainy season.

Hybrids	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges /fruit	Ascorbic acid (mg/100g)
IC - 128883 × AA	2.74	0.02	-0.32*	0.22	-0.23	1.23**	-0.47	-0.05	0.15	-0.10	0.05	4.16	-4.55**	0.01	0.94**
IC - 128883 × PS	6.35**	0.15*	-0.20	-0.52	1.24**	-1.67**	0.55	0.14	-0.20	0.19**	0.04	-4.36	1.76	0.00	-2.35**
IC - 128883 × PK	-9.09**	-0.18*	0.52**	0.29	-1.01*	0.44	-0.08	-0.08	0.05	-0.09	-0.09*	0.19	2.79	-0.01	1.41**
VRO - 5 × AA	-17.48**	-0.39**	0.01	2.52**	-2.02**	0.23	1.20*	0.50	-1.00	1.56**	-0.02	-11.18*	-4.77**	0.01	0.16
VRO - 5 × PS	18.09**	0.44**	0.32*	-0.02	0.90*	-0.67	0.88	-0.81*	1.59**	-0.69**	-0.03	34.00**	5.57**	0.00	-0.17
VRO - 5 × PK	-0.61	-0.06	-0.36*	-2.51**	1.13**	0.44	2.08**	0.31	-0.60*	-0.87**	0.05	-22.82**	-0.80	-0.01	0.01
VRO - 6 × AA	4.00	-0.15*	-0.48**	0.45	0.93*	-2.10**	-1.14*	-1.20**	-1.17**	-0.45**	-0.05	-14.72**	-4.63**	0.01	-0.58
VRO - 6 × PS	0.27	0.04	0.43**	0.74	-0.93*	0.99*	2.88**	0.52	0.68**	0.63**	0.04	9.67*	4.28**	0.00	0.52
VRO - 6 × PK	-4.27	0.11	0.05	-1.18**	0.00	1.11**	-1.75**	0.67	0.49	-0.18**	0.01	5.05	0.35	-0.01	0.06
AC - 108 × AA	3.89	0.04	0.42**	1.66**	-0.70	-1.22**	-3.14**	0.31	-0.26	-0.15*	-0.15**	-11.09*	1.47	0.01	-0.11
AC - 108 × PS	-4.81**	-0.07	-0.17	-1.39**	0.77	-0.45	1.55**	-1.13	0.66**	-0.07	0.14**	20.05**	-2.65	0.00	0.07
AC - 108 × PK	0.92	0.03	-0.25	-0.27	-0.08	1.67**	1.59**	0.82*	-0.40	0.22**	0.01	-8.96	1.18	-0.01	0.04
IC - 45806 × AA	11.09**	0.14*	-0.06	0.09	0.84*	1.12**	1.42**	-0.07	0.44	0.08	0.01	6.33	7.91**	0.01	0.42
IC - 45806 × PS	-1.57	-0.10	-0.18	0.28	0.00	-1.78**	-1.23*	0.06	-0.94**	-0.20**	0.01	-12.76**	-8.37**	0.00	-0.44
IC - 45806 × PK	-9.51**	-0.03	0.24	-0.37	-0.84*	0.67	-0.19	0.01	0.50*	0.12*	-0.02	6.43	0.46	-0.01	0.03
IC - 218877 × AA	-2.91	-0.10	-0.14	-1.31**	0.44	-1.77**	-0.14	0.65	0.53*	0.00	0.05	12.72**	-7.95**	0.01	0.28
IC - 218877 × PS	-1.31	0.13	-0.46**	0.31	0.15	0.33	-0.45	0.74	-0.55*	0.12*	-0.06	-3.60	9.33**	0.00	0.32
IC - 218877 × PK	4.22	-0.03	0.60**	0.99*	-0.59	1.44**	0.59	-1.38**	0.03	-0.13*	0.01	-9.12	-1.38	-0.01	-0.61
IC - 218844 × AA	-15.50**	0.04	0.01	-2.40**	-0.93*	-1.88**	2.31**	-0.65	2.71**	1.50**	0.15**	17.28**	6.07**	0.01	-0.15
IC - 218844 × PS	9.87**	0.20**	0.39**	1.63**	0.25	0.22	-0.67	-0.43	-1.86**	-1.38**	-0.06	-24.13**	0.25	0.00	0.32
IC - 218844 × PK	5.63*	-0.23**	-0.39**	0.77	0.68	1.67**	-1.63**	1.08**	-0.85**	-0.13*	-0.09*	6.85	-6.32**	-0.01	-0.17
Arka Abhay × AA	20.20**	0.54**	0.13	3.66**	-1.04*	0.90*	2.53**	0.59	-1.26**	0.05	-0.02	-9.74*	8.97**	0.01	-0.99**
Arka Abhay × PS	0.60	-0.07	-0.56**	-0.25	0.22	0.99*	-0.78	-0.49	-0.21	-0.37**	-0.03	-10.32*	-8.22**	0.00	-0.32
Arka Abhay × PK	-20.80**	-0.47**	0.43**	-3.41**	0.83*	-1.89**	-1.75**	-0.10	1.47**	0.32**	0.05	20.06**	-0.75	-0.01	1.31**
IC - 43720 × AA	-11.64**	-0.06	-0.04	-0.51	-0.94*	-5.10**	-2.14**	-2.13**	-0.06	-0.03	0.01	-19.54**	8.59**	-0.21*	-0.08
IC - 43720 × PS	6.80**	0.13	0.51**	0.85	0.12	4.99**	-1.45**	1.26**	-0.37	0.39**	0.01	4.34	-0.43	-0.02*	0.16
IC - 43720 × PK	4.83*	-0.07	-0.47**	-0.34	0.82*	0.11	3.59**	0.87*	0.44	-0.36**	-0.02	15.19**	-8.16**	0.23*	-0.07
IIVR-342 × AA	-12.20**	-0.04	-0.24	-3.72**	2.45**	0.01	-1.03*	0.29	-0.44	-0.56**	0.18**	-2.05	2.14	0.01	0.14
IIVR-342 × PS	12.10**	0.02	0.44**	4.84**	-3.11**	-0.23	-0.01	0.41	1.08**	0.06	-0.03	13.10**	-0.42	0.00	-0.55
IIVR-342 × PK	0.10	0.02	-0.20	-1.12*	0.67	0.22	1.03*	-0.70	-0.64*	0.51**	-0.15**	-11.05	-1.72	-0.01	0.41
IC - 140906 × AA	-8.41**	-0.25**	0.31*	-0.59	-0.18	1.56**	-0.47	-0.41	-0.16	-0.35**	-0.02	-4.12	-1.97	0.01	0.34
IC - 140906 × PS	11.23**	0.24**	-0.05	1.54**	-0.84*	-1.34**	-0.78	-0.52	0.16	0.27**	-0.03	-7.70	-1.43	0.00	0.11
IC - 140906 × PK	-2.81	0.01	-0.26	-0.95*	1.01*	-0.22	1.25*	0.93*	0.00	0.09	0.05	11.82*	3.40*	-0.01	-0.45
IIVR-198 × AA	12.81**	0.22**	-0.22	1.35**	-0.18	0.90*	1.20*	-0.27	0.04	-0.32**	-0.05	-1.19	0.61	0.01	0.35
IIVR-198 × PS	-27.02**	-0.48**	-0.44**	-6.83**	1.95**	-1.01*	-0.12	-0.14	-0.44	-0.63**	-0.06	-9.78*	4.73**	0.00	0.19

Where, AA-Alka Anamika; PS-Pusa Sawani; PK-Prabhani Kranti

Table 4.2.4a: Continued….

Hybridsy	Plant height (cm)	Stem diameter (cm)	Number of branches/ plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)
IIVR-198 × PK	14.21**	0.25**	0.65**	5.48**	-1.77**	0.11	-1.08*	0.41	0.40	0.95**	0.11**	10.97*	-5.34**	-0.01	-0.54
EC - 305612 × AA	5.64*	0.05	0.88**	3.10**	-1.84**	1.24**	-2.36**	-0.77*	0.11	-0.41**	-0.09*	-6.39	-0.45	0.01	-0.36
EC - 305612 × PS	-2.09	0.08	-0.77**	-1.84**	1.45**	-0.56	0.66	2.02**	0.07	0.71**	-0.09*	19.12**	5.36**	0.00	2.01**
EC - 305612 × PK	-3.56	-0.12	-0.12	-1.26**	0.39	-0.78	1.70*	-1.26**	-0.19	-0.30**	0.18**	-12.73**	-4.91**	-0.01	-1.65**
IIVR-435 × AA	-2.76	-0.11	0.16	0.88*	-0.85*	-2.22**	-0.80	0.48	-0.21	0.07	0.01	2.51	6.17**	0.01	0.78*
IIVR-435 × PS	-3.55	-0.11	0.61**	-1.36**	1.24**	2.55**	1.88**	-0.13	-0.58*	-0.51**	0.01	-11.38*	2.18	0.00	-0.71*
IIVR-435 × PK	6.31**	0.22**	-0.78**	0.48	-0.39	-0.33	-1.08*	-0.35	0.79**	0.44**	-0.02	8.87	-8.35**	-0.01	-0.07
IIVR-401 × AA	7.16**	0.06	-0.65**	-1.83**	1.30**	-0.10	-0.36	1.09**	-0.46	-0.02	-0.09*	6.89	-3.31*	0.01	0.24
IIVR-401 × PS	-17.96**	-0.28**	-0.24	-2.14**	0.37	0.99*	-0.34	-0.49	1.43**	0.00	0.11**	7.18	-2.93	0.00	-0.05
IIVR-401 × PK	10.80**	0.22**	0.89**	3.97**	-1.67**	0.89*	0.70	-0.60	-0.96**	0.02	-0.02	-14.07**	6.24**	-0.01	-0.19
SA - 2 × AA	-10.44**	-0.20**	0.28*	-3.60**	1.95**	0.34	-1.92**	0.01	1.01**	0.05	0.01	12.34**	-11.24**	0.01	-0.01
SA - 2 × PS	0.70	-0.03	0.00	3.56**	-2.78**	-0.23	0.44	-0.06	-0.63*	0.50**	0.01	-11.08*	-0.99	0.00	0.14
SA - 2 × PK	9.73**	0.23**	-0.28*	0.04	0.82*	-0.11	1.48**	0.05	-0.39	-0.55**	-0.02	-1.26	12.24**	-0.01	-0.13
IC - 140934 × AA	13.82**	0.20**	-0.07	0.02	1.01*	6.78**	5.31**	1.62**	0.05	-0.90**	0.01	17.79**	-3.05	0.01	-1.36**
IC - 140934 × PS	-7.71**	-0.30**	0.37**	0.61	-1.00*	-3.12**	-3.01**	-0.95*	0.10	0.96**	0.01	-12.36**	-8.04**	0.00	0.75*
IC - 140934 × PK	-6.11**	0.10	-0.30*	-0.64	-0.01	-3.67**	-2.30**	-0.67	-0.15	-0.06	-0.02	-5.44	11.09**	-0.01	0.61
SE ± F_1	2.32	0.07	0.14	0.43	0.41	0.42	0.48	0.39	0.25	0.06	0.04	4.65	1.63	0.01	0.32

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

Table 4.2.5a: Ranking of three desirable hybrids on the basis of performance and SCA effects for 14 characters in okra during Rainy season.

S.No.	Characters	Best specific combiner	Desirable hybrids based on *per se* performance	Best hybrids based on *per se* performance and SCA effects
1	Plant height (cm)	IIVR – 198 × Arka Anamika Arka Abhay × Arka Anamika IIVR – 401 × Arka Anamika	Arka Abhay × Arka Anamika VRO – 5 × Pusa Sawani IIVR – 198 × Prabhani Kranti	Arka Abhay × Arka Anamika
2	Stem diameter (cm)	Arka Abhay × Arka Anamika IIVR – 198 × Arka Anamika IIVR – 401 × Prabhani Kranti	Arka Abhay × Arka Anamika VRO – 5 × Pusa Sawani IIVR – 198 × Prabhani Kranti	Arka Abhay × Arka Anamika
3	Number of branches / plant	IIVR – 435 × Pusa Sawani IIVR – 435 × Arka Anamika EC – 305612 × Arka Anamika	IIVR – 401 × Prabhani Kranti EC – 305612 × Arka Anamika IIVR – 198 × Prabhani Kranti	EC – 305612 × Arka Anamika
4	Number of nodes / plant	IIVR – 198 × Prabhani Kranti IIVR – 198 × Arka Anamika EC – 305612 × Arka Anamika	IIVR – 198 × Prabhani Kranti IIVR – 342 × Pusa Sawani IIVR – 401 × Prabhani Kranti	IIVR – 198 × Prabhani Kranti
5	Internodal length (cm)	VRO – 5 × Arka Anamika IIVR – 198 × Prabhani Kranti IIVR – 198 × Arka Anamika	IIVR – 342 × Pusa Sawani SA – 2 × Pusa Sawani VRO – 5 × Arka Anamika	VRO – 5 × Arka Anamika
6	Days to first flowering	IC – 43720 × Arka Anamika VRO – 6 × Arka Anamika IC – 218844 × Arka Anamika	IC – 43720 × Arka Anamika IC – 140934 × Prabhani Kranti IC – 140934 × Pusa Sawani	IC – 43720 × Arka Anamika
7	Days to 50 % flowering	IC – 43720 × Arka Anamika IC – 43720 × Pusa Sawani IC – 218844 × Pusa Sawani	AC – 108 × Arka Anamika IC – 140934 × Pusa Sawani EC – 305612 × Arka Anamika	

Table 4.2.5a: Continued….

8	Number of fruits / plant	EC – 305612 × Pusa Sawani VRO – 5 × Prabhani Kranti AC – 108 × Prabhani Kranti	EC – 305612 × Pusa Sawani IC – 140934 × Arka Anamika IC – 43720 × Pusa Sawani	EC – 305612 × Pusa Sawani
9	Single fruit weight (g)	VRO – 5 × Pusa Sawani IC – 218844 × Arka Anamika IIVR- 401 × Pusa Sawani	IC – 218844 × Arka Anamika VRO – 5 × Pusa Sawani Arka Anamika × Prabhani Kranti	VRO – 5 × Pusa Sawani IC – 218844 × Arka Anamika
10	Fruit length (cm)	IC – 218844 × Arka Anamika IC – 140934 × Pusa Sawani VRO – 6 × Pusa Sawani	VRO – 5 × Arka Anamika IC – 218844 × Arka Anamika IC – 140934 × Pusa Sawani	IC – 218844 × Arka Anamika IC – 140934 × Pusa Sawani
11	Fruit diameter (cm)	IC – 218844 × Arka Anamika AC – 108 × Pusa Sawani IIVR – 401 × Pusa Sawani	IIVR – 342 × Arka Anamika EC – 305612 × Prabhani Kranti IC – 218844 × Arka Anamika	IC – 218844 × Arka Anamika
12	Fruit yield / plant (g)	VRO – 5 × Pusa Sawani AC – 108 × Pusa Sawani EC – 305612 × Pusa Sawani	VRO – 5 × Pusa Sawani Arka Abhay × Prabhani Kranti AC – 108 × Pusa Sawani	VRO – 5 × Pusa Sawani AC – 108 × Pusa Sawani
13	Number of seeds / fruit	SA – 2 × Arka Anamika AC – 108 × Pusa Sawani IIVR – 435 × Prabhani Kranti	SA – 2 × Arka Anamika IC – 45806 × Pusa Sawani IIVR – 435 × Prabhani Kranti	SA – 2 × Arka Anamika IIVR – 435 × Prabhani Kranti
14	Ascorbic acid (mg / 100 g)	VRO – 5 × Prabhani Kranti VRO – 5 × Arka Anamika Arka Abhay × Prabhani Kranti	EC – 305612 × Pusa Sawani IC – 128883 × Prabhani Kranti Arka Abhay × Prabhani Kranti	Arka Abhay × Prabhani Kranti

Ranking of the parents and hybrids on the basis of gca and sca effects and *per se* performance are furnished in Table 4.2.3a (Rainy season parents), Table 4.2.5a (Rainy season F_1's), Table 4.2.3b (Summer season parents) and Table 4.2.5b (Summer season F_1's). The details of combining ability effects are explained character wise as follows:

4.2.2.1 Plant height

In Rainy season crop, out of 17 female lines, IIVR-401 (12.63) expressed maximum positive significant gca followed by IIVR-342 (8.36) and IIVR-198 (8.12). Whereas, VRO-5 (-14.36) expressed maximum negative significant gca followed by IC-140934 (-11.03) and IC-45806 (-7.33). The estimate of gca effects for male parental lines with significant and positive direction was observed in Arka Anamika (3.84) while Pusa Sawani (-2.94) showed negative significant gca effect. The parents IIVR-401 and IIVR-342 were good general combiner which showed good *per se* performance and gca effects.

Among 51 F_1's, 18 combinations had positive significant sca effects. Few promising crosses of these were Arka Abhay × Arka Anamika (20.20) followed by VRO-5 × Pusa Sawani (18.09) and IIVR-198 × Prabhani Kranti (14.21). Whereas, IIVR-198 × Pusa Sawani (-27.02) showed maximum negative sca effect. Based on *per se* performance and sca effects, Arka Abhay × Arka Anamika was good specific combination for tallness.

In Summer season, crop out of 17 female lines, IIVR - 401 (9.94) expressed maximum positive significant gca followed by IIVR - 198 (7.42) and IIVR - 342 (5.86). Whereas VRO - 5 (-11.71) shows maximum negative gca followed by IC-128883 (-4.90) and IC - 140934 (-3.68). The estimate of gca effects for male parental line with significant and positive direction was not observed, while Pusa Sawani (-1.23) showed negative significant gca effect.

Table 4.2.2b: Estimates of general combining ability effects of parents (lines and testers) for 15 characters in okra during Summer season.

Parents	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)
IC – 128883	-4.90**	-0.06	-0.02	-1.10**	-0.12	-0.98**	-0.07	-0.93**	-1.49**	0.16	0.01	-19.61**	10.60**	-0.05**	1.17**
VRO-5	-11.71**	0.02	0.16**	-0.82*	-0.76**	0.35	2.93**	0.23	1.00**	0.38**	-0.03	10.38**	6.96**	-0.05**	1.94**
VRO-6	0.15	0.05	0.20**	-0.53	0.45**	-0.98**	-0.07	0.30*	0.98**	0.13	-0.03	10.77**	-1.13	-0.05**	1.90**
AC-108	-1.04	0.04	0.02	-0.01	-0.30**	2.69**	2.05**	-0.27*	0.73**	0.29**	-0.03	3.15	-8.66**	-0.05**	-0.87**
IC-45806	-1.92	0.01	0.10	-1.43**	0.62**	2.80**	1.71**	-0.18	-0.15	0.27**	-0.09**	-3.66*	0.52	-0.05**	-0.75**
IC-218877	0.34	0.01	0.39**	-0.71	0.22*	0.35	1.60**	-0.39**	-1.24**	-0.47**	-0.03	-13.18**	5.68**	-0.05**	-0.49*
IC-218844	1.42	0.01	-0.35**	-0.59	0.28*	2.35**	2.71**	-0.50**	0.12	0.49**	0.11**	-4.66**	-2.56*	-0.05**	-0.12
Arka Abhay	-0.13	-0.09	-0.03	-0.42	0.40**	1.58**	0.82*	0.11	0.60**	-0.08	-0.03	6.65**	-1.35	-0.05**	1.19**
IC-43720	-2.85	-0.11**	-0.02	-0.86*	0.54**	0.24	-0.40	-0.23	-0.51**	-0.33**	-0.03	-5.60**	-4.63**	0.72**	-1.16**
IIVR-342	5.86	-0.03	-0.15*	1.08**	0.02	0.13	-0.95**	-0.01	-0.17	-0.22*	-0.07*	-1.31	6.26**	-0.05**	-1.83**
IC-140906	-1.45	0.04	-0.40**	-1.81**	0.81**	1.69**	-1.18**	0.87**	-0.35*	-0.17	-0.02	5.10**	-2.35*	-0.05**	-0.57*
IIVR-198	7.42**	0.12**	-0.14*	3.37**	-0.78**	0.80*	-0.07	1.34**	-0.59**	-0.95**	0.07*	7.31**	2.34*	-0.05**	0.39
EC - 305612	5.13**	0.14**	0.06	0.64	0.09	1.24**	-0.95**	1.31**	-0.25	-0.34**	0.01	10.37**	-0.01	-0.05**	0.35
IIVR-435	-2.38	-0.16**	0.46**	0.87*	-0.11	-1.76**	-2.18**	-0.12	0.32*	0.09	0.04	1.54	-5.33**	-0.05**	-2.12**
IIVR-401	9.94**	0.15**	-0.18**	2.94**	-0.57**	-3.76**	-2.29**	-0.27*	1.20**	-0.44**	0.04	6.10**	-6.63**	-0.05**	0.77**
SA-2	-0.18	-0.15**	0.35**	0.81*	-0.30**	-4.65**	-3.40**	-0.90**	-0.50**	0.19*	0.04	-11.80**	-6.47**	-0.05**	0.51*
IC-140934	-3.68*	0.02	-0.45**	-0.43	-0.43**	-3.09**	-0.29	-0.36**	0.29*	0.97**	0.04	-1.54	6.76**	-0.05**	-0.31
SE ± F	1.70	0.04	0.06	0.41	0.11	0.31	0.35	0.13	0.14	0.09	0.03	1.70	1.14	0.01	0.24
Arka Anamika	1.11	0.02*	0.15**	0.93**	-0.45*	0.00	-0.41**	0.38**	0.21**	0.02	0.03**	5.50**	2.05**	-0.01**	-0.22**
Pusa Sawani	-1.23*	-0.04**	-0.07**	-0.99**	0.36**	0.73**	0.81**	-0.16**	-0.04	-0.01	0.00	-2.08**	-3.90**	0.00	-0.20*
Prabhani Kranti	0.13	0.02*	-0.08**	0.06	0.10*	-0.73**	-0.41**	-0.21**	-0.17**	-0.02	-0.03**	-3.42**	1.85**	0.01**	0.41**
SE ± M	0.60	0.01	0.02	0.14	0.04	0.11	0.12	0.05	0.05	0.03	0.01	0.60	0.40	0.00	0.08

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

Table 4.2.3b: Ranking of three desirable parents on the basis of performance and GCA effects for 14 characters in okra during Summer season.

S. No.	Characters	Best general combiner	Desirable parents based on *per se* performance	Best parent based on *per se* performance and GCA effects
1	Plant height (cm)	IIVR – 435 IC-218844 IC-218877	IIVR – 401 IIVR-198 IIVR – 342	-
2	Stem diameter (cm)	EC – 305612 Arka Anamika IIVR – 342	IIVR – 401 Arka Anamika EC-305612	EC – 305612 Arka Anamika
3	Number of branches / plant	IIVR – 435 SA – 2 Arka Anamika	IIVR – 435 IC-218877 SA – 2	-
4	Number of nodes / plant	IIVR – 435 AC – 108 IC – 218844	IIVR – 198 IIVR – 401 IIVR – 342	-
5	Internodal length (cm)	VRO – 5 VRO – 6 IIVR – 435	IIVR – 198 VRO – 5 IIVR – 401	VRO – 5
6	Days to first flowering	IIVR – 435 VRO – 6 EC – 140906	SA – 2 IIVR – 401 IC – 140934	-
7	Days to 50 % flowering	EC – 305612 IIVR – 435 IIVR – 342	SA – 2 IIVR – 401 IIVR – 435	IIVR – 435
8	Number of fruits / plant	VRO – 6 IIVR – 342 EC – 305612	IIVR – 198 EC – 305612 IC – 140906	IC – 305612
9	Single fruit weight (g)	Prabhani Kranti VRO – 6 VRO – 5	IIVR – 401 VRO – 5 VRO – 6	VRO – 6 VRO – 5
10	Fruit length (cm)	Prabhani Kranti IC – 43720 VRO – 6	IC – 140934 IC – 218844 VRO – 5	-
11	Fruit diameter (cm)	IC – 43720 IC – 140906 IIVR – 435	IC – 218844 IIVR – 198	-
12	Fruit yield / plant (g)	VRO – 6 VRO – 5 Prabhani Kranti	VRO – 6 VRO – 5 EC – 305612	VRO – 6 VRO – 5
13	Number of seeds / fruit	IC – 218844 Arka Anamika IC – 45806	AC – 108 IIVR – 401 SA – 2	-
14	Ascorbic acid (mg / 100 g)	VRO – 6 VRO – 5 IC – 218883	VRO – 5 VRO – 6 Arka Abhay	VRO – 6 VRO - 5

Table 4.2.4b: Estimates of specific combining ability effects of hybrids (F1's) for 15 characters in okra during Summer season.

Hybrids	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges /fruit	Ascorbic acid (mg/ 100g)
IC - 128883 × AA	-2.62	-0.16**	0.08	-0.43	0.75**	-2.33**	-2.48**	0.37	-9.00**	-0.29*	-0.09*	1.43	1.10	0.01	-0.31
IC - 128883 × PS	5.42*	0.09	0.04	0.39	0.04	-0.06	-0.03	-0.46*	0.18	0.61**	0.13**	-1.56	1.96	0.00	-0.06
IC - 128883 × PK	-2.81	0.07	-0.12	0.04	-0.80**	2.39**	2.52**	0.09	-0.09	-0.32*	-0.04	0.12	-3.06	-0.01	0.36
VRO - 5 × AA	-13.77**	-0.21**	-0.06	-0.64	-2.15**	-0.67	-1.48**	-0.30	1.25**	0.99**	0.04	7.35**	1.78	0.01	0.93**
VRO - 5 × PS	7.13**	0.28**	0.26**	1.31*	0.64**	0.61	-0.03	-0.46*	-0.67**	-1.02**	-0.14**	-9.91**	3.37*	0.00	-0.36
VRO - 5 × PK	6.64**	-0.07	-0.20*	-0.67	1.50**	0.06	1.52**	0.76**	-0.58**	0.03	0.10*	2.57	-5.15**	-0.01	-0.57
VRO - 6 × AA	0.24	-0.08	-0.37**	-1.63**	0.58**	-4.33**	-1.48**	-0.27	1.17**	0.74**	0.14**	7.32**	-1.10	0.01	0.23
VRO - 6 × PS	5.35*	0.05	0.18*	2.15**	-0.80**	1.94**	0.97	1.61**	-0.48*	0.21	-0.04	12.16**	3.56*	0.00	-0.58
VRO - 6 × PK	-5.58*	0.03	0.19*	-0.52	0.23	2.39**	0.52	-1.34**	-0.69**	-0.95**	-0.10*	-19.49**	-2.46	-0.01	-0.80*
AC - 108 × AA	-1.17	0.04	0.38**	-0.45	-0.10	-2.00**	1.41**	1.60**	-0.35	-0.49**	-0.16**	13.21**	-0.33	0.01	-0.43
AC - 108 × PS	0.77	-0.01	-0.06	0.63	-0.05	0.27	-2.81**	-0.46*	0.46*	0.37**	0.16**	-1.18	1.86	0.00	0.05
AC - 108 × PK	0.40	-0.03	-0.32**	-0.18	0.15	1.73**	1.41**	-1.14**	-0.11	0.12	0.00	-12.03**	-1.53	-0.01	0.37
IC - 45806 × AA	4.74	-0.03	-0.34**	-1.40*	1.01**	1.89**	-0.26	-0.45*	0.76**	-0.33*	0.01	2.19	4.29**	0.01	-1.85**
IC - 45806 × PS	-2.42	0.06	0.18*	0.25	0.10	-3.50**	-0.48	-0.11	-0.26	-0.37**	0.13**	-4.00	-12.72**	0.00	0.67*
IC - 45806 × PK	-2.32	-0.03	0.16*	1.14*	-1.11**	1.61**	0.74	0.57**	-0.50*	0.70**	-0.14**	1.81	8.43**	-0.01	1.19**
IC - 218877 × AA	-2.68	-0.06	-0.29**	-0.85	0.54**	1.33**	-0.15	-1.11**	0.28	0.14	0.04	-7.93**	-7.74**	0.01	0.05
IC - 218877 × PS	0.49	0.09	-0.11	-0.27	0.03	1.61**	0.63	0.30	-0.17	0.24	0.06	1.88	4.65**	0.00	0.17
IC - 218877 × PK	2.19	-0.03	0.40**	1.12	-0.57**	-2.94**	-0.48	0.81**	-0.11	-0.38**	-0.10*	6.06*	3.10	-0.01	-0.21
IC - 218844 × AA	-6.89**	0.10	-0.25**	-2.11**	0.82**	0.33	-1.26*	0.50**	-1.64**	0.71**	0.11**	-8.18**	-3.17	0.01	-0.28
IC - 218844 × PS	4.95*	-0.11	0.27**	2.54**	-0.82**	-0.30	0.52	-0.02	-0.93**	-0.89**	-0.17**	-6.04*	-5.31**	0.00	0.20
IC - 218844 × PK	1.95	0.00	-0.02	-0.43	0.00	0.06	0.74	-0.48*	2.57**	0.18	0.06	14.21**	8.47**	-0.01	0.09
Arka Abhay × AA	14.28**	0.24**	-0.04	2.86**	-0.70**	0.11	0.96	1.42**	0.82**	-0.18	-0.06	21.85**	6.96**	0.01	1.47**
Arka Abhay × PS	0.92	0.03	-0.32**	-0.59	0.49**	0.39	0.41	-0.30	-1.17**	-0.32*	0.06	-12.61**	-5.32**	0.00	-0.78*
Arka Abhay × PK	-15.21**	-0.26**	0.36**	-2.27**	0.21	-0.50	-1.37**	-1.12**	0.36	0.49**	0.00	-9.23**	-1.64	-0.01	-0.69*
IC - 43720 × AA	-9.09**	0.12*	0.65**	1.63**	-1.15**	0.11	-1.48**	-0.37	-0.27	0.37**	0.04	-6.41**	3.70*	-0.09**	-0.34
IC - 43720 × PS	5.39*	0.05	0.07	0.15	-0.12	1.72**	-0.37	1.68**	0.54**	0.26*	-0.14**	19.60**	2.12	-0.06**	0.04
IC - 43720 × PK	3.78	-0.17**	-0.72**	-1.79**	1.27**	-1.83**	1.85**	-1.31**	-0.27	-0.63**	0.10*	-13.19**	-5.83**	0.16**	0.30
IIVR-342 × AA	-9.37**	-0.20**	-0.38**	-4.31**	1.41**	2.22**	3.41**	-0.35	-0.58**	-0.31*	0.05	-8.47**	-4.62**	0.01	-0.21
IIVR-342 × PS	8.40**	0.16**	0.47**	3.88**	-1.37**	-1.17**	-0.81	0.39*	1.06**	-0.15*	0.01	12.54**	4.10*	0.00	-0.72*

Table 4.2.4b: Continued…

Hybrids	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield/ plant (g)	Number of seeds/ fruit	Number of ridges /fruit	Ascorbic acid (mg/100g)
IIVR-342 × PK	0.97	0.04	-0.09	0.43	-0.04	-1.05*	-2.59**	-0.03	-0.48*	0.46**	-0.06	-4.08	0.52	-0.01	0.93**
IC - 140906 × AA	-2.09	-0.13*	0.46**	-0.05	-0.11	-2.00**	-1.71**	-0.60**	0.03	-0.42**	-0.07	-5.54*	-1.41	0.01	0.04
IC - 140906 × PS	3.15	0.09	-0.25**	0.27	-0.09	-0.73	0.41	-0.92**	-0.13	0.61**	0.05	-9.07**	-4.32**	0.00	0.32
IC - 140906 × PK	-1.05	0.04	-0.21**	-0.21	0.20	2.73**	1.29*	1.52**	0.10	-0.18	0.02	14.61**	5.73**	-0.01	-0.36
IIVR-198 × AA	12.84**	0.22**	-0.03	3.03**	-0.69**	2.22**	1.52**	-1.28**	-0.26	-0.28*	0.04	-14.15**	-1.07	0.01	0.30
IIVR-198 × PS	-22.22**	-0.49**	-0.48**	-6.41**	1.50**	0.16	-0.03	-0.57**	-0.22	-0.62**	-0.14**	-6.85**	7.86**	0.00	0.12
IIVR-198 × PK	9.38**	0.26**	0.50**	3.38**	-0.81**	-2.39**	-1.48**	1.85**	0.48*	0.89**	0.10*	21.00**	-6.79**	-0.01	-0.43
EC - 305612 × AA	6.86**	0.14*	0.37**	3.60**	-0.89**	2.44**	1.41**	1.59**	-0.11	-0.62**	0.01	13.32**	-6.45**	0.01	1.45**
EC - 305612 × PS	-2.90	-0.01	-0.38**	-2.31**	0.83**	-1.28**	-1.81**	0.16	0.27	0.67**	-0.07	4.03	6.37**	0.00	-0.23
EC - 305612 × PK	-3.96	-0.13*	0.00	-1.29*	0.06	-1.16**	0.41	-1.75**	-0.17	-0.05	0.06	-17.35**	0.08	-0.01	-1.21**
IIVR-435 × AA	1.04	-0.03	0.47**	2.97**	-1.18**	-1.22**	-0.71	-1.11**	-0.36	0.48**	0.07	-13.94**	1.57	0.01	0.58
IIVR-435 × PS	-2.35	-0.07	-0.08	-2.35**	0.93**	1.05*	2.41**	-0.64**	-0.05	-0.49**	-0.10*	-6.50**	2.62	0.00	-0.73*
IIVR-435 × PK	1.32	0.10	-0.40**	-0.62	0.26	0.17	-1.71**	1.75**	0.41*	0.02	0.03	20.45**	-4.19*	-0.01	0.15
IIVR-401 × AA	3.95	0.06	-0.68**	-1.90**	1.17**	0.11	-0.26	0.00	-0.12	0.04	-0.03	-0.01	-0.47	0.01	0.09
IIVR-401 × PS	-13.48**	-0.28**	-0.20*	-2.21**	0.02	2.72**	1.52**	-1.09**	0.96**	-0.79**	0.10*	-4.77	-3.24*	0.00	-0.09
IIVR-401 × PK	9.53**	0.23**	0.88**	4.11**	-1.19**	-2.83**	-1.26*	1.09**	-0.84**	0.75**	-0.07	4.78*	3.71*	-0.01	0.00
SA - 2 × AA	-0.63	-0.04	-0.02	-0.04	-0.03	0.33	1.18*	0.03	0.58**	0.01	-0.13**	3.76	4.25**	0.01	-0.32
SA - 2 × PS	4.25	0.08	0.60**	2.04**	-0.81**	-1.39**	-0.03	1.41**	-0.27	0.71**	0.10*	10.53**	-3.56*	0.00	0.20
SA - 2 × PK	-3.62	-0.04	-0.59**	-2.00**	0.85**	1.06*	-1.15*	-1.44**	-0.31	-0.72**	0.03	-14.29**	-0.68	-0.01	0.12
IC - 140934 × AA	4.37	0.02	0.02	-0.27	0.73**	1.44**	1.41**	0.32	-1.11**	-0.57**	-0.03	-5.80*	2.71	0.01	-1.40**
IC - 140934 × PS	-2.75	-0.02	-0.20*	0.52	-0.51**	-1.95**	-0.48	-0.50**	0.87**	0.96**	0.00	1.74	-4.00*	0.00	0.62
IC - 140934 × PK	-1.62	-0.01	0.18*	-0.26	-0.22	0.50	-0.93	0.18	0.23	-0.40**	0.03	4.06	1.28	-0.01	0.77*
SE ± F_1	2.40	0.06	0.08	0.57	0.16	0.44	0.50	0.19	0.20	0.13	0.04	2.41	1.61	0.01	0.33

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

Table 4.2.5b: Ranking of three desirable hybrids on the basis of performance and SCA effects for 14 characters in okra during Summer season.

S.No.	Characters	Best specific combiner	Desirable hybrids based on *per se* performance	Best hybrids based on *per se* performance and SCA effects
1	Plant height (cm)	Arka Abhay × Arka Anamika IIVR – 198 × Arka Anamika IIVR – 401 × Prabhani Kranti	IIVR – 198 × Arka Anamika IIV R – 401 × Prabhani Kranti IIVR – 198 × Prabhani Kranti	IIVR – 198 × Arka Anamika IIVR – 401 × Prabhani Kranti
2	Stem diameter (cm)	VRO – 5 × Pusa Sawani IIVR – 198 × Prabhani Kranti Arka Abhay × Arka Anamika	IIVR – 401 × Prabhani Kranti IIVR – 198 × Prabhani Kranti IIVR – 198 × Arka Anamika	IIVR – 198 × Prabhani Kranti
3	Number of branches / plant	IIVR – 401 × Prabhani Kranti IC – 43720 × Arka Anamika SA – 2 × Pusa Sawani	IIVR – 435 × Arka Anamika SA – 2 × Pusa Sawani IC – 43720 × Arka Anamika	SA – 2 × Pusa Sawani IC – 43720 × Pusa Sawani
4	Number of nodes / plant	IIVR – 401 × Prabhani Kranti IIVR – 342 × Pusa Sawani EC – 305612 × Arka Anamika	IIVR – 198 × Arka Anamika IIVR – 401 × Prabhani Kranti IIVR – 198 × Prabhani Kranti	- - -
5	Internodal length (cm)	VRO – 5 × Arka Anamika IIVR – 342 × Pusa Sawani IIVR – 401 × Prabhani Kranti	VRO – 5 × Arka Anamika IIVR – 198 × Arka Anamika IIVR – 435 × Arka Anamika	VRO – 5 × Arka Anamika
6	Days to first flowering	VRO – 6 × Arka Anamika IC – 45806 × Pusa Sawani IC – 218877 × Prabhani Kranti	IIVR – 401 × Prabhani Kranti SA – 2 × Pusa Sawani VRO – 6 × Arka Anamika	VRO – 6 × Arka Anamika
7	Days to 50 % flowering	AC – 108 × Pusa Sawani IIVR – 342 × Prabhani Kranti IC – 128883 × Arka Anamika	SA – 2 × Prabhani Kranti IIVR – 435 × Prabhani Kranti IIVR – 342 × Prabhani Kranti	IIVR – 342 × Prabhani Kranti

Table 4.2.5b: Continued….

8	Number of fruits / plant	IIVR – 198 × Prabhani Kranti IIVR – 435 × Prabhani Kranti IC – 43720 × Pusa Sawani	EC – 305612 × Arka Anamika IIVR – 198 × Prabhani Kranti IC – 140906 × Prabhani Kranti	IIVR – 198 × Prabhani Kranti
9	Single fruit weight (g)	IC – 218844 × Prabhani Kranti VRO – 5 × Arka Anamika VRO – 6 × Arka Anamika	IC – 218844 × Prabhani Kranti VRO – 5 × Arka Anamika VRO – 6 × Arka Anamika	IC – 218844 × Prabhani Kranti VRO – 5 × Arka Anamika VRO – 6 × Arka Anamika
10	Fruit length (cm)	VRO – 5 × Arka Anamika IC – 140934 × Pusa Sawani IIVR – 198 × Prabhani Kranti	IC – 140934 × Pusa Sawani VRO – 5 × Arka Anamika IC – 218844 × Arka Anamika	IC – 140934 × Pusa Sawani VRO – 5 × Arka Anamika
11	Fruit diameter (cm)	AC – 108 × Pusa Sawani VRO – 6 × Arka Anamika IC – 45806 × Pusa Sawani	IC – 218844 × Arka Anamika VRO – 6 × Arka Anamika IC – 218844 × Prabhani Kranti	VRO – 6 × Arka Anamika
12	Fruit yield / plant (g)	Arka Abhay × Arka Anamika IIVR – 198 × Prabhani Kranti IC – 140906 × Pusa Sawani	Arka Abhay × Arka Anamika EC – 305612 × Arka Anamika IIVR – 198 × Prabhani Kranti	Arka Abhay × Arka Anamika IIVR – 198 × Prabhani Kranti
13	Number of seeds / fruit	IC – 45806 × Pusa Sawani IC – 218877 × Arka Anamika IIVR – 198 × Prabhani Kranti	IC – 45806 × Pusa Sawani SA – 2 × Pusa Sawani IIVR – 401 × Pusa Sawani	IC – 45806 × Pusa Sawani
14	Ascorbic acid (mg / 100 g)	Arka Abhay × Arka Anamika EC – 305612 × Arka Anamika IC -45806 × Prabhani Kranti	VRO – 5 × Arka Anamika Arka Abhay × Arka Anamika VRO – 6 × Pusa Sawani	Arka Abhay × Arka Anamika

Out of 51 F_1's only 16 combinations showed positive significant sca effects in which few promising crosses of these were Arka Abhay × Arka Anamika (14.28) followed by IIVR-198 × Arka Anamika (12.84) and IIVR-401 × Prabhani Kranti (9.53). Whereas IIVR-198 × Pusa Sawani (-22.22) showed maximum negative sca effect. Based on *per se* performance and sca effects, IIVR-198 × Arka Anamika and IIVR-401 × Prabhani Kranti were good specific combinations for plant height.

4.2.2.2 Stem diameter

In Rainy season female line IIVR-401 (0.28) expressed maximum positive significant gca effect followed by EC-305601 (0.22) and IIVR-198 (0.21). Whereas IC-128883 (-0.22) shows maximum negative gca effect. The estimate of gca effect for male parental line with significant and positive direction was observed in Arka Anamika (0.05), while Pusa Sawani (-0.04) expressed negative significant gca effect. The parent EC-305612 was good general combiner which showed good *per se* performance and gca effect.

In hybrids among 51 F_1's, 12 cross combinations have positive significant sca effects. The three most promising crosses of these were Arka Abhay × Arka Anamika (0.54) followed by VRO-5 × Pusa Sawani (0.44) and IIVR-198 × Prabhani Kranti (0.25). Whereas IIVR-198 × Pusa Sawani (-0.48) showed maximum negative sca effect. Based on *per se* performance and sca effects Arka Abhay × Arka Anamika was best specific combination for stem diameter.

In Summer season, out of 17 female lines, IIVR-401 (0.15) expressed maximum positive significant gca effect followed by EC-305612 (0.14) and IIVR-198 (0.12). Whereas IIVR-435 (-0.16) showed maximum negative gca effect. The estimate of gca effect for male parental line with significant and positive direction was observed in Arka Anamika (0.15) while Prabhani Kranti (-0.08) and Pusa sawani (-0.07) expressed negative significant gca effect. The parents EC-

305612 and Arka Anamika were good general combiner which showed good *per se* performance and gca effects.

Among 51 crosses, 7 expressed positive significant sca effects. The maximum sca effects were observed in VRO-5 × Pusa Sawani (0.28) followed by IIVR-198 × Prabhani Kranti (0.26) and Arka Abhay × Arka Anamika (0.24) while IIVR-198 × Pusa Sawani (-0.49) showed maximum negative sca effect. On the basis of *per se* performance and sca effects IIVR-198 × Prabhani Kranti was best specific combination for stem diameter.

4.2.2.3 Number of branches per plant

In Rainy season, among 17 female lines, IIVR-435 (1.02) showed maximum positive significant gca effect followed by VRO-5 (0.35) and IC-218877 (0.32). Whereas IC-140906 (-0.59) have maximum negative sca effect. In male parents Arka Anamika (0.10) have positive significant sca effect while Prabhani Kranti (-0.10) have negative significant sca effect. The parent IIVR-435 was best general combiner which showed good *per se* performance and gca effect.

The significant positive sca effects were manifested in 16 hybrids, the best three hybrids manifested were IIVR-401 × Prabhani Kranti (0.89), EC-305612 × Arka Anamika (0.88) and IIVR-198 × Prabhani Kranti (0.65) while minimum in case of IIVR-435 × Prabhani Kranti (-0.78). On the basis of *per se* performance and sca effects IIVR-401 × Prabhani Kranti was the best specific combination.

In Summer season crop, out of 17 female parents, IIVR-435 (0.46) has maximum positive significant gca effect followed by IC-218877 (0.39) and SA-2 (0.35). Whereas IC-140934 (-0.45) expressed minimum gca effect. The parents IIVR-435 and SA-2 were good general combiner which showed better *per se* performance and gca effects.

Among hybrids, the best general combiner was IIVR-401 × Prabhani Kranti (0.88) followed by IC-43720 × Arka Anamika (0.65) and SA-2 × Pusa Sawani (0.60) while minimum in case of IC-43720 × Prabhani Kranti (-0.72). Basis of *per se* performance and the effect of sca SA-2 × Pusa Sawani and IC-43720 × Pusa Sawani were found the good specific combiner.

4.2.2.4 Number of nodes per plant

In Rainy season for number of nodes per plant, three female parental lines *viz.*, IIVR-198 (4.82), IIVR-401 (1.03) and VRO-6 (0.86) showed positive significant gca effects. However, 6 lines were poor general combiners. In which IC - 218844 exhibited significant gca effects with a higher value (-1.27). The gca effects of male parental lines were also significant in positive direction for Arka Anamika (1.41) and in negative direction for Pusa Sawani (-1.11) and Prabhani Kranti (-0.29). On the basis of *per se* performance and gca effect, VRO-6 was found best general combiner.

The significant positive sca effects were manifested in 13 hybrids, the best three hybrids manifested were IIVR-198 × Prabhani Kranti (5.48), IIVR-342 × Pusa Sawani (4.84) and IIVR-401 × Prabhani Kranti (3.97). Whereas IIVR-198 × Pusa Sawani (-6.83) exhibited the maximum negative significant effect. On the basis of *per se* performance and sca effect IIVR-198 × Prabhani Kranti was the best specific combination.

In Summer season crop, three female parental lines showed high positive significant gca effects *viz.*, IIVR-198 (3.37), IIVR-401 (2.94) and IIVR-342 (1.08). Whereas, IC-140906 (-1.81) showed maximum negative significant effect. The gca effect of male parental lines were also significant in positive direction for Arka Anamika (0.93) and in negative direction for Pusa Sawani (-0.99).

Out of 51 F_1's, positive significant sca effects were observed in 13 hybrids. The best three hybrids *viz.*, IIVR-401 × Prabhani Kranti (4.11), IIVR-342 × Pusa Sawani (3.88) and EC-305612 × Arka Anamika (3.60) showed high positive significant sca effects while IIVR-198 × Pusa Sawani (-6.41) have minimum sca effect.

4.2.2.5 Internodal length

In Rainy season crop, IIVR-198 (-1.66), IC-140934 (-1.12), IC-45806 (-0.73) and VRO-5 (-0.67) expressed negative significant gca effect for female parental lines while, IIVR-342 (1.19) expressed maximum positive significant effect. Among the male parental lines Arka Anamika (-0.75) expressed high negative significant gca effect i.e. desirable.

The significant negative sca effects were observed in 15 crosses. The best three cross combinations *viz.*, IIVR-342 × Pusa Sawani (-3.11), SA-2 × Pusa Sawani (-2.78) and VRO-5 × Arka Anamika (-2.02) while IIVR-342 × Arka Anamika (2.45) expressed maximum positive significant sca effect i.e. undesirable. The combined results of *per se* performance and sca effect clearly showed that VRO-5 × Arka Anamika was the best specific combination for internodal length.

In case of Summer season crop, 6 female lines expressed negative significant gca effect i.e. valuable. The promising female lines were IIVR-198 (-0.78), VRO-5 (-0.76) and IIVR-401 (-0.57) expressed high negative significant gca effects. While IC-140906 (0.81) expressed maximum positive significant gca effect. In case of male parental lines, Arka Anamika (-0.45) showed high negative significant gca effect. On the basis of *per se* performance and gca effect VRO-5 was the best combiner for this trait.

The significant and negative sca effects were observed in 17 crosses out of 51 crosses. The best three cross combinations *viz.*, VRO-5 × Arka Anamika (-2.15), IIVR-342 × Pusa Sawani (-1.37) and

IIVR-401 × Prabhani Kranti (-1.19) expressed high negative significant sca effects i.e. desirable for breeding point of view. Whereas, VRO-5 × Prabhani Kranti (1.50) expressed highest positive significant sca effect. The combined results of *per se* performance and sca effect indicate that VRO-5 × Arka Anamika was the best specific combination for internodal length.

4.2.2.6 Days to first flowering

In Rainy season crop, for days taken to first flowering general combiners with negative values are usually desirable. Out of 17 female lines 6 expressed the negative significant gca effects. The three most desirable female lines were IC-43720 (-3.25), SA-2 (-2.03) and IC-218844 (-1.47). Whereas the female line IC-140934 (1.86) expressed the highest positive significant gca effect i.e. undesirable. In case of male parental lines Prabhani Kranti (-0.44) and Arka Anamika (-0.23) were valuable because these showed highly negative significant gca effects. On the basis of *per se* performance and gca effects IC-218844 was good general combiners for earliness.

The significant negative sca effects for earliness were observed in 13 F_1's. The best three promising crosses in order of performance for earliness were IC-43720 × Arka Anamika (-5.10), IC-140934 × Prabhani Kranti (-3.67) and IC 140934 × Pusa Sawani (-3.12). The significant positive sca effect for lateness was observed in IC-140934 × Arka Anamika (6.78). On the basis of *per se* performance and sca effects, the most promising specific combination for earliness was IC-43720 × Arka Anamika.

In Summer season crop, 6 female parents showed negative significant gca effects. The most promising 3 female parents for earliness were SA-2 (-4.65), IIVR-401 (-3.76) and IC-140934 (-3.09). Whereas the female parent IC-45806 (2.80) express maximum positive significant gca effect for lateness. In male parental lines only Prabhani

Kranti (-0.73) expressed the significant gca effect and useful for earliness.

The significant negative sca effects for earliness were found in 16 hybrids. The best three most useful hybrids for earliness were VRO-6 × Arka Anamika (-4.33), IC-45806 × Pusa Sawani (-3.50) and IC- 218877 × Prabhani Kranti (-2.94) while the hybrid IC- 140906 × Prabhani Kranti (2.73) showed maximum positive significant sca effect, showed lateness. On the basis of *per se* performance and sca effects, the most promising specific combination for earliness was VRO-6 × Arka Anamika.

4.2.2.7 Days to 50 per cent flowering

In Rainy season crop, the gca effects for this trait were negative significant in 6 female parental lines. The maximum negative significant gca effect were observed in IC-43720 (-4.47) followed by IC-218844 (-3.25) and Arka Abhay (-1.80) these are valuable for earliness. Whereas the female parent IC-140934 (5.08) expressed the highest positive significant gca effect. Among 3 male parental lines none of the lines were expressed the negative significant gca effects. On the basis of *per se* performance and gca effect, IC-218844 was best general combiner for days to 50 per cent flowering.

Among 51 F_1's, only 15 were expressed the negative significant sca effects. The most promising three crosses were AC-108 × Arka Anamika (-3.14), IC-140934 × Pusa Sawani (-3.01) and EC-305612 × Arka Anamika (-2.36) while IC-140934 × Arka Anamika (5.31) expressed the maximum positive significant sca effect.

In Summer season crop, the 6 female parents were expressed the negative significant gca effects in which SA-2 (-3.40), IIVR-401 (-2.29) and IIVR-435 (-2.18) were the most promising lines for this trait. Where as VRO-5 (2.93) expressed the highest positive significant gca effect. Basis of *per se* performance IIVR-435 was the most valuable line and good general combiner for earliness.

In case of hybrids, 14 crosses expressed negative significant sca effects. The most promising three hybrids were AC-108 × Pusa Sawani (-2.81), IIVR-342 × Prabhani Kranti (-2.59) and IC-128883 × Arka Anamika (-2.48) showed negative significant sca effects for this trait. Whereas hybrid IIVR-342 × Arka Anamika (3.41) was highly positive significant sca effect for lateness. On the basis of *per se* performance and sca effect, the most promising specific combination for this trait was IIVR-342 × Prabhani Kranti.

4.2.2.8 Number of fruits per plant

In Rainy season crop, for number of fruits per plant, 7 female parental lines showed positive significant gca effect. The most promising three female parents were IC-128883 (1.79), VRO-5 (1.53) and Arka Abhay (1.28) expressed the positive significant gca effects. Whereas the female parental line IC- 218844 (-2.61) expressed highest negative significant gca effect for number of fruits per plant. When compared with *per se* performance and gca effects, IC-128883 was found good general combiner. In male parental lines only Prabhani Kranti (0.22) expressed the positive significant gca effect.

The significant positive sca effects were found in 8 crosses. The three most promising F_1's were EC-305612 × Pusa Sawani (2.02), IC-140934 × Arka Anamika (1.62) and IC-43720 × Pusa Sawani (1.26) expressed positive significant sca effects while IC-43720 × Arka Anamika (-2.13) showed maximum negative significant sca effect. The combined results of *per se* performance and sca effect clearly showed that EC-305612 × Pusa Sawani were the best specific combination for number of fruits per plant.

In case of Summer season crop, 4 female lines were expressed positive significant gca effects *viz.*, IIVR-198 (1.34), EC-305612 (1.31), IC-140906 (0.87) and VRO-6 (0.30). Where as IC-128883 (-0.93) showed the highest negative significant gca effect. In three male parental lines only Arka Anamika (0.38) expressed the positive significant gca effect and remaining showed negative significant gca effects. The combined results of *per se* performance and gca effect, EC-305612 was the good general combiner.

Among 51 F_1's, only 15 were expressed the positive significant sca effects. The three most promising hybrids were IIVR-198 × Prabhani Kranti (1.85), IIVR-435 × Prabhani Kranti (1.75) and IC-43720 × Pusa Sawani (1.68) expressed positive significant sca effects while EC-305612 × Prabhani Kranti (-1.75) showed maximum negative significant sca effect. The combined results of *per se* performance and sca effect clearly showed that IIVR-198 × Prabhani Kranti was the best specific combination for number of fruits per plant.

4.2.2.9 Single fruit weight

Examination of gca value revealed that VRO-5 (1.50), IIVR-401 (0.70), AC-108 (0.54), VRO-6 (0.51) and EC-305612 (0.49) were desirable female parental lines. Whereas IIVR-198 (-0.96) expressed maximum negative significant gca effect. In case of male parental lines only Pusa Sawani (0.41) showed positive significant gca effect. Based on *per se* performance and gca effects VRO-5 was good general combiner.

Among 51 F_1's, only 11 crosses showed the positive significant sca effects. The most promising three crosses were IC-218844 × Arka Anamika (2.71), VRO-5 × Pusa Sawani (1.59) and Arka Abhay × Prabhani Kranti (1.47) expressed high positive significant sca effects while IC-218844 × Pusa Sawani (-1.86) showed maximum negative significant sca effect. Considering the estimates of sca effects and *per* *se* performance of the crosses, VRO-5 × Pusa Sawani and IC-218844 × Arka Anamika were the good cross combinations for this trait.

In Summer season crop, out of 17 female parental lines 7 were showed positive significant gca effects. The three most promising lines were IIVR-401 (1.20), VRO-5 (1.00) and VRO-6 (0.98) expressed high positive significant gca effect. Whereas IC-128883 (-1.49) expressed maximum negative significant gca effect. In male parental lines only Arka Anamika (0.21) expressed high positive significant gca effect. Based on *per se* performance and gca effect, VRO-6 and VRO-5 were the most promising lines.

Among 51 F_1's only 7 showed positive significant sca effects. The most promising three crosses were IC-218844 × Prabhani Kranti (2.57), VRO-5 × Arka Anamika (1.25) and VRO-6 × Arka Anamika (1.17) expressed high positive significant sca effects. Whereas IC-128883 × Arka Anamika (-9.00) expressed maximum negative significant sca effect. Considering the estimates of sca effects and *per se* performance of the crosses IC-218844 × Prabhani Kranti, VRO-5 × Arka Anamika and VRO-6 × Arka Anamika were good cross combinations for single fruit weight.

4.2.2.10 Fruit length

In Rainy season crop, for fruit length, estimate of gca effects with significant positive values are desirable. Four female parental lines *viz.,* IC-140934 (0.76), VRO-5 (0.73), IC-218844 (0.62) and VRO-6 (0.25) expressed positive significant gca effects. Among the male parental lines only Arka Anamika expressed positive significant gca effects, while IIVR-198 (-0.69) expressed the highest negative significant gca effects. On the other hand male parental line Prabhani Kranti (-0.09) showed opposite trend.

Out of 51 F_1's, positive significant sca effects were observed in 16 hybrids. Best three hybrids *viz.*, VRO-5 × Arka Anamika (1.56), IC-

218844 × Arka Anamika (1.50) and IC-140934 × Pusa Sawani (0.96) showed positive significant sca effect. Whereas IC-218844 × Pusa Sawani (-1.38) expressed highest negative significant sca effect. On the basis of *per se* performance IC-218844 × Arka Anamika and IC-140934 × Pusa Sawani were found good general combiners.

In Summer season crop, out of 17 female parental lines, only 6 expressed positive significant gca effects. The most promising female parental lines were IC-140934 (0.97), IC-218844 (0.49) and VRO-5 (0.38) expressed high positive significant gca effects while IIVR-198 (-0.95) showed maximum negative significant gca effect. In male parental lines none of them expressed the significant effect.

Among 51 hybrids (F_1's) only 15 F_1's were observed positive significant sca effects. In hybrids the three most promising crosses were VRO-5 × Arka Anamika (0.99), IC-140934 × Pusa Sawani (0.96) and IIVR-198 × Prabhani Kranti (0.89) showed high positive significant sca effects. While VRO-5 × Pusa Sawani (-1.02) showed highest negative significant sca effect. On the basis of *per se* performance and sca effect IC-140934 × Pusa Sawani and VRO-5 × Arka Anamika were the good cross combinations for this trait.

4.2.2.11 Fruit diameter

In Rainy season crop, examination of gca value revealed that only 5 female parental lines were positive significant gca effects in which the most promising 3 lines were IC-218844 (0.06), IIVR-198 (0.06) and IC-128883 (0.06) showed positive significant gca effects. Whereas IIVR-435 showed highest negative significant gca effect. The male parental lines, Pusa Sawani (0.03) and Arka Anamika (0.02) showed positive significant gca effects.

Among 51 F1's, significant and positive sca effects were manifested in 6 hybrids in which most promising 3 hybrids were IIVR-342 × Arka Anamika, EC-305612 × Prabhani Kranti (0.18) and

IC-218844 × Arka Anamika (0.15) showed high positive significant sca effects. While AC-108 × Arka Anamika (-0.15) expressed highest negative significant sca effect. On the basis of *per se* performance and sca effects, IC-218844 × Arka Anamika was the best specific combiner.

In Summer season crop, out of 17 female parental lines only two lines *viz.*, IC-218844 (0.11) and IIVR-198 (0.07) showed positive significant gca effects while IC-45806 (-0.09) showed highest negative significant gca effect. Among male parental lines only Arka Anamika (0.03) showed positive significant gca effect.

Among the 51 F_1's, only 10 cross combiners expressed positive significant sca effects the best three *viz.*, AC-108 × Pusa Sawani (0.16), VRO-6 × Arka Anamika (0.14) and IC-45806 × Pusa Sawani (0.13) displayed positive significant sca effects. Whereas the hybrid IC-218844 × Pusa Sawani (-0.17) displayed maximum negative significant sca effect. Considering the estimate of sca effects and *per se* performance of the crosses, VRO-6 × Arka Anamika was best specific combination for fruit diameter.

4.2.2.12 Fruit yield per plant

In Rainy season, 7 female parental lines were found for positive significant gca effects, in which VRO-5 (26.12), VRO-6 (19.28) and Arka Abhay (14.81) were identified as good combiners for fruit yield per plant. The undesirable high negative and highly significant general combining ability effect was maximum in IC-218844 (-24.05). In male parental lines only Pusa Sawani (7.52) expressed high positive significant gca effect. Based on *per se* performance and gca effects VRO-6 and VRO-5 were found good general combiners.

Among the 51 cross combinations, the sca effects revealed that 13 crosses displayed positive significant effects. Best three cross combinations, VRO-5 × Pusa Sawani (34.00), Arka Abhay × Prabhani

Kranti (20.06) and AC-108 × Pusa Sawani (20.05) were most promising specific combiners. Highest negative sca estimates were observed in cross IC-218844 × Pusa Sawani (-24.13). Considering the estimates of sca effects and *per se* performance of the crosses, VRO-5 × Pusa Sawani and AC-108 × Pusa Sawani were best combinations for fruit yield per plant.

In Summer season crop, out of 17 female parental lines only 7 showed positive significant gca effects. The most valuable 3 lines were VRO-6 (10.77), VRO-5 (10.38) and EC-305612 (10.37) displayed high positive significant gca effects, while IC-128883 (-19.61) showed highest negative significant gca effect. In male parental lines only Arka Anamika (5.50) expressed positive significant gca effect. Based on *per se* performance and gca effects VRO-6 and VRO-5 were the best general combiners.

Out of 51 F_1's, only 15 crosses were expressed positive significant sca effects, the best three *viz.*, Arka Abhay × Arka Anamika (21.85), IIVR-198 × Prabhani Kranti (21.00) and IC-140906 × Pusa Sawani (20.45) expressed positive significant sca effects. While the cross VRO-6 × Prabhani Kranti (-19.49) showed maximum negative significant sca effect. Considering the estimates of sca effects and *per se* performance of the crosses Arka Abhay × Arka Anamika and IIVR-198 × Prabhani Kranti were good specific combinations for fruit yield per plant.

4.2.2.13 Number of seeds per fruit

In Rainy season crop, for number of seeds per fruit 6 female parental lines expressed useful negative significant gca effects. The best three lines were AC-108 (-7.79), SA- 2 (-7.31) and IC-218844 (-7.05) showed high negative significant gca effects. The female line IIVR-342 (8.21) exhibited maximum number of seeds because of highest positive significant gca effects. In male parental lines only

Pusa Sawani (-1.85) was the good general combiner. On the basis of *per se* performance and gca effects, IC-218844 was the best general combiner.

In case of hybrids only 14 were showed valuable negative significant sca effects. The most promising 3 crosses were SA-2 × Arka Anamika (-11.24), IC-45806 × Pusa Sawani (-8.37) and IIVR-435 × Prabhani Kranti (-8.35) expressed high negative significant sca effects i.e. desirable. Whereas SA-2 × Prabhani Kranti (12.24) displayed highest positive significant sca effect. The combined results of *per se* performance and sca effects clearly showed that SA-2 × Arka Anamika and IIVR-435 × Prabhani Kranti were the good specific combinations.

In Summer season crop, out of 17 female parental lines only 7 were expressed desirable negative significant gca effects. The most promising 3 lines were AC-108 (-8.66), IIVR-401 (-6.63) and SA-2 (-6.47) displayed high negative significant gca effects and IC-128883 (10.60) showed highest positive significant gca effect. In male parental lines Pusa Sawani (-3.90) expressed high negative significant gca effect i.e. desirable.

Among 51 hybrids only 14 were found for negative significant sca effects and the three best crosses were IC-45806 × Pusa Sawani (-12.72), IC-218877 × Arka Anamika (-7.74) and IIVR-198 × Prabhani Kranti (-6.79) displayed high negative significant sca effects, while the cross IC-218844 × Prabhani Kranti (8.47) had maximum positive significant sca effect. When compared with *per se* performance and sca effect IC-45806 × Pusa Sawani was best cross combination for number of seeds per fruit.

4.2.2.14 Number of ridges per fruit

In Rainy season crop, all female parental lines showed valuable negative significant gca effects except for IC-43720 (0.71). Whereas male parental line Arka Anamika (-0.01) showed high negative significant gca effect i.e. desirable.

In case of hybrids only 2 were, IC-43720 × Arka Anamika (-0.21) and IC-43720 × Pusa Sawani (-0.02) expressed valuable negative significant sca effects, while the cross IC-43720 × Prabhani Kranti (0.23) showed positive significant sca effect. Considering the estimates of sca effects and *per se* performance of the crosses IC-43720 × Arka Anamika and IC-43720 × Pusa Sawani were good cross combinations for this trait.

In Summer season crop, only IC-43720 (0.72) showed undesirable positive significant gca effect and remaining were found desirable negative significant gca effects. Among male parental lines only Arka Anamika (-0.01) has high negative significant and useful gca effect.

However, only two crosses IC-43720 × Arka Anamika (-0.09) and IC-43720 × Pusa Sawani (-0.06) were found useful negative significant sca effects, while the cross IC-43720 × Prabhani Kranti (0.16) had undesirable high positive significant sca effect. *Per se* performance was same as Rainy season crop.

4.2.2.15 Ascorbic acid content

In Rainy season crop, among 17 female parents only 6 were found positive significant gca effects. The most promising three females lines were VRO-5 (2.80), VRO-6 (1.68) and IIVR- 401 (0.79) has high positive significant gca effects i.e. desirable. Whereas IIVR-435 (-2.02) expressed maximum negative significant gca effect. In male parents only Prabhani Kranti (0.57) showed positive significant gca effect. On compared with *per se* performance and gca effects VRO-5 and VRO-6 were found good general combiners.

Only 6 hybrids were found to has positive significant sca effects. The most valuable three hybrids were EC-305612 × Pusa Sawani (2.01), IC-128883 × Prabhani Kranti (1.41) and Arka Abhay × Prabhani Kranti (1.31) found for positive significant sca effects while IC-128883 × Pusa Sawani (-2.35) has highest negative significant sca effects. When compared with *per se* performance and sca effects, Arka Abhay × Prabhani Kranti was the best cross combination among them.

In Summer season crop, only 6 female parental lines were found for positive significant gca effects in which VRO-5 (1.94), VRO-6 (1.90) and Arka Abhay (1.19) were most promising three lines. Whereas IIVR-435 (-2.12) has maximum negative significant gca effect. Considering the estimate of gca effects and *per se* performance VRO-6 and VRO-5 were the good general combiners.

However, in crosses only 6 were expressed positive significant gca effects i.e. desirable. The most promising three hybrids were Arka Abhay × Arka Anamika (1.47), EC- 305612 × Arka Anamika (1.45) and IC- 45806 × Prabhani Kranti (1.19) showed positive significant sca effects and IC- 45806 × Arka Anamika (-1.85) has highest negative significant sca effects. The combined results of *per se* performance and sca effect clearly showed that Arka Abhay × Arka Anamika was found good general combiner for ascorbic acid content.

4.3 Estimates of heterosis

Heterosis was estimated as per cent increase or decrease of F_1 values over better parent (BP) and standard parent (SP) / standard variety (SV) VRO-6. The extent of heterosis for different characters is presented in Table 4.3a (Rainy season) and Table 4.3b (Summer season). The results obtained are described character wise in Rainy season crop and Summer season crop ensuing paragraphs.

Table 4.3a: Extent of heterosis over better parent (BP) and standard parent (SP) in 51 hybrids for 15 characters in okra during Rainy season.

S.N.	Crosses	Plant height (cm)		Stem diameter (cm)		Number of branches/ plant		Number of nodes/ plant		Internodal length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
1	IC - 128883 × AA	1.77	1.13	-20.29**	-9.69	-38.39**	-6.30	27.85**	-23.17**	-16.64	6.27
2	IC - 128883 × PS	-0.63	-1.70	1.82	-8.05	-41.53**	-6.30	-28.17**	-42.93**	40.73**	43.18**
3	IC - 128883 × PK	-8.77	-13.66**	-14.55	-22.82**	-11.11	17.16	10.67	-33.05**	-14.11	7.71
4	VRO - 5 × AA	-27.13**	-27.59**	-28.99**	-19.54*	-23.21**	14.69	40.46**	-2.00	-18.32	-32.98**
5	VRO - 5 × PS	-0.81	-1.88	36.54**	16.58*	-22.03**	22.10*	-15.23*	-32.65**	49.87**	22.96*
6	VRO - 5 × PK	-10.70*	-16.76**	9.62	-6.40	-35.19**	-5.06	-17.92*	-42.73**	46.04**	19.83
7	VRO - 6 × AA	8.04	8.04	-17.39*	-6.40	-48.21**	-19.88	-10.28	-10.26	10.59	10.59
8	VRO - 6 × PS	-1.34	-1.34	-1.64	-1.48	-30.51**	9.75	-23.79**	-23.77**	4.10	4.10
9	VRO - 6 × PK	-3.57	-3.57	3.28	3.45	-31.31**	-7.53	-30.44**	-30.43**	10.15	10.15
10	AC - 108 × AA	2.22	1.58	-11.59	0.16	-29.46**	6.05	8.65	-8.85	1.40	-11.63
11	AC - 108 × PS	-11.28*	-12.23**	-6.78	-9.69	-50.85**	-19.88	-31.49**	-42.53**	43.85**	25.36*
12	AC - 108 × PK	1.60	-5.30	0.00	-3.12	-52.25**	-26.05*	-17.55**	-30.83**	24.10	8.15
13	IC - 45806 × AA	4.85	4.20	-11.59	0.16	-39.29**	-7.53	26.58**	-19.34**	-17.33	3.75
14	IC - 45806 × PS	-12.21**	-13.15**	-5.56	-16.26*	-48.31**	-16.17	-16.24*	-33.45**	8.61	10.50
15	IC - 45806 × PK	-13.86**	-18.42**	0.00	-11.33	-28.28**	-3.83	6.01	-32.45**	-25.57**	-6.67
16	IC - 218877 × AA	-2.66	-2.02	-17.39*	-6.40	-27.68**	8.52	-2.58	-31.44**	1.71	13.99
17	IC - 218877 × PS	-7.24	-6.64	3.39	0.16	-42.37**	-7.53	-20.56**	-36.88**	25.74*	27.93*
18	IC - 218877 × PK	-0.53	0.12	-3.39	-6.40	-2.02	28.27**	2.58	-27.81**	0.04	12.11
19	IC - 218844 × AA	-10.87*	-11.43**	-4.35	8.37	-46.43**	-17.41	-20.22**	-40.31**	-16.93	-11.68
20	IC - 218844 × PS	6.32	5.18	7.94	11.66	-42.37**	-7.53	-13.45	-31.24**	19.36	21.44
21	IC - 218844 × PK	5.41	3.21	-11.11	-8.05	-57.58**	-39.63**	-8.36	-31.44**	13.81	21.00
22	Arka Abhay × AA	17.12**	18.51**	8.70	23.15**	-41.07**	-10.00	17.77**	4.25	-0.63	-10.76
23	Arka Abhay × PS	-6.15	-5.03	-15.63*	-11.33	-64.41**	-39.63**	-26.20**	-34.66**	37.46**	23.44*
24	Arka Abhay × PK	-23.24**	-22.32**	-32.81**	-29.39**	-30.30**	-6.30	-42.14**	-48.78**	39.59**	25.36*
25	IC - 43720 × AA	-9.69*	-9.82*	-18.84**	-8.05	-31.25**	3.58	-0.81	-25.59**	-11.03	-3.70

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

Table 4.3a: Continued….

S.N.	Crosses	Plant height (cm)		Stem diameter (cm)		Number of branches/ plant		Number of nodes/ plant		Internodal length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
26	IC - 43720 × PS	0.75	0.60	-3.28	-3.12	-23.73**	19.63	-15.23*	-32.65**	25.74*	27.93*
27	IC - 43720 × PK	0.80	0.65	-11.48	-11.33	-42.57**	-19.88	-13.17	-34.87**	21.01	30.98**
28	IIVR-342 × AA	-8.42*	-2.59	-8.70	3.45	-36.61**	-3.83	-23.66**	-42.73**	27.49**	49.76**
29	IIVR-342 × PS	6.30	13.07**	-10.14	1.81	-25.42**	17.16	18.02**	-6.23	-6.85	-5.23
30	IIVR-342 × PK	-2.07	4.17	-8.70	3.45	-33.33**	-10.00	-16.40*	-37.29**	17.54	38.08**
31	IC - 140906 × AA	-4.58	-5.18	-21.74**	-11.33	-40.18**	-8.77	6.69	-29.22**	-0.31	13.90
32	IC - 140906 × PS	7.46	6.31	32.00**	8.37	-55.08**	-26.05*	-13.96*	-31.64**	20.90	23.01*
33	IC - 140906 × PK	2.55	-4.40	20.00*	-1.48	-55.56**	-37.16**	-12.16	-41.72**	23.46*	41.05**
34	IIVR-198 × AA	20.28**	19.52**	7.25	21.51**	-47.32**	-18.64	106.64**	19.18**	-44.14**	-21.87
35	IIVR-198 × PS	-21.24**	-22.08**	-19.35*	-17.90*	-58.47**	-30.99**	-31.47**	-45.55**	21.58	23.70*
36	IIVR-198 × PK	19.24**	16.55**	17.74*	19.87*	-20.20*	6.05	121.33**	33.90**	-44.93**	-30.94**
37	EC - 305612 × AA	7.67	11.61**	-8.00	13.30	-4.46	40.62**	77.97**	2.64	-38.72**	-14.29
38	EC - 305612 × PS	-4.82	-1.34	-10.67	10.02	-54.24**	-24.81*	-27.66**	-42.53**	44.03**	46.54**
39	EC - 305612 × PK	-4.34	-0.83	-17.33*	1.81	-28.28**	-3.83	9.00	-34.06**	0.87	26.49*
40	IIVR-435 × AA	-4.67	-0.39	-20.29**	-9.69	-28.85**	45.56**	-4.25	-13.69*	2.89	-8.41
41	IIVR-435 × PS	-11.14**	-7.14	-17.46*	-14.61	-22.44**	57.90**	-36.24**	-42.53**	53.50**	36.64**
42	IIVR-435 × PK	-0.97	3.48	0.00	3.45	-50.64**	3.58	-18.34**	-26.40**	22.81	9.32
43	IIVR-401 × AA	7.97*	18.51**	2.90	16.58*	-45.54**	-16.17	9.46	-22.97**	-6.44	19.61
44	IIVR-401 × PS	-17.98**	-9.97*	-10.77	-4.76	-40.68**	-5.06	-24.62**	-40.11**	23.13*	25.27**
45	IIVR-401 × PK	7.08	17.53**	13.85	21.51**	2.02	33.21**	44.70**	1.84	-26.27**	-7.54
46	SA - 2 × AA	-15.32**	-13.13**	-26.09**	-16.26*	-18.75*	20.86*	-20.61*	-47.17**	7.21	34.81**
47	SA - 2 × PS	-11.52**	-9.23*	-15.87*	-12.97	-33.05**	6.05	1.78	-19.14**	-10.88	-9.32
48	SA - 2 × PK	-1.89	0.65	-1.59	1.81	-31.31**	-7.53	-3.03	-35.47**	5.00	31.68**
49	IC - 140934 × AA	-3.42	3.33	-11.59	0.16	-36.61**	-3.83	7.94	-17.73**	-10.83	0.78
50	IC - 140934 × PS	-27.04**	-21.93**	-29.51**	-29.39**	-31.36**	8.52	-11.17	-29.42**	-9.29	-7.71
51	IC - 140934 × PK	-24.01**	-18.69**	-8.20	-8.05	-41.41**	-19.88	-10.85	-32.04**	-12.30	-0.87

Table 4.3a: Continued….

S.N.	Crosses	Days to first flowering		Days to 50% flowering		Number of fruits/plant		Single fruit weight (g)		Fruit length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
1	IC - 128883 × AA	12.50**	10.65**	3.33	7.64**	-4.34	-11.36	6.42	-16.59**	-3.12*	-3.43**
2	IC - 128883 × PS	7.50**	5.73**	6.00**	10.42**	-2.41	-9.58	-7.87	-16.89**	-0.62	-0.93
3	IC - 128883 × PK	10.00**	8.19**	4.67*	9.03**	-1.93	-9.13	-11.82*	-22.80**	-4.38**	-4.67**
4	VRO - 5 × AA	10.00**	8.19**	12.50**	12.50**	0.50	-9.35	-7.89	-6.83	21.79**	18.38**
5	VRO - 5 × PS	10.00**	8.19**	12.50**	12.50**	5.73	-17.62**	17.54**	18.90**	0.00	-2.80*
6	VRO - 5 × PK	10.00**	8.19**	6.25**	6.25**	17.77*	-8.24	-9.65*	-8.61	-2.88*	-5.61**
7	VRO - 6 × AA	-4.10	-4.11*	2.78	2.78	-27.01**	-26.99**	-17.16*	-17.18**	-4.98**	-4.98**
8	VRO - 6 × PS	5.74**	5.73**	11.81**	11.81**	-14.96*	-14.94*	2.07	2.04	4.98**	4.98**
9	VRO - 6 × PK	3.28	3.27	2.08	2.08	-12.05*	-12.03*	-7.69	-7.72	-3.74**	-3.74**
10	AC - 108 × AA	8.55**	4.09	5.07*	0.69	-4.95	-14.27*	20.31**	-8.90*	4.04**	-3.74**
11	AC - 108 × PS	12.82**	8.19**	15.94**	11.11**	2.08	-23.42**	13.11**	2.04	7.24**	-3.12*
12	AC - 108 × PK	15.38**	10.65**	15.94**	11.11**	20.59**	-8.46	-3.38	-15.41**	8.97**	-1.56
13	IC - 45806 × AA	8.94**	9.83**	4.00	8.33**	-10.64	-19.40**	10.73*	-5.35	6.06**	-1.87
14	IC - 45806 × PS	4.07	4.91*	-0.67	3.47	1.66	-18.06**	-5.57	-14.82**	5.15**	-4.67**
15	IC - 45806 × PK	8.20**	8.19**	1.33	5.56*	3.60	-16.50**	2.70	-10.09*	7.22**	-2.80*
16	IC - 218877 × AA	10.81**	0.81	7.97**	3.47	-18.81**	-26.77**	5.11	-14.82**	2.69	-4.98**
17	IC - 218877 × PS	18.92**	8.19**	7.97**	3.47	-2.92	-25.65**	-13.11**	-21.62**	15.36**	-4.05**
18	IC - 218877 × PK	18.92*	8.19**	10.14**	5.56*	-18.95*	-37.93**	-13.85**	-24.58**	9.19**	-7.48**
19	IC - 218844 × AA	0.00	-4.11	10.14**	5.56*	-38.86**	-44.85**	34.36**	15.65**	26.26**	16.82**
20	IC - 218844 × PS	7.69**	3.27	4.35	0.00	-23.81**	-42.84**	-13.77**	-22.21**	-3.03*	-10.28**
21	IC - 218844 × PK	8.55**	4.09	2.17	-2.08	-8.82	-30.79**	-10.14	-21.33**	8.42**	0.31
22	Arka Abhay × AA	0.00	8.19**	4.67*	9.03**	-0.74	-10.47	-8.56	-21.03**	-7.53**	-4.36**
23	Arka Abhay × PS	9.76**	10.65**	-1.33	2.78	8.16	-17.17**	0.98	-8.90*	-11.45**	-8.41**
24	Arka Abhay × PK	0.82	0.81	-4.61*	0.69	13.99	-12.70*	11.82*	-2.10	-6.45**	-3.24**
25	IC - 43720 × AA	-12.82**	-16.40**	-10.00**	-6.25**	-35.89**	-42.17**	13.41*	-17.48**	3.03*	-4.67**

Table 4.3a: Continued….

S.N.	Crosses	Days to first flowering		Days to 50% flowering		Number of fruits/plant		Single fruit weight (g)		Fruit length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
26	IC - 43720 × PS	15.38**	10.65**	-8.00**	-4.17	8.04	-18.96**	-8.52	-17.48**	10.42**	-0.93
27	IC - 43720 × PK	0.00	-4.11	0.66	6.25**	5.88	-19.62**	-6.76	-18.37**	1.39	-9.03**
28	IIVR-342 × AA	2.44	3.27	1.33	5.56*	-15.59*	-23.87**	-0.71	-17.78**	-3.03*	-10.28**
29	IIVR-342 × PS	4.07	4.91**	4.00	8.33**	3.27	-22.53**	9.18	-1.51	16.79**	-4.67**
30	IIVR-342 × PK	3.28	3.27	4.61*	10.42**	-5.29	-28.11**	-14.19**	-24.87**	16.18**	-1.56
31	IC - 140906 × AA	15.38**	10.65**	6.00**	10.42**	-28.47**	-35.48**	-4.83	-18.37**	-8.13**	-8.41**
32	IC - 140906 × PS	10.26**	5.73**	6.00**	10.42**	-14.29	-35.70**	-3.28	-12.75**	-2.50	-2.80*
33	IC - 140906 × PK	10.26**	5.73**	8.55**	14.58**	0.00	-24.09**	-11.15*	-22.21**	-5.31**	-5.61**
34	IIVR-198 × AA	7.32**	8.19**	12.77**	10.42**	-23.76**	-31.23**	-4.23	-19.55**	-12.46**	-12.46**
35	IIVR-198 × PS	4.88*	5.73**	10.64**	8.33**	-6.55	-29.90**	-12.46*	-21.03**	-15.58**	-15.58**
36	IIVR-198 × PK	5.74**	5.73**	8.51**	6.25**	-0.29	-24.31**	-10.47*	-21.62**	-1.87	-1.87
37	EC - 305612 × AA	2.33	8.19**	3.40	5.56*	-14.85*	-23.20**	21.84**	-5.94	-4.38**	-11.53**
38	EC - 305612 × PS	4.88*	5.73**	10.20**	12.50**	26.10**	-4.00	6.89	-3.58	20.99**	-1.25
39	EC - 305612 × PK	2.46	2.45	12.24**	14.58**	-0.29	-24.09**	-1.69	-13.93**	4.04**	-11.84**
40	IIVR-435 × AA	-4.07	-3.29	4.00	8.33**	-11.14	-19.85**	10.51	-16.00**	1.35	-6.23**
41	IIVR-435 × PS	9.76**	10.65**	10.00**	14.58**	-6.54	-23.42**	-7.54	-16.59**	-1.74	-11.84**
42	IIVR-435 × PK	0.82	0.81	2.63	8.33**	-5.99	-22.97**	0.00	-12.45**	6.94**	-4.05**
43	IIVR-401 × AA	-10.87**	0.81	3.33	7.64**	-9.16	-18.06**	24.80**	-9.20*	-2.20	-3.12*
44	IIVR-401 × PS	4.88*	5.73**	4.00	8.33**	-15.26*	-28.11**	22.30**	10.32*	-2.20	-3.12*
45	IIVR-401 × PK	-1.64	-1.65	4.61*	10.42**	-13.95*	-26.99**	-7.43	-18.96**	-3.14*	-4.05**
46	SA - 2 × AA	-3.17	-0.01	2.67	6.94**	-13.86*	-22.30**	20.36**	-2.10	0.32	-2.49
47	SA - 2 × PS	0.00	0.81	8.00**	12.50**	-7.94	-22.30**	-4.59	-13.93**	4.49**	1.56
48	SA - 2 × PK	-1.64	-1.65	8.55**	14.58**	-4.76	-19.62**	-8.45	-19.85**	-6.73**	-9.35**
49	IC - 140934 × AA	27.50**	25.40**	24.00**	29.17**	-1.49	-11.14	15.33**	-10.97*	3.37*	-4.36**
50	IC - 140934 × PS	5.00*	3.27	8.00**	12.50**	-11.02	-27.89**	2.30	-7.72	23.13**	12.77**
51	IC - 140934 × PK	0.83	-0.83	7.89**	13.89**	-6.34	-24.09**	-6.42	-18.07**	11.56**	2.18

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

Table 4.3a: Continued…

S.N.	Crosses	Fruit diameter (cm)		Fruit yield/plant (g)		Number of seeds/fruit		Number of ridges/fruit		Ascorbic acid (mg/100g)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
1	IC - 128883 × AA	6.25	13.33*	3.77	-25.01**	-11.54	-22.21**	0.00	0.00	-12.57*	-14.38**
2	IC - 128883 × PS	6.25	13.33*	3.96	-24.87**	-4.20	-15.15**	0.00	0.00	-38.50**	-39.77**
3	IC - 128883 × PK	-6.25	0.00	-10.09	-30.37**	14.76*	-7.72	0.00	0.00	-1.60	-3.64
4	VRO - 5 × AA	6.67	6.67	-2.81	-23.59**	5.04	-21.54**	0.00	0.00	0.52	1.60
5	VRO - 5 × PS	0.00	6.67	37.80**	8.33	22.21**	-8.72	0.00	0.00	-1.63	-0.58
6	VRO - 5 × PK	0.00	6.67	-15.39*	-33.48**	18.00*	-11.86*	0.00	0.00	6.22	7.36
7	VRO - 6 × AA	0.00	0.00	-29.72**	-29.72**	-17.62**	-27.55**	0.00	0.00	-13.09**	-13.07**
8	VRO - 6 × PS	0.00	6.67	-10.13	-10.13	-16.78**	-16.77**	0.00	0.00	-3.93	-3.90
9	VRO - 6 × PK	-6.25	0.00	-21.02**	-21.02**	3.91	-16.44**	0.00	0.00	-1.05	-1.02
10	AC - 108 × AA	-11.76*	0.00	28.01*	-30.35**	6.41	-28.83**	0.00	0.00	-12.50*	-30.35**
11	AC - 108 × PS	5.88	20.00**	36.59**	-6.70	-5.35	-36.70**	0.00	0.00	-11.94*	-28.52**
12	AC - 108 × PK	-5.88	6.67	-12.30	-32.08**	11.76	-25.26**	0.00	0.00	-16.34**	-22.23**
13	IC - 45806 × AA	6.67	6.67	11.88	-23.05**	47.52**	-6.62	0.00	0.00	-2.77	-17.26**
14	IC - 45806 × PS	0.00	6.67	2.95	-29.19**	7.61	-31.88**	0.00	0.00	-10.15	-23.54**
15	IC - 45806 × PK	-6.25	0.00	-4.43	-25.99**	36.97**	-13.29*	0.00	0.00	-6.76	-13.33**
16	IC - 218877 × AA	8.51	13.33*	1.70	-37.43**	-1.09	-22.06**	0.00	0.00	-4.93	-24.33**
17	IC - 218877 × PS	0.00	6.67	-14.95	-41.90**	27.77**	0.67	0.00	0.00	-5.81	-23.54**
18	IC - 218877 × PK	0.00	6.67	-39.79**	-53.37**	15.91*	-8.67	0.00	0.00	-18.59**	-24.33**
19	IC - 218844 × AA	20.00**	20.00**	0.62	-36.45**	41.28**	-21.21**	0.00	0.00	-3.95	-23.54**
20	IC - 218844 × PS	0.00	6.67	-35.25**	-55.77**	22.82*	-31.50**	0.00	0.00	-0.65	-19.35**
21	IC - 218844 × PK	-6.25	0.00	-29.77**	-45.61**	16.67	-34.93**	0.00	0.00	-10.42*	-16.73**
22	Arka Abhay × AA	6.67	6.67	6.89	-29.43**	60.20**	-2.71	0.00	0.00	-7.69	-24.59**
23	Arka Abhay × PS	0.00	6.67	10.38	-24.60**	16.48	-29.26**	0.00	0.00	-0.64	-18.83**
24	Arka Abhay × PK	0.00	6.67	10.05	-14.78*	43.88**	-12.63*	0.00	0.00	8.17	0.55
25	IC - 43720 × AA	0.00	6.67	-12.42	-52.34**	24.54**	-9.77	10.67**	10.67**	-11.84	-29.82**

Table 4.3a: Continued….

S.N.	Crosses	Fruit diameter (cm)		Fruit yield/plant (g)		Number of seeds/fruit		Number of ridges/fruit		Ascorbic acid	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
26	IC - 43720 × PS	0.00	6.67	-1.98	-33.04**	4.01	-24.64**	14.60**	14.60**	-10.65	-27.47**
27	IC - 43720 × PK	-6.25	0.00	-15.80*	-34.80**	-3.03	-29.74**	20.00**	20.00**	-16.90**	-22.75**
28	342 × AA	6.25	13.33*	13.33	-37.85**	23.56**	-5.00	0.00	0.00	-17.76**	-34.54**
29	342 × PS	-6.25	0.00	11.68	-23.71**	16.24*	-10.62*	0.00	0.00	-25.48**	-39.51**
30	342 × PK	-18.75**	-13.33*	-30.51**	-46.19**	21.57**	-6.53	0.00	0.00	-19.72**	-25.37**
31	IC - 140906 × AA	-11.76*	0.00	-14.97	-47.34**	-1.31	-20.78**	0.00	0.00	-5.23	-24.06**
32	IC - 140906 × PS	-11.76*	0.00	-18.44	-44.29**	-2.79	-21.97**	0.00	0.00	-8.06	-25.37**
33	IC - 140906 × PK	-11.76*	0.00	-23.69**	-40.90**	13.24	-9.10	0.00	0.00	-17.46**	-23.28**
34	198 × AA	0.00	6.67	-13.68	-44.94**	-3.20	-14.87**	0.00	0.00	-9.47	-14.90**
35	198 × PS	0.00	6.67	-19.27*	-44.86**	-7.89	-10.96*	0.00	0.00	-10.31*	-15.68**
36	198 × PK	6.25	13.33*	-23.50**	-40.76**	0.24	-19.40**	0.00	0.00	-9.47	-14.90**
37	EC - 305612 × AA	-6.25	0.00	13.78	-28.04**	-7.74	-19.35**	0.00	0.00	-0.66	-20.92**
38	EC - 305612 × PS	-6.25	0.00	35.01**	-7.78	-0.49	-13.01*	0.00	0.00	20.97**	-1.81
39	EC - 305612 × PK	6.25	13.33*	-15.80*	-34.80**	-2.67	-21.73**	0.00	0.00	-18.31**	-24.06**
40	435 × AA	-11.76*	0.00	4.41	-33.50**	-6.45	-17.73**	0.00	0.00	-13.82*	-31.40**
41	435 × PS	-11.76*	0.00	-7.09	-36.53**	-16.09**	-25.40**	0.00	0.00	-29.35**	-42.66**
42	435 × PK	-17.65**	-6.67	-13.15	-32.74**	-18.55**	-34.51**	0.00	0.00	-25.92**	-31.13**
43	401 × AA	7.14	0.00	27.13**	-25.98**	-16.03*	-31.84**	0.00	0.00	8.55	-13.59**
44	401 × PS	6.25	13.33*	16.19	-20.63**	-17.79**	-33.27**	0.00	0.00	4.19	-15.42**
45	401 × PK	-6.25	0.00	-24.30**	-41.37**	6.70	-14.20**	0.00	0.00	-3.10	-9.92*
46	SA - 2 × AA	0.00	6.67	14.53	-24.97**	-38.97**	-46.33**	0.00	0.00	-3.14	-19.35**
47	SA - 2 × PS	0.00	6.67	-2.84	-33.63**	-30.75**	-33.65**	0.00	0.00	-1.26	-17.78**
48	SA - 2 × PK	-6.25	0.00	-17.36*	-36.01**	13.46*	-8.77	0.00	0.00	-6.76	-13.33**
49	IC - 140934 × AA	6.67	6.67	13.93	-21.31**	3.12	-18.20**	0.00	0.00	-17.11**	-34.01**
50	IC - 140934 × PS	0.00	6.67	-4.40	-33.97**	-8.35	-27.31**	0.00	0.00	2.26	-16.99**
51	IC - 140934 × PK	-6.25	0.00	-20.03**	-38.07**	33.65**	6.01	0.00	0.00	-4.79	-11.50*

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

4.3.1 Plant height

In Rainy season crop, heterosis for plant height ranged from -27.13 (VRO-5 × Arka Anamika) to 20.28 per cent (IIVR-198 × Arka Anamika) over better parent and from -27.59 per cent (VRO-5 × Arka Anamika) to 19.52 per cent (IIVR-198 × Arka Anamika) over standard variety. Among the 51 crosses, significant positive heterosis was observed in 5 and 7 hybrids over better parent and standard variety, respectively. The negative significant values were obtained in 14 crosses over better parent and 15 crosses over standard variety. It is very obvious from the Table 4.3a that the tendency of hybrids was towards tallness than the parents in most of the cases.

In Summer season crop, it was ranged from -33.47 per cent (VRO-5 × Arka Anamika) to 11.03 per cent (IIVR-198 × Arka Anamika) over better parent and from -33.02 (VRO-5 × Arka Anamika) to 11.79 per cent (IIVR-198 × Arka Anamika) over standard variety. Out of 51 F_1's, only IIVR-198 × Arka Anamika showed positive significant effect for both better parent and standard variety heterosis. The negative significant values were obtained in 20 hybrids in both better and standard parent heterosis.

4.3.2 Stem diameter

In Rainy season crop, the hybrid with positive heterosis is more desirable for this trait. Among 51 F_1's, only 4 hybrids scored significant positive heterosis over better parent in desirable direction and 6 hybrids also exhibited positive significant heterosis when tested against standard variety. The extent of heterosis over better parent ranged from -32.81 per cent (Arka Abhay × Prabhani Kranti) to 36.54 per cent (VRO - 5 × Pusa Sawani) and over standard variety ranged from -29.39 per cent (Arka Abhay × Prabhani Kranti) to 23.15 per cent (Arka Abhay × Arka Anamika). Whereas negative heterosis was found in 15 crosses over better parent and 6 crosses over standard variety.

Table 4.3b: Extent of heterosis over better parent (BP) and standard parent (SP) in 51 hybrids for 15 characters in okra during Summer season.

S.N.	Crosses	Plant height (cm)		Stem diameter (cm)		Number of branches/ plant		Number of nodes/plant		Internodal length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
1	IC - 128883 × AA	-15.99**	-15.42**	-21.88**	-20.63**	-38.75	0.20	1.84	-36.60**	-2.13	119.05**
2	IC - 128883 × PS	-7.60	-9.83	5.66	-11.11	-24.07*	-16.16	-21.29**	-41.99**	15.43*	122.62**
3	IC - 128883 × PK	-14.26*	-16.56**	7.55	-9.52	-34.55**	-26.38*	13.25	-38.56**	-18.09**	83.33**
4	VRO - 5 × AA	-33.47**	-33.02**	-20.31**	-19.05**	-37.50**	2.25	-21.23**	-41.18**	-2.50	-7.14
5	VRO - 5 × PS	-12.72*	-14.83**	28.00**	1.59	-13.11	8.38	-21.01**	-41.01**	132.50**	121.43**
6	VRO - 5 × PK	-11.61*	-13.98*	10.00	-12.70*	-36.07**	-20.25	-27.13**	-45.59**	155.00**	142.86**
7	VRO - 6 × AA	-8.30	-7.68	-12.50*	-11.11	-47.50**	-14.11	-39.71**	-39.71**	133.33**	133.33**
8	VRO - 6 × PS	-4.96	-4.97	-7.94	-7.94	6.12	6.34	-30.56**	-30.56**	113.10**	113.10**
9	VRO - 6 × PK	-14.34*	-14.34*	-6.35	-6.35	-5.45	6.34	-38.56**	-38.56**	140.48**	140.48**
10	AC - 108 × AA	-10.83	-10.23	-7.81	-6.35	-26.25**	20.65	-16.33*	-31.37**	14.18	82.14**
11	AC - 108 × PS	-8.40	-10.62	-5.08	-11.11	-33.90**	-20.25	-21.31**	-35.46**	33.58**	113.10**
12	AC - 108 × PK	-7.15	-9.64	-3.39	-9.52	-47.46**	-36.61	-19.92**	-34.31**	32.09**	110.71**
13	IC - 45806 × AA	-5.94	-5.29	-12.50*	-11.11	-50.00**	-18.20**	-8.40	-42.97**	10.31	154.76**
14	IC - 45806 × PS	-12.48	-14.60**	16.33*	-9.52	19.51	0.20	-24.39**	-44.28**	30.25**	151.19**
15	IC - 45806 × PK	-10.77	-13.16*	14.29	-11.11	-12.73	-1.84	20.18	-34.80**	-25.78**	98.81**
16	IC - 218877 × AA	-13.05*	-10.36	-14.06*	-12.70*	-37.50**	2.25	1.57	-36.76**	-3.09	123.81**
17	IC - 218877 × PS	-12.26*	-9.54	3.57	-7.94	-3.92	0.20	-23.06**	-43.30**	21.60**	134.52**
18	IC - 218877 × PK	-9.34	-6.53	0.00	-11.11	16.36	30.88**	17.98	-31.37**	-20.09**	103.57**
19	IC - 218844 × AA	-16.37**	-13.43*	-6.25	-4.76	-63.75**	-40.70**	-28.40**	-42.32**	32.89**	135.71**
20	IC - 218844 × PS	-7.38	-4.12	-14.75*	-17.46**	-7.32	-22.29*	-11.76	-28.92**	16.11	105.95**
21	IC - 218844 × PK	-8.93	-5.72	-6.56	-9.52	-47.27**	-40.70**	-23.53**	-38.40**	27.52**	126.19**
22	Arka Abhay × AA	5.09	5.81	-4.69	-3.17	-43.75**	-7.98	17.91*	-17.16**	-0.64	85.71**
23	Arka Abhay × PS	-7.33	-9.57	-13.11*	-15.87*	-26.83*	-38.65**	-23.28**	-43.46**	37.58**	157.14**
24	Arka Abhay × PK	-21.95**	-24.04**	-24.59**	-26.98**	-9.09	2.25	-23.95**	-46.57**	27.39**	138.10**
25	IC - 43720 × AA	-20.30**	-19.76**	-10.94	-9.52	-17.50**	34.97**	19.95*	-25.33**	-24.23**	75.00**

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

Table 4.3b: Continued….

S.N.	Crosses	Plant height (cm)		Stem diameter (cm)		Number of branches/ plant		Number of nodes/plant		Internodal length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
26	IC - 43720 × PS	-5.66	-7.94	-11.67	-15.87*	-33.33**	-14.11	-21.29**	-41.99**	24.69**	140.48**
27	IC - 43720 × PK	-5.57	-8.10	-20.00**	-23.81**	-71.43**	-63.19**	-1.20	-46.41**	15.12*	180.95**
28	342 × AA	-12.33*	-11.50*	-21.88**	-20.63**	-61.25**	-36.61**	-12.24	-44.93**	7.22	147.62**
29	342 × PS	2.65	3.62	-6.35	-6.35	21.95	2.25	16.41*	-14.22*	-8.02	77.38**
30	342 × PK	-3.24	-2.32	-9.52	-9.52	-40.00**	-32.52**	17.97	-25.98**	-13.81*	115.48**
31	IC - 140906 × AA	-12.13*	-11.53*	-15.63*	-14.29*	-38.75**	0.20	-0.79	-38.24**	38.81**	121.43**
32	IC - 140906 × PS	-6.43	-8.69	28.26**	-6.35	-58.82**	-57.06**	-26.83**	-46.08**	57.46**	151.19**
33	IC - 140906 × PK	-9.03	-11.47*	22.92**	-6.35	-60.00**	-55.01**	4.52	-43.30**	58.21**	152.38**
34	198 × AA	11.03*	11.79*	4.69	6.35	-47.50**	-14.11	64.30**	2.29	-37.63**	44.05**
35	198 × PS	-22.99**	-24.86**	-25.42*	-30.16**	-50.00**	-55.01**	-36.81**	-53.43**	30.25**	151.19**
36	198 × PK	10.40	7.44	15.25*	7.94	-7.27	4.29	83.73**	-0.33	-36.49**	59.52**
37	EC - 305612 × AA	2.98	3.69	-9.72	3.17	-25.00**	22.70*	46.48**	-8.33	-27.32**	67.86**
38	EC - 305612 × PS	-5.89	-8.17	-18.06**	-6.35	-50.00**	-36.61**	-27.72**	-46.73**	33.95**	158.33**
39	EC - 305612 × PK	-5.34	-7.87	-20.83**	-9.52	-32.26**	-14.11	1.31	-36.60**	-9.27	121.43**
40	435 × AA	-14.96**	-9.38	-20.31**	-19.05**	-36.44**	53.37**	-11.88*	-10.29	0.80	50.00**
41	435 × PS	-20.23**	-14.99**	-21.31**	-23.81**	-55.93**	6.34	-46.71**	-45.75**	71.20**	154.76**
42	435 × PK	-15.60**	-10.06	-9.84	-12.70*	-64.41**	-14.11	-33.39**	-32.19**	48.80**	121.43**
43	401 × AA	4.83	5.55	-1.72	-0.16	-73.75**	-57.06**	22.05*	-24.02**	-5.67	117.86**
44	401 × PS	-14.21*	-13.82*	-17.74**	-19.05**	-29.27*	-40.70**	-11.75	-34.97**	6.79	105.95**
45	401 × PK	9.56	10.06	9.68	7.94	10.91	24.74*	86.45**	1.14	-42.67**	53.57**
46	SA - 2 × AA	-9.47	-8.85	-20.31**	-19.05**	-28.75**	16.56	12.29	-25.33**	-10.00	82.14**
47	SA - 2 × PS	-4.05	-6.37	-15.87*	-15.87*	1.47	41.10**	2.44	-24.51**	-4.94	83.33**
48	SA - 2 × PK	-10.34	-12.74*	-19.05**	-19.05**	-51.47**	-32.52**	-8.60	-39.22**	15.29*	133.33**
49	IC - 140934 × AA	-8.01	-7.38	-9.38	-7.94	-57.50**	-30.47**	8.40	-32.52**	-10.31	107.14**
50	IC - 140934 × PS	-14.59*	-16.66**	-5.17	-12.70*	-58.82**	-57.06**	-15.96*	-38.07**	-0.62	91.67**
51	IC - 140934 × PK	-11.85*	-14.21*	-1.72	-9.52	-41.82**	-34.56**	5.74	-36.76**	-23.94**	92.86**

Table 4.3b: Continued….

S.N.	Crosses	Days to first flowering		Days to 50% flowering		Number of fruits/plant		Single fruit weight (g)		Fruit length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
1	IC - 128883 × AA	-4.10	2.63	-7.84**	-2.08**	-10.00	-20.16**	2.13	-19.76**	-6.67*	-7.28**
2	IC - 128883 × PS	7.69**	10.53**	5.56**	5.56**	-8.53	-34.15**	-16.61**	-19.42**	1.59	0.91
3	IC - 128883 × PK	4.88*	13.16**	8.33**	8.33**	1.96	-29.03**	-34.57**	-23.44**	-10.43**	-7.92**
4	VRO - 5 × AA	3.28	10.53**	4.08	6.25**	-4.23	-15.05**	21.99**	18.69**	6.94*	6.91*
5	VRO - 5 × PS	12.82**	15.79**	11.81**	11.81**	-10.59	-22.21**	-0.34	-3.04	-12.30**	-12.33**
6	VRO - 5 × PK	2.44	10.53**	12.50**	12.50**	3.14	-10.27*	-17.43**	-3.38	-5.21*	-2.55
7	VRO - 6 × AA	-2.63	-2.63	0.00	0.00	-13.99**	-14.02**	17.73**	17.69**	2.21	2.18
8	VRO - 6 × PS	15.79**	15.79**	7.64**	7.64**	-0.34	-0.38	-1.34	-1.37	-3.15	-3.19
9	VRO - 6 × PK	13.16**	13.16**	4.17	4.17**	-31.06**	-31.08**	-18.57**	-4.71	-16.56**	-14.22**
10	AC - 108 × AA	10.26**	13.16**	7.43**	10.42**	11.92*	-0.72	27.23**	-0.03	-2.34	-7.92**
11	AC - 108 × PS	17.95**	21.05**	4.17	4.17**	0.95	-27.33**	9.34*	5.65	6.02*	-0.03
12	AC - 108 × PK	17.95**	21.05**	10.42**	10.42**	-6.37	-34.83**	-15.71**	-1.37	-5.21*	-2.55
13	IC - 45806 × AA	20.51**	23.68**	4.08	6.25**	-10.77*	-20.85**	30.21**	2.31	-0.67	-6.65*
14	IC - 45806 × PS	8.55**	11.40**	8.33**	8.33**	7.11	-22.89**	-7.27	-10.40*	4.26	-7.28**
15	IC - 45806 × PK	17.95**	21.05**	8.33**	8.33**	20.10**	-16.41**	-26.57**	-14.08**	0.00	2.81
16	IC - 218877 × AA	12.50**	18.42**	3.38	6.25**	-20.77**	-29.72**	3.19	-13.41**	-3.36	-9.18**
17	IC - 218877 × PS	17.95**	21.05**	10.42**	10.42**	3.57	-20.85**	-17.65**	-20.43**	2.47	-8.55**
18	IC - 218877 × PK	0.00	5.26	5.56**	5.56**	9.82	-16.07**	-32.57**	-21.10**	-16.87**	-14.54**
19	IC - 218844 × AA	15.38**	18.42**	4.08	6.25**	-3.46	-14.36**	-10.37*	-19.09**	12.08**	5.33*
20	IC - 218844 × PS	15.38**	18.42**	12.50**	12.50**	3.79	-25.28**	-11.42*	-14.41**	-4.04	-10.12**
21	IC - 218844 × PK	12.82**	15.79**	10.42**	10.42**	-0.97	-30.40**	2.00	19.36**	-2.76	-0.03
22	Arka Abhay × AA	13.79**	15.79**	6.94**	6.94**	14.23**	1.33	28.40**	10.33**	-2.68	-8.55**
23	Arka Abhay × PS	16.38**	18.42**	8.33**	8.33**	-4.58	-21.87**	-9.00*	-12.07**	-4.04	-10.12**
24	Arka Abhay × PK	10.34**	12.28**	2.08	2.08**	-15.42**	-30.74**	-12.86**	1.97	-5.21*	-2.55
25	IC - 43720 × AA	9.40**	12.28**	-3.38	-0.69**	-10.38	-20.50**	12.34*	-11.74**	-5.68*	-5.71*

Table 4.3b: Continued….

S.N.	Crosses	Days to first flowering		Days to 50% flowering		Number of fruits/plant		Single fruit weight (g)		Fruit length (cm)	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
26	IC - 43720 × PS	15.38**	18.42**	4.17	4.17**	31.75**	-5.15	-2.77	-6.05	-6.94*	-6.97*
27	IC - 43720 × PK	2.56	5.26	6.25**	6.25**	-8.33	-36.20**	-27.71**	-15.41**	-17.79**	-15.48**
28	342 × AA	14.53**	17.54**	10.64**	8.33**	-11.76*	-18.12**	12.77*	-11.40**	-5.37	-11.07**
29	342 × PS	7.69**	10.53**	4.26	2.08**	-9.56	-16.07**	6.23	2.64	-2.39	-9.81**
30	342 × PK	4.27	7.02**	-2.13	-4.17**	-14.71**	-20.85**	-26.57**	-14.08**	-6.75*	-4.13
31	IC - 140906 × AA	10.53**	10.53**	-2.78	-2.78**	-0.38	-11.63*	18.30**	-7.05	-10.26**	-11.70**
32	IC - 140906 × PS	15.79**	15.79**	4.17	4.17**	10.43	-20.50**	-7.96	-11.07*	-0.64	-2.24
33	IC - 140906 × PK	21.05**	21.05**	3.47	3.47**	49.51**	4.06	-23.14**	-10.06*	-12.27**	-9.81**
34	198 × AA	19.30**	19.30**	2.00	6.25**	-2.69	-13.68**	-4.03	-12.40**	-12.71**	-17.69**
35	198 × PS	15.79**	15.79**	5.56**	5.56**	22.27**	-11.98**	-11.42*	-14.41**	-16.39**	-21.16**
36	198 × PK	5.26*	5.26	0.00	0.00	61.27**	12.25**	-22.00**	-8.73*	-9.51**	-6.97*
37	EC - 305612 × AA	17.95**	21.05**	11.11**	4.17**	27.07**	15.32**	17.87**	-7.39	-9.73**	-15.17**
38	EC - 305612 × PS	10.26**	13.16**	6.67**	0.00	4.89	-4.81	-2.77	-6.05	11.64**	-3.19
39	EC - 305612 × PK	6.84**	9.65**	8.89**	2.08**	-17.29**	-24.94**	-24.57**	-11.74**	-12.58**	-10.12**
40	435 × AA	3.51	3.51	-2.10	-2.78**	-17.69**	-26.99**	22.13**	-4.05	5.35	-0.66
41	435 × PS	11.40**	11.40**	6.99**	6.25**	-17.51**	-27.67**	0.00	-3.38	-4.68	-10.12**
42	435 × PK	5.26*	5.26*	-4.20	-4.86**	9.73	-3.79	-14.57**	-0.03	-7.98**	-5.39*
43	401 × AA	-0.85	1.75	-7.84**	-2.08**	-6.54	-17.09**	36.17**	6.99	-4.03	-9.81**
44	401 × PS	7.69**	10.53**	4.17	4.17**	-17.45**	-33.81**	19.38**	15.35**	-10.03**	-18.01**
45	401 × PK	-10.26**	-7.89**	-4.17	-4.17**	9.79	-11.98*	-18.00**	-4.05	-6.13*	-3.50
46	SA - 2 × AA	-5.00*	0.00	-0.70	-1.39**	-13.46*	-23.23**	13.73**	-3.04	-3.18	-4.13
47	SA - 2 × PS	-5.13*	-2.63	-0.70	-1.39**	9.65	-14.70**	-11.07*	-14.08**	3.18	2.18
48	SA - 2 × PK	-5.00*	0.00	-5.59**	-6.25**	-28.51**	-44.39**	-28.00**	-15.75**	-13.80**	-11.38**
49	IC - 140934 × AA	4.27	7.02**	3.40	5.56**	-3.85	-14.70**	7.35	-12.07**	4.03	-2.24
50	IC - 140934 × PS	-2.56	0.00	4.17	4.17**	-0.95	-28.69**	9.00	5.32	23.26**	11.95**
51	IC - 140934 × PK	0.00	2.63	0.69	0.69**	11.76	-22.21**	-16.57**	-2.37	-3.68	-0.98

Table 4.3b: Continued….

S.N.	Crosses	Fruit diameter (cm)		Fruit yield/plant (g)		Number of seeds/fruit		Number of ridges/fruit		Ascorbic acid	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
1	IC - 128883 × AA	-6.25	7.14	-11.39	-35.98**	30.66**	5.88	0.00	0.00	-11.96*	-14.08**
2	IC - 128883 × PS	6.25	21.43**	-23.71**	-46.84**	21.71**	-1.38	0.00	0.00	-9.78	-11.96*
3	IC - 128883 × PK	-6.25	7.14	-34.47**	-46.50**	29.83**	-0.33	0.00	0.00	-1.36	-3.74
4	VRO - 5 × AA	6.67	14.29*	18.91**	0.93	34.42**	1.66	0.00	0.00	2.13	1.83
5	VRO - 5 × PS	-12.50*	0.00	-11.17	-24.60**	26.21**	-4.55	0.00	0.00	-7.98	-8.25
6	VRO - 5 × PK	6.67	14.29*	2.31	-13.15*	21.00**	-8.49	0.00	0.00	-4.79	-5.06
7	VRO - 6 × AA	13.33*	21.43**	1.31	1.31	-13.94**	-13.94**	0.00	0.00	-3.98	-4.00
8	VRO - 6 × PS	-6.25	7.14	-1.50	-1.50	-15.79**	-15.79**	0.00	0.00	-1.06	-1.09
9	VRO - 6 × PK	-6.67	0.00	-35.43**	-35.43**	9.20	-16.17**	0.00	0.00	-7.16	-7.19
10	AC - 108 × AA	-12.50*	0.00	37.76**	-0.47	16.98*	-23.57**	0.00	0.00	-13.09*	-31.32**
11	AC - 108 × PS	6.25	21.43**	10.43	-23.06**	8.78	-28.92**	0.00	0.00	-10.46	-27.34**
12	AC - 108 × PK	-6.25	7.14	-21.12**	-35.60**	13.93	-25.56**	0.00	0.00	-14.45**	-19.92**
13	IC - 45806 × AA	-6.25	7.14	12.38	-18.81**	53.25**	-3.94	0.00	0.00	-2.52	-17.79**
14	IC - 45806 × PS	0.00	14.29*	-3.79	-32.96**	1.13	-36.61**	0.00	0.00	-6.92	-21.51**
15	IC - 45806 × PK	-18.75*	-7.14	-12.26	-28.37**	62.18**	1.66	0.00	0.00	-6.52	-12.49*
16	IC - 218877 × AA	0.00	14.29*	-15.58*	-39.01**	8.79	-13.70**	0.00	0.00	-4.36	-24.42**
17	IC - 218877 × PS	0.00	14.29*	-9.16	-36.71**	20.32**	-4.55	0.00	0.00	-5.56	-23.36**
18	IC - 218877 × PK	-12.50*	0.00	-18.89**	-33.79**	32.12**	1.42	0.00	0.00	-16.15**	-21.51**
19	IC - 218844 × AA	20.00**	28.57**	-3.78	-30.48**	31.94**	-18.92**	0.00	0.00	-4.03	-24.16**
20	IC - 218844 × PS	-6.25	7.14	-8.26	-36.08**	13.19	-30.44**	0.00	0.00	-1.63	-20.18**
21	IC - 218844 × PK	13.33*	21.43**	2.12	-16.64**	58.41**	-2.66	0.00	0.00	-10.48	-16.20**
22	Arka Abhay × AA	0.00	7.14	55.00**	11.98*	55.19**	-2.80	0.00	0.00	21.15**	0.24
23	Arka Abhay × PS	0.00	14.29*	-2.39	-31.19**	13.78	-28.73**	0.00	0.00	-0.32	-17.53**
24	Arka Abhay × PK	0.00	7.14	-13.19*	-29.13**	35.20**	-15.32**	0.00	0.00	-5.95	-11.96*
25	IC - 43720 × AA	-5.88	14.29*	-2.60	-29.63**	12.64*	-12.09**	13.33**	13.33**	-15.10*	-32.91**

Table 4.3b: Continued….

S.N.	Crosses	Fruit diameter (cm)		Fruit yield/plant (g)		Number of seeds/fruit		Number of ridges/fruit		Ascorbic acid	
		Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent	Better Parent	Standard Parent
26	IC - 43720 × PS	-17.65**	0.00	28.18**	-10.69*	-1.09	-22.81**	14.00**	14.00**	-13.40*	-29.73**
27	IC - 43720 × PK	-5.88	14.29*	-33.57**	-45.77**	-3.52	-25.94**	18.67**	18.67**	-17.56**	-22.83**
28	IIVR-342 × AA	4.44	11.90*	0.14	-27.34**	7.04	-8.44	0.00	0.00	-20.47**	-37.15**
29	IIVR-342 × PS	-6.25	7.14	19.15*	-13.55*	11.64*	-4.50	0.00	0.00	-27.45**	-41.13**
30	IIVR-342 × PK	-6.67	0.00	-16.73*	-32.02**	28.41**	-1.42	0.00	0.00	-17.85**	-23.10**
31	IC - 140906 × AA	-11.76*	7.14	13.88	-17.73**	4.99	-16.12**	0.00	0.00	-5.69	-25.22**
32	IC - 140906 × PS	-5.88	14.29*	1.70	-29.14**	-10.80	-28.73**	0.00	0.00	-4.90	-22.83**
33	IC - 140906 × PK	-9.80*	9.52	14.87*	-6.22	22.11**	-6.26	0.00	0.00	-18.13**	-23.36**
34	IIVR-198 × AA	6.25	21.43**	4.69	-24.37**	-5.51	-8.96	0.00	0.00	-9.12	-15.41**
35	IIVR-198 × PS	-6.25	7.14	8.21	-24.60**	-1.13	-4.74	0.00	0.00	-10.54	-16.73**
36	IIVR-198 × PK	6.25	21.43**	25.74**	2.65	7.60	-17.40**	0.00	0.00	-10.48	-16.20**
37	EC - 305612 × AA	6.67	14.29	48.20**	7.07	-13.44*	-19.96**	0.00	0.00	18.12**	-6.66
38	EC - 305612 × PS	-6.25	7.14*	28.74**	-10.30	-2.87	-10.19*	0.00	0.00	-1.31	-19.92**
39	EC - 305612 × PK	6.67	14.29*	-18.74**	-33.66**	16.00*	-10.95*	0.00	0.00	-17.56**	-22.83**
40	IIVR-435 × AA	6.25	21.43**	-3.20	-30.07**	-12.81*	-16.12**	0.00	0.00	-15.44*	-33.17**
41	IIVR-435 × PS	-6.25	7.14	0.20	-30.19**	-20.06**	-23.09**	0.00	0.00	-30.39**	-43.52**
42	IIVR-435 × PK	0.00	14.29*	17.72**	-3.89	-1.79	-24.61**	0.00	0.00	-26.91**	-31.58**
43	IIVR-401 × AA	6.67	14.29*	23.13**	-11.05*	-1.24	-20.86**	0.00	0.00	4.52	-14.08**
44	IIVR-401 × PS	6.25	21.43**	9.49	-23.71**	-16.75**	-33.29**	0.00	0.00	2.90	-15.41**
45	IIVR-401 × PK	0.00	7.14	3.75	-15.30**	10.44	-15.22**	0.00	0.00	-3.68	-9.84
46	SA - 2 × AA	-6.25	7.14	3.02	-25.57**	-10.59*	-13.94**	0.00	0.00	0.66	-19.38**
47	SA - 2 × PS	6.25	21.43**	5.63	-26.40**	-30.94**	-33.52**	0.00	0.00	4.58	-15.14**
48	SA - 2 × PK	0.00	14.29*	-42.78**	-53.29**	2.59	-21.24**	0.00	0.00	-4.82	-10.90*
49	IC - 140934 × AA	0.00	14.29*	4.04	-24.84**	20.94**	2.70	0.00	0.00	-17.11**	-34.50**
50	IC - 140934 × PS	0.00	14.29*	7.81	-24.89**	-0.28	-15.32**	0.00	0.00	0.65	-18.32**
51	IC - 140934 × PK	0.00	14.29*	-6.78	-23.90**	30.76**	0.38	0.00	0.00	-6.23	-12.22*

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

In Summer season crop, only 5 hybrids show positive significant heterosis over better parent and none over standard variety. The better parent heterosis ranged from -24.59 (Arka Abhay × Prabhani Kranti) to 28.26 per cent (IC-140906 × Pusa Sawani). The highest negative heterosis over standard variety was -30.16 per cent (IIVR-198 × Pusa Sawani). However, negative heterosis was observed in 19 hybrids for both (better parent and standard variety) of the heterosis.

4.3.3 Number of branches per plant

In Rainy season crop, 7 crosses exhibit significant positive heterosis over standard parent while 47 showed negative significant heterosis over better parent. The highest negative significant better parent heterosis found in IIVR-198 × Pusa Sawani (-58.47 %). However, 7 hybrids showed positive and 7 were negative significant standard parent heterosis. In which IIVR-435 × Pusa Sawani (57.90 %) exhibit maximum positive, while IC-218844 × Pusa Sawani (-39.63 %) and Arka Abhay × Pusa Sawani (-39.63 %) showed maximum negative standard parent heterosis.

In Summer season crop, out of 51 crosses 5 were expressed positive significant standard parent heterosis. Whereas 37 and 20 crosses exhibited negative significant better and standard parent heterosis, respectively. In all the hybrids IIVR-401 × Arka Anamika (-73.75 %) had maximum negative significant better parent heterosis, while SA-2 × Pusa Sawani (41.10 %) and IC-43720 × Prabhani Kranti (-63.19 %) exhibited maximum positive and negative significant standard parent heterosis, respectively.

4.3.4 Number of nodes per plant

In Rainy season crop, heterosis over better parent and standard variety with their mean and range is presented in Table 4.3a. Out of 51 F_1's, 9 and 2 crosses displayed positive heterosis with significant values over better parent and standard variety, respectively. Among the F_1's, negative significant heterosis was observed in 22 crosses over better parent and 42 crosses over standard variety. The extent of heterosis over better parent ranged from -42.14 (Arka Abhay × Prabhani Kranti) to 121.33 per cent (IIVR-198 × Prabhani Kranti) and standard parent heterosis varied from -48.78 per cent (Arka Abhay × Prabhani Kranti) to 33.90 per cent (IIVR-198 × Prabhani Kranti).

In Summer season crop, better parent heterosis ranged from -46.71 per cent (IIVR-435 × Pusa Sawani) to 86.45 per cent (IIVR-401 × Prabhani Kranti) and standard parent heterosis was maximum negative significant in IIVR- 198 × Pusa Sawani (-53.43 %)**.** Among all hybrids 8 crosses displayed positive significant better parent heterosis. Whereas 30 and 46 crosses expressed negative significant better and standard parent heterosis, respectively.

4.3.5 Internodal length

In Rainy season crop, better parent heterosis for internodal length varied from -44.93 (IIVR-198 × Prabhani Kranti) to 53.50 per cent (IIVR-435 × Pusa Sawani) and standard parent heterosis ranged from -32.98 (VRO-5 × Arka Anamika) to 49.76 per cent (IIVR-342 × Arka Anamika). The desirable negative significant heterosis were found in 5 and 2 crosses over better parent and standard variety, respectively. While undesirable positive significant heterosis were observed in 13 and 19 hybrids over better and standard parent, respectively.

In Summer season crop, useful negative heterosis was maximum expressed in IIVR- 401 × Pusa Sawani (- 42.67 %) whereas highest positive heterosis over better parent was expressed in VRO-5 × Prabhani Kranti (155.00 %). However, 20 and 10 crosses were showed positive and negative significant better parent heterosis, respectively. However, 50 crosses were expressed positive significant standard parent heterosis.

4.3.6 Days to first flowering

In Rainy season crop, negative significant heterosis is useful for this trait the magnitude of standard parent heterosis (SPH) ranged from -12.82 (IC-43720 × Arka Anamika) to 27.50 per cent (IC-140934 × Arka Anamika). Out of 51 F_1's, 2 crosses showed significant positive heterosis over better and standard parent, respectively. The value of standard parent ranged from -16.40 (IC-43720 × Arka Anamika) to 25.40 per cent (IC-140934 × Arka Anamika). However, 30 and 29 crosses exhibited positive significant better and standard parent heterosis.

In Summer season crop, among 51 F_1's only 4 and 1 hybrids exhibited valuable negative significant better and standard parent heterosis, respectively in which maximum was found in IIVR-401 × Prabhani Kranti (BPH = -10.26 % & SPH = -7.89 %). The positive significant better and standard parent heterosis were expressed in 35 and 38 crosses, respectively. However, the maximum positive significant heterosis was observed in IC-140934 × Prabhani Kranti (21.05 %) and IC-45806 × Arka Anamika (23.68 %) for better and standard parent, respectively.

4.3.7 Days to 50 per cent flowering

In Rainy season crop, for days to 50 per cent flowering, negative heterosis is usually desirable, because this will cause the hybrid to mature earlier as compared to the parents, there by increasing their productivity per day per unit area. For days taken to 50 per cent flowering, better parent heterosis ranged form -10.00 (IC-43720 × Arka Anamika) to 24.00 per cent (IC-140934 × Arka Anamika) and heterosis over stanrdard variety ranged from -6.25 (IC-43720 × Arka Anamika) to 29.17 per cent (IC-140934 × Arka Anamika). Out of 51 hybrids, negative significant heterosis was observed in 3 and 1 crosses over better and standard parent, respectively.

In Summer season crop, only 3 and 11 hybrids were found to exhibited negative significant heterosis over better parent and standard variety, respectively. The rang of heterosis varied from -7.84 (IC-128883 × Arka Anamika) to 12.50 per cent (VRO-5 × Prabhani Kranti and IC-218844 × Pusa Sawani) over better parent and -6.25 (SA-2 × Prabhani Kranti) to 12.50 per cent (VRO-5 × Prabhani Kranti and IC-218844 × Pusa Sawani) over standard parent. However, positive significant heterosis was found in 22 and 37 hybrids for better and standard parent, respectively.

4.3.8 Number of fruits per plant

In Rainy season crop, the hybrid EC-305612 × Pusa Sawani (26.10%) showed maximum significant positive heterosis over better parent while IC-218844 × Arka Anamika showed maximum negative significant better parent (-38.86%) and standard parent (-44.85%) heterosis. However, the 3 hybrids showed positive significant heterosis over better parent.

In Summer season crop, among 51 hybrids only 8 and 2 were expressed positive significant better and standard parent heterosis, respectively. The range of better parent heterosis were -28.51 (SA-2 × Prabhani Kranti) to 61.87 per cent (IIVR-198 × Prabhani Kranti) and standard parent heterosis ranged from -44.39 (SA-2 × Prabhani Kranti) to 15.32 per cent (EC-305612 × Arka Anamika). Out of 51 crosses, 13 and 42 F_1's expressed negative significant better and standard parent heterosis, respectively.

4.3.9 Single fruit weight

In Rainy season crop, the extent of heterosis over better parent ranged from -13.77 (IC-218844 × Pusa Sawani) to 34.36 per cent (IC-218844 × Arka Anamika) and over standard variety ranged from -24.87 (IIVR-342 × Prabhani Kranti) to 18.90 per cent (VRO-5 × Pusa Sawani). Among the 51 hybrids, only 12 and 3 hybrids showed significant positive heterosis over better parent and over standard variety, respectively. Significant negative heterosis was observed in 10 hybrids over better parent and 35 hybrids over standard variety.

In Summer season crop, out of 51 crosses only 14 and 5 hybrids expressed positive significant heterosis over better parent and standard variety, respectively. However, negative significant heterosis was observed in 22 and 24 crosses over better and standard parent, respectively. The maximum positive significant heterosis was 36.17 per cent (IIVR-401 × Arka Anamika) over better parent and 19.36 per cent (IC-218844 × Prabhani Kranti) over standard parent. While maximum negative significant heterosis were observed in IC-128883 × Prabhani Kranti over better parent (-34.57 %) and standard parent (-23.44 %) heterosis, respectively.

4.3.10 Fruit length

In Rainy season crop, the extent of heterosis over better parent ranged form -15.58 per cent (IIVR-198 × Pusa Sawani) to 26.26 per cent (IC-218844 × Arka Anamika) and over standard variety ranged from -15.58 per cent (IIVR-198 × Pusa Sawani) to 18.38 per cent (VRO-5 × Arka Anamika). Out of 51 F_1's, 23 and 4 crosses showed significant positive heterosis over better parent and over standard variety, respectively. However, 17 and 37 crosses showed significant negative heterosis over better parent and standard variety, respectively.

In Summer season crop, the highest positive and negative significant heterosis were observed in the hybrids IC-140934 × Pusa Sawani (23.26%) and IC-43720 × Prabhani Kranti (-17.79%), respectively. However, standard parent heterosis were ranged from -21.16 per cent (IIVR-198 × Pusa Sawani) to 11.95 per cent (IC-140934 × Pusa Sawani). Among all hybrids 4 and 2 crosses were expressed positive significant heterosis over better and standard parent, respectively. Whereas 23 and 30 crosses was displayed negative significant heterosis over better and standard parent, respectively.

4.3.11 Fruit diameter

In Rainy season crop, the extent of heterosis ranged from -18.75 per cent (IIVR-342 × Prabhani Kranti) to 20.00 per cent (IC-218844 × Arka Anamika) over better parent and -13.33 per cent (IIVR-342 × Prabhani Kranti) to 20.00 per cent (AC-108 × Pusa Sawani and IC-218844 × Arka Anamika) over standard variety. Out of 51 F_1's, 1 and 9 hybrids showed positive significant heterosis over better parent and standard variety, respectively. However, 8 and 1 were displayed negative significant heterosis over better and standard parent, respectively.

In Summer season crop, in case of fruit diameter positive significant heterosis were showed in 3 and 28 hybrids over better and standard parent, respectively. However, negative significant heterosis were observed in 7 crosses over better parent. The value of better parent heterosis ranged from -18.75 (IC-45806 × Prabhani Kranti) to 20.00 per cent (IC-218844 × Arka Anamika). While, maximum positive significant standard variety heterosis was found in IC-218844 × Arka Anamika (28.57%).

4.3.12 Fruit yield per plant

In Rainy season crop, among 51 hybrids, 5 hybrids scored significant positive heterosis over better parents in desirable direction and none of them exhibited positive significant heterosis when tested against check variety (standard variety) VRO-6. However, 15 and 47 hybrids expressed heterosis in negative direction over better parent and standard variety, respectively. The extent of heterosis over better parent ranged from -39.79 per cent (IC-218877 × Prabhani Kranti) to 37.80 per cent (VRO-5 × Pusa Sawani) and in case of standard parent heterosis highest negative significant heterosis was found in IC-218844 × Pusa Sawani (-55.77%).

In Summer season crop, heterosis ranged from -42.78 (SA-2 × Prabhani Kranti) to 55.00 per cent (Arka Abhay × Arka Anamika) and -5.29 (SA-2 × Prabhani Kranti) to 11.98 per cent (Arka Abhay × Arka Anamika) over better and standard parent, respectively. Among all the crosses 11 and 1 cross combinations showed positive while 11 and 41 crosses exhibited negative significant heterosis over better parent and standard variety, respectively.

4.3.13 Number of seeds per fruit

In Rainy season crop, out of 51 crosses, 9 and 39 hybrids displayed negative (desirable) heterosis over better and standard parent, respectively. However, 17 crosses expressed positive significant heterosis over better parent. The better parent heterosis ranged from -38.97 (SA-2 × Arka Anamika) to 60.20 per cent (Arka Abhay × Arka Anamika) while maximum negative (desirable) heterosis over standard parent was expressed in SA-2 × Arka Anamika (-46.33%).

In Summer season crop, 8 and 31 hybrids showed useful negative significant heterosis over better parent and standard variety, respectively. The positive significant heterosis was found in 23 hybrids over better parent. The range of better parent heterosis were observed from -30.94 (SA-2 × Pusa Sawani) to 62.18 per cent (IC-45806 × Prabhani Kranti). While maximum valuable negative significant heterosis over standard parent was found in IC-45806 × Pusa Sawani (-36.61%).

4.3.14 Number of ridges per fruit

In Rainy season crop, the hybrid with negative heterosis is more desirable for this trait. Among 51 hybrids, only 3 were expressed positive significant heterosis over both better and standard parent. The hybrid IC-43720 × Prabhani Kranti (20.00%) showed maximum positive significant heterosis over both better and standard parent.

In Summer season crop, same results as Rainy season crop were found. The hybrid IC-43720 × Prabhani Kranti (18.67%) expressed maximum positive significant heterosis over both better and standard parent. None of the hybrid was displayed useful negative significant heterosis over better and standard parent in both seasons.

4.3.15 Ascorbic acid content

In Rainy season crop, the extent of heterosis over better parent ranged from -38.50 (IC-128883 × Pusa Sawani) to 20.97 per cent (EC-305612 × Pusa Sawani). However, maximum negative heterosis over standard parent was -42.66 per cent (IIVR-435 × Pusa Sawani). Out of 51 F_1's, only 1 hybrid showed significant positive heterosis over better parent and none were observed for standard parent. Significant negative heterosis was observed in 19 hybrids over better parent and 43 hybrids over standard variety.

In Summer season crop, only 2 hybrids showed positive significant heterosis over better parent. However, 16 and 41 hybrids were expressed negative significant heterosis over better parent and standard variety, respectively. The better parent heterosis ranged from -30.39 (IIVR-435 × Pusa Sawani) to 21.15 per cent (Arka Abhay × Arka Anamika). The highest negative significant standard parent heterosis was found in IIVR-435 × Pusa Sawani (-43.52%).

4.4 Variability, heritability and genetic advance

The estimate of mean, range, phenotypic and genotypic coefficients of variation (PCV and GCV, respectively), heritability, genetic advance and genetic gain for 15 characters in parents and F_1's are presented in Table 4.4.1a (Rainy season parents), Table 4.4.1b (Rainy season F_1's) and Table 4.4.2a (Summer season parents), Table 4.4.2.b (Summer season F_1's), respectively. For regarding expression of the heritability are three categories viz., low (below 10%), moderate (above 10 and below 30%) and high (above 30%). The character wise description is presented below:

4.4.1 Plant height

In Rainy season crop, the maximum plant height for parents was found in IIVR-401 (122.93 cm) and minimum in VRO-5 (85.03 cm). The phenotypic (PCV) and genotypic coefficients of variability (GCV) were 8.90 and 7.14 per cent, respectively. The heritability value was high (64.4%) in parents with moderate genetic advance (13.00%). However, the hybrids (F_1's) ranged from 81.10 cm (VRO-5 × Arka Anamika) to 133.87 cm (IIVR-198 × Arka Anamika) while PCV and GCV were 12.39 per cent and 11.12 per cent, respectively. In hybrids the heritability (80.50%) was higher as compared to parents with moderate (22.41%) genetic advance. The genetic gains were 11.81 and 20.54 per cent in parents and F_1's, respectively.

In Summer season crop, the plant height ranged from 69.83 cm (VRO-5) to 108.77 cm (IIVR-435) for parents while 68.37 cm (VRO-5 × Arka Anamika) to 114.10 cm (IIVR-198 × Arka Anamika) for hybrids. Whereas the GCV and PCV was 9.82 and 13.27 per cent for parents, while 8.44 and 10.77 in F_1's respectively. However, genetic advance (14.32 %) and genetic gain (14.98 %) with a general mean value of 95.57 cm in parents. In hybrids the genetic advance was 12.65 per cent and genetic gain 13.64 per cent with a general mean value of 92.47 cm were observed.

Table 4.4.1a: Estimation of various variability parameters of parents in okra in Rainy season.

S. No.	Characters	Range		Mean	S.E.	GCV	PCV	Heritability	Genetic advance	Genetic gain
		Min.	Max.							
1.	Plant height (cm)	85.03	122.93	110.08	4.775	7.14	8.90	64.4	13.00	11.81
2.	Stem diameter (cm)	1.40	2.50	1.99	0.169	11.42	15.47	54.5	0.35	17.59
3.	Number of branches/plant	1.70	5.20	2.97	0.246	26.72	28.57	87.4	1.53	51.52
4.	Number of nodes/plant	8.90	16.53	11.90	0.899	15.94	18.43	74.8	3.38	28.40
5.	Inter nodal length (cm)	6.28	11.92	8.76	0.947	15.30	20.24	57.2	2.09	23.86
6.	Days to first flowering	37.00	47.00	41.07	0.882	5.66	6.24	82.3	4.34	10.57
7.	Days to 50 % flowering	46.00	54.00	49.72	1.158	4.27	5.14	69.2	3.64	7.32
8.	Number of fruits/plant	8.60	14.93	11.55	0.969	12.34	16.07	59.0	2.26	19.57
9.	Single fruit weight (g)	7.67	11.40	9.28	0.469	9.93	11.70	72.0	1.61	17.35
10.	Fruit length (cm)	8.33	11.07	9.85	0.152	8.02	8.24	94.7	1.58	16.04
11.	Fruit diameter (cm)	1.30	1.70	1.56	0.078	5.29	8.08	42.8	0.11	7.05
12.	Fruit yield/plant (g)	66.03	168.90	109.54	10.467	17.97	21.45	70.2	33.99	31.03
13.	Number of seeds/fruit	39.00	70.77	56.55	4.143	15.03	17.51	73.7	15.04	26.60
14.	Number of ridges/fruit	5.00	5.92	5.05	0.014	4.06	4.07	99.3	0.42	8.32
15.	Ascorbic acid (mg/100g)	6.80	12.87	10.05	0.352	17.31	17.83	94.2	3.48	34.63

Table 4.4.1b: Estimation of various variability parameters of F_1's in okra in Rainy season.

S. No.	Characters	Range		Mean	S.E.	GCV	PCV	Heritability	Genetic advance	Genetic gain
		Min.	Max.							
1.	Plant height (cm)	81.10	133.87	109.11	4.876	11.12	12.39	80.5	22.41	20.54
2.	Stem diameter (cm)	1.43	2.47	1.96	0.157	11.52	15.08	58.3	0.36	18.37
3.	Number of branches/plant	1.40	4.03	2.41	0.286	22.08	26.42	69.8	0.92	38.17
4.	Number of nodes/plant	8.47	22.13	12.12	0.907	22.72	24.50	86.0	5.26	43.40
5.	Inter nodal length (cm)	5.13	11.46	8.57	0.868	16.07	20.30	62.7	2.25	26.25
6.	Days to first flowering	34.00	51.00	42.58	0.874	5.50	6.05	82.7	4.39	10.31
7.	Days to 50 % flowering	45.00	62.00	51.80	1.010	5.13	5.66	82.2	4.96	9.58
8.	Number of fruits/plant	8.23	14.33	11.64	0.823	10.95	13.96	61.5	2.06	17.70
9.	Single fruit weight (g)	8.47	13.40	9.89	0.519	10.50	12.31	72.7	1.83	18.50
10.	Fruit length (cm)	9.03	12.50	10.32	0.134	6.52	6.71	94.3	1.35	13.08
11.	Fruit diameter (cm)	1.30	1.80	1.57	0.082	4.64	7.91	34.4	0.09	5.73
12.	Fruit yield/plant (g)	74.70	183.00	115.36	9.797	17.02	19.94	72.8	34.50	29.91
13.	Number of seeds/fruit	37.53	74.13	56.55	3.435	12.67	14.69	74.4	12.73	22.51
14.	Number of ridges/fruit	5.00	6.00	5.04	0.031	3.65	3.73	95.8	0.37	7.34
15.	Ascorbic acid (mg/100g)	7.30	13.67	10.29	0.684	12.95	15.30	71.6	2.32	22.55

4.4.2 Stem diameter

In Rainy season crop, the range varied form 1.40 cm (Prabhani Kranti) to 2.50 cm (EC-305612) and 1.43 cm (IC-140934 × Pusa Sawani) to 2.50 cm (Arka Abhay × Arka Anamika) in parents and hybrids, respectively. The GCV and PCV varied from 11.42 to 15.47 and 11.52 to 15.08 in parents and hybrids, respectively. The genetic advance in hybrids was 0.36 per cent and genetic gain 18.37 per cent i.e. low with high heritability 58.3 per cent. Genetic advance of parents was 0.35 per cent, genetic gain 17.59 per cent i.e. low with high heritability 54.5 per cent.

In Summer season crop, the variability of parents and hybrids ranged from 1.43 cm (IC-140906) to 2.40 cm (EC-305612) and 1.47 cm (IIVR-198 × Pusa Sawani) to 2.27 cm (IIVR-198 × Prabhani Kranti and IIVR-401 × Prabhani Kranti), respectively. The GCV and PCV of parents were 11.39 and 14.65, respectively and in hybrids GCV was 7.92 and PCV was 11.36. The genetic advance and genetic gain was lower in parents (0.35% and 18.23%, respectively) and hybrids (0.21% and 11.23%, respectively) with high heritability value of 60.4 per cent and 48.6 per cent in parents and hybrids, respectively.

4.4.3 Number of branches per plant

In Rainy season crop, the variability of parents were 26.72 (GCV) and 28.57 (PCV) with high heritability of 87.4 per cent and low genetic advance (1.53%) and genetic gain (51.52%). The range of parents for this trait is varied from 1.70 (IIVR-401) to 5.20 (IIVR-435) with a general mean value of 2.97. However, in hybrids the variability ranged from 1.40 (IC-218844 × Prabhani Kranti) to 4.03 (IIVR-435 × Pusa Sawani) and the coefficient of variation were 22.08 (GCV) and 26.42 (PCV) with high heritability 69.8% and low genetic advance (0.92%) and genetic gain (38.17%).

Table 4.4.2a: Estimation of various variability parameters of parents in okra in Summer season.

S. No.	Characters	Range		Mean	S.E.	GCV	PCV	Heritability	Genetic advance	Genetic gain
		Min.	Max.							
1.	Plant height (cm)	69.83	108.77	95.57	6.959	9.82	13.27	54.8	14.32	14.98
2.	Stem diameter (cm)	1.43	2.40	1.92	0.144	11.39	14.65	60.4	0.35	18.23
3.	Number of branches/plant	0.67	3.93	1.78	0.163	38.03	39.64	92.0	1.34	75.28
4.	Number of nodes/plant	10.07	20.77	13.46	1.078	22.85	24.87	84.4	5.82	43.24
5.	Inter nodal length (cm)	2.67	7.80	5.87	0.576	25.49	28.18	81.8	2.79	47.53
6.	Days to first flowering	38.00	45.00	39.47	0.876	3.73	4.62	65.4	2.45	6.21
7.	Days to 50 % flowering	45.00	51.00	48.72	0.943	2.66	3.56	55.7	1.99	4.08
8.	Number of fruits/plant	3.70	8.87	7.12	0.538	22.27	24.11	85.3	3.02	42.42
9.	Single fruit weight (g)	7.13	11.67	8.38	0.405	13.68	14.91	84.2	2.17	25.89
10.	Fruit length (cm)	8.27	10.87	9.94	0.321	5.68	6.92	67.3	0.95	9.56
11.	Fruit diameter (cm)	1.40	1.70	1.55	0.076	5.04	7.84	41.3	0.10	6.45
12.	Fruit yield/plant (g)	26.33	97.26	60.25	5.196	28.13	30.05	87.6	32.68	54.24
13.	Number of seeds/fruit	43.20	75.70	58.51	3.323	16.16	17.59	84.4	17.89	30.58
14.	Number of ridges/fruit	5.00	6.00	5.05	0.000	4.43	4.43	99.9	0.46	9.11
15.	Ascorbic acid (mg/100g)	6.97	12.57	9.86	0.476	17.29	18.27	89.5	3.32	33.67

Table 4.4.2b: Estimation of various variability parameters of F_1's in okra in Summer season.

S. No.	Characters	Range		Mean	S.E.	GCV	PCV	Heritability	Genetic advance	Genetic gain
		Min.	Max.							
1.	Plant height (cm)	68.37	114.10	92.74	5.057	8.44	10.77	61.5	12.65	13.64
2.	Stem diameter (cm)	1.47	2.27	1.87	0.124	7.92	11.36	48.6	0.21	11.23
3.	Number of branches/plant	0.60	2.50	1.42	0.178	30.58	34.22	79.8	0.80	56.34
4.	Number of nodes/plant	9.50	20.87	13.53	1.211	18.44	21.45	73.9	4.42	32.67
5.	Inter nodal length (cm)	2.60	7.87	5.96	0.339	16.44	17.85	84.8	1.86	31.21
6.	Days to first flowering	35.00	47.00	42.31	0.935	6.59	7.13	85.6	5.32	12.57
7.	Days to 50 % flowering	45.00	54.00	49.95	1.052	4.39	5.09	74.4	3.90	7.81
8.	Number of fruits/plant	5.43	11.27	7.99	0.396	14.54	15.76	85.1	2.21	27.66
9.	Single fruit weight (g)	7.63	11.90	9.38	0.424	10.66	12.01	78.7	1.83	19.51
10.	Fruit length (cm)	8.33	11.83	9.91	0.268	6.80	7.56	80.8	1.25	12.61
11.	Fruit diameter (cm)	1.30	1.80	1.56	0.082	5.52	8.45	42.6	0.21	13.46
12.	Fruit yield/plant (g)	45.43	108.91	74.94	5.077	18.50	20.28	83.3	26.07	34.79
13.	Number of seeds/fruit	44.57	74.43	60.67	3.387	12.08	13.88	75.7	13.14	21.66
14.	Number of ridges/fruit	5.00	5.93	5.05	0.029	3.63	3.70	96.3	0.37	7.33
15.	Ascorbic acid (mg/100g)	7.10	12.80	10.15	0.704	12.53	15.14	68.5	2.17	21.38

In Summer season crop, the variability for this trait ranged from 0.67 (IIVR-401) to 3.93 (IIVR-435) and 0.60 (IC-43720 × Prabhani Kranti) to 2.50 (IIVR-435 × Arka Anamika) for parents and hybrids, respectively. The GCV and PCV were 38.03 and 39.64, respectively for parents while GCV and PCV of hybrids were 30.58 and 34.22, respectively. The genetic advance of parents was 1.34 per cent with genetic gain of 75.28 per cent i.e. low and in hybrids genetic advance was 0.80 per cent and genetic gain was 56.34 per cent i.e. also low. The heritability of parents (92.0%) was more than hybrids (79.8%) for this trait.

4.4.4 Number of nodes per plant

In Rainy season crop, the coefficient of variation for this trait were 15.94 (GCV) and 18.43 (PCV) for parents and 22.72 (GCV) and 24.50 (PCV) for hybrids. The heritability of parents was lower (74.8%) than hybrids (86.0%) with low genetic advance 3.38 per cent and 5.26 per cent for parents and hybrids, respectively. The genetic gain of parents was 28.40 and hybrids were 43.40 per cent. The variability ranged from 8.90 (IIVR-198) to 16.53 (VRO-6) and 8.47 (Arka Abhay × Prabhani Kranti) to 22.13 (IIVR-198 × Prabhani Kranti) in parents and hybrids, respectively.

In Summer season crop, variability ranged from 10.07 (IIVR-198) to 20.77 (IIVR-435) and 9.50 (IIVR-198 × Pusa Sawani) to 20.87 (IIVR-198 × Arka Anamika) in parents and hybrids, respectively. The GCV and PCV of parents were 22.85 and 24.87, respectively. In hybrids GCV was 18.44 and PCV was 21.45. However, genetic advance and genetic gain of parents were 5.82 per cent and 43.24 per cent, respectively while in hybrids 4.42 per cent and 32.67 per cent, respectively i.e. quite low. The heritability was 84.4 per cent in parents and 73.9 per cent in hybrids i.e. high.

4.4.5 Internodal length

In Rainy season crop, the length of internodes ranged from 6.28 cm (VRO-5) to 11.92 cm (IIVR-198) and 5.3 cm (VRO-5 × Arka Anamika) **(Plate I)** to 11.46 (IIVR-342 × Arka Anamika) in parents and hybrids, respectively. However, the coefficient of variation were 15.30 (GCV), 20.24 (PCV) and 16.07 (GCV), 20.30 (PCV) for parents and hybrids, respectively. The genetic advance was low (2.09% and 2.25%) with low genetic gain i.e. 23.86 per cent and 26.25 per cent for parents and hybrids, respectively. The heritability of hybrids (62.7%) was higher than parents (57.2%) i.e. high heritability. The general mean value of parents and hybrids was 8.76 cm and 8.57 cm, respectively.

In Summer season crop, variability ranged from 2.67 cm (VRO-5) to 7.80 cm (IIVR-401) and 2.60 cm (VRO-5 × Arka Anamika) to 7.87 cm (IC-43720 × Prabhani Kranti) in parents and hybrids, respectively. The GCV were 25.49 and 16.44, and PCV were expressed 28.18 and 17.85, respectively for parents and hybrids. However, genetic advance for parents were 2.79 per cent, and 1.86 per cent for hybrids while genetic gain 47.53 per cent for parents and 31.21 per cent for hybrids that showed low genetic advance and genetic gain. The heritability was 81.8 per cent in parents and 84.8 per cent in hybrids which showed high heritability.

4.4.6 Days to first flowering

In Rainy season crop, for days to first flowering the genotypic and Phenotypic coefficient of variation were 5.66 (GCV) and 6.24 (PCV) in parents while in F_1's 5.50 (GCV) and 6.05 (PCV) were found. The variability among parents and hybrids ranged from 37.00 (IC-218877) to 47.00 days (Arka Anamika) and 34.00 (IC-43720 × Arka Anamika) to 51.00 days (IC-140934 × Arka Anamika), respectively. The genetic advance and genetic gain were 4.34 per cent and 10.57 per cent, respectively in parents while genetic advance (4.39%) and

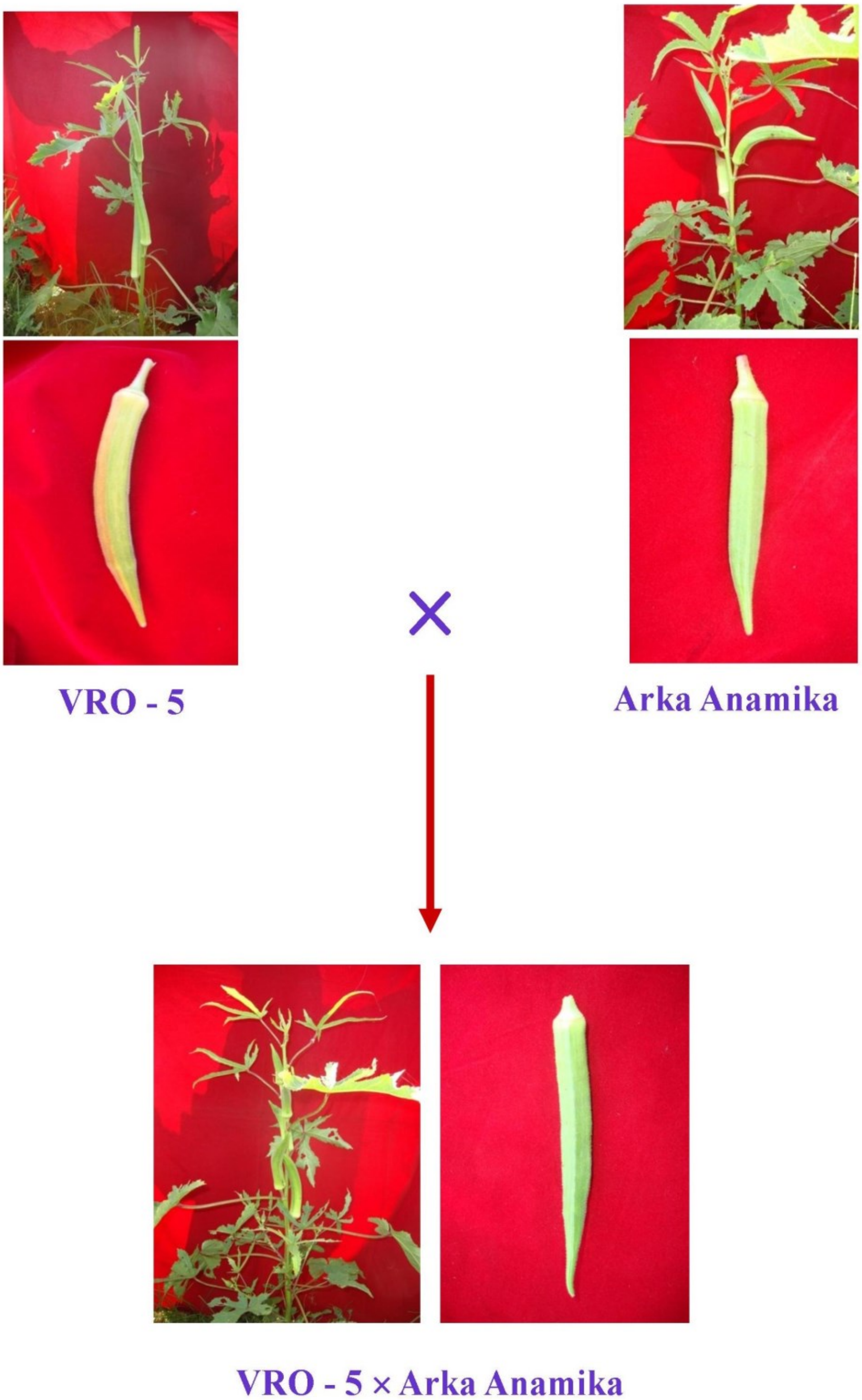


Plate I: Internodal length in okra

genetic gain (10.31%) in hybrids showed low in magnitude. However, heritability of hybrids (82.7%) was higher than parents (82.3%) i.e. high heritability.

In Summer season crop, the phenotypic and genotypic coefficients of variation were 4.62 and 3.73 for parents while 7.13 and 6.59 for hybrids, respectively. However, genetic advance and genetic gain was 2.45 per cent and 6.21 per cent for parents and 5.32 per cent and 12.57 per cent for hybrids. The high heritability was observed in parents (65.4%) and hybrids (85.6%). The variability for this trait ranged from 38.00 (VRO-6) to 45.00 days (IC-128883) in parents and 35.00 (IIVR-401 × Prabhani Kranti) to 47.00 days (IC-45806 × Arka Anamika) with a general mean value of 39.47 and 42.31 days, respectively.

4.4.7 Days to 50 per cent flowering

In Rainy season crop, the variability ranged from 46.00 (IC-218877) to 54.00 days (SA-2) and 45.00 (IC-43720 × Arka Anamika) to 62.00 days (IC-140934 × Arka Anamika) in parents and hybrids, respectively. However, coefficient of variation for parents were 4.27 (GCV) and 5.14 (PCV) while in hybrids 5.13 (GCV) and 5.66 (PCV) were found. The heritability was observed in higher amount in which parents (69.2%) showed lower heritability as compared to the hybrids (82.2%). The genetic advance and genetic gain were 3.64 per cent and 7.32 per cent for parents, while 4.96 per cent and 9.58 per cent for hybrid denotes low genetic advance and genetic gain.

In Summer season crop, variability ranged from 45.00 (EC-305612) to 51.00 days (IC-128883) for parents and 45.00 (SA-2 × Prabhani Kranti) to 54.00 days (VRO-5 × Prabhani Kranti) for hybrids. However, GCV and PCV of parents was 2.66 and 3.56, respectively, while in hybrids GCV and PCV was 4.39 and 5.09, respectively. The heritability of parents (55.7%) was lower than hybrids (74.4%) which showed higher heritability. The genetic advance and genetic gain were 1.99 and 4.08 per cent for parents and 3.90 and 7.81 per cent for hybrids, respectively that expressed in lower amount.

4.4.8 Number of fruits per plant

In Rainy season crop, the GCV and PCV of parents was 12.34 and 16.07 with high heritability (59.0%) and low genetic advance (2.26%) and genetic gain (19.57%) observed while in hybrids the GCV and PCV was 10.95 and 13.96 with high heritability (61.5%) and low genetic advance (2.06%) and genetic gain (17.70%) had found. The range varied from 8.60 (IC-43720) to 14.93 (VRO-6) and 8.23 (IC-218844 × Arka Anamika) to 14.33 (EC-305612 × Pusa Sawani) for parents and hybrids, respectively.

In Summer season crop, this trait ranged from 3.70 (IC-43720) to 9.77 (VRO-6) and 5.43 (SA-2 × Prabhani Kranti) to 11.27 (EC-305612 × Arka Anamika) in parents and hybrids, respectively. Whereas the GCV and PCV was 22.27 and 24.11 in parents and 14.54 and 15.76 in hybrids, respectively. However, genetic advance (3.02%) and genetic gain (42.42%) of parents and hybrids (GA=2.21% and GG = 27.66%) was low. The heritability was expressed in higher amount in parents (85.3%) as well as in hybrids (85.1%).

4.4.9 Single fruit weight

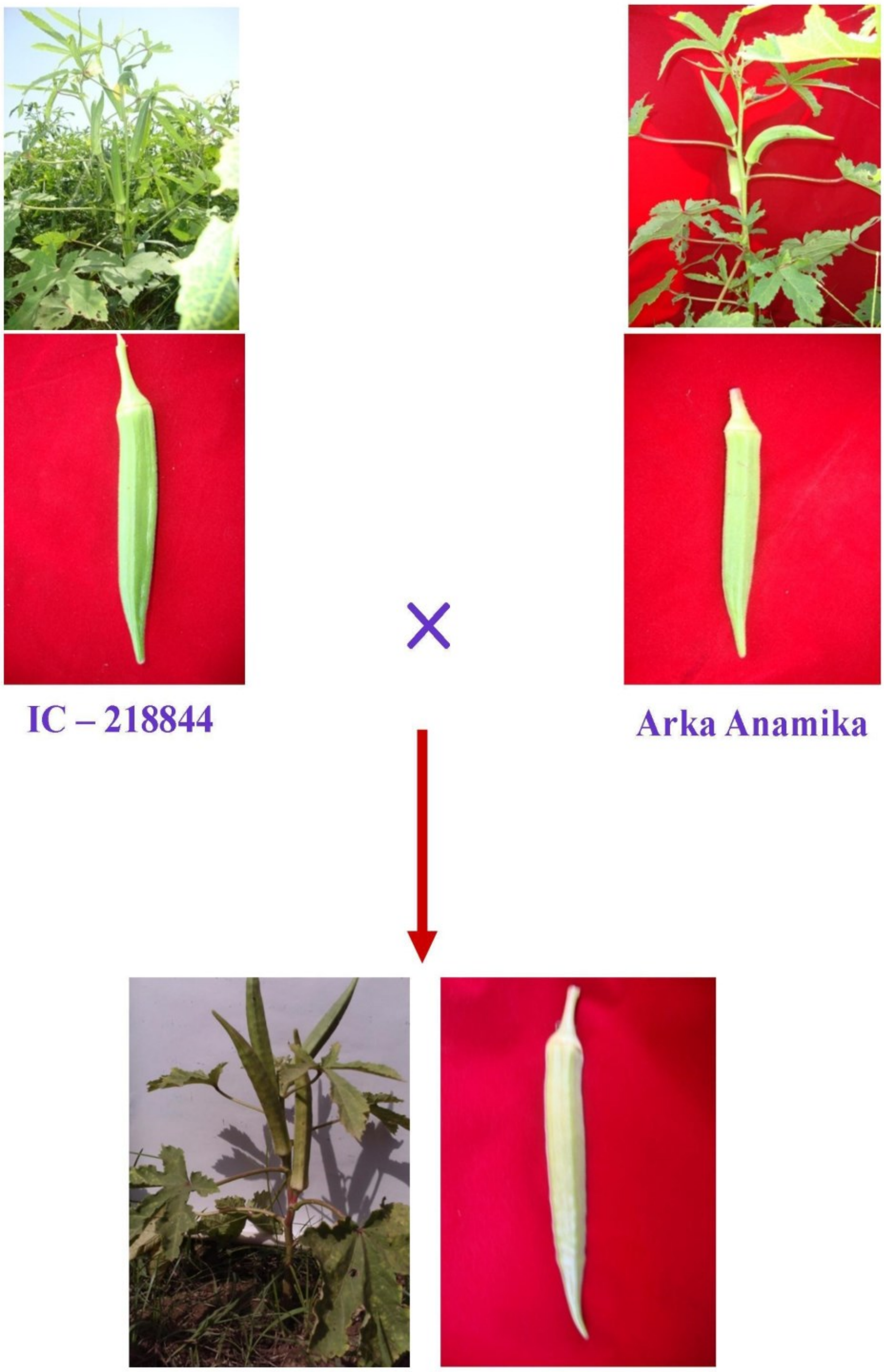
In Rainy season crop, the variability ranged from 7.67 (IC-43720) to 11.40 g (VRO-5) and 8.47 (IIVR-342 × Prabhani Kranti) to 13.40 g (VRO-5 × Pusa Sawani) in parents and hybrids, respectively. The coefficient of variation were 9.93 (GCV) and 11.70 (PCV) of parents, while 10.50 (GCV) and 12.31 (PCV) of hybrids. The heritability was higher in both cases i.e. 72.0 per cent for parents and 72.7 per cent for hybrids were expressed. However, genetic advance and genetic gain was lower in both parents (GA = 1.61% and GG = 17.35%) and hybrids (GA = 1.83% and GG = 18.50%).

In Summer season crop, the coefficient of variation for parent were 13.68 per cent (GCV) and 14.91 per cent (PCV) and in hybrids 10.66 (GCV) and 12.01 (PCV) were expressed. The heritability was expressed in higher amount for parents (84.2%) and hybrids (78.7%). However, genetic advance and genetic gain for parents (GA = 2.17% and GG = 25.89%) and hybrids (GA = 1.83% and GG = 19.51%) were expressed in lower amount. The variability for this trait ranged from 7.13 (IC-43720) to 11.67 g (Prabhani Kranti) and 7.63 (IC-128883 × Prabhani Kranti) to 11.90 g (IC-218844 × Prabhani Kranti) in parents and hybrids, respectively.

4.4.10 Fruit length

In Rainy season crop, the value of GCV and PCV were 8.02 and 8.24 for parents while 6.52 and 6.71 for hybrids, respectively. Whereas, very high heritability was observed in parents (94.7%) as well as in hybrids (94.3%). The genetic advance was 1.58 per cent for parents and 1.35 per cent for hybrids with genetic gain of 16.04 per cent for parents and 13.08 per cent for hybrids. The variability ranged from 8.33 (EC-305612) to 11.07 cm (Arka Abhay) in parents and 9.03 (IIVR-198 × Pusa Sawani) to 12.50 cm (IC-218844 × Arka Anamika) **(Plate II)** in hybrid were found.

In Summer season crop, the coefficient of variation for parents were 5.68 (GCV) and 6.92 (PCV) while 6.80 (GCV) and 7.56 (PCV) for hybrids were observed. The heritability was in higher amount for both, parents (67.3%) and hybrids (80.8%) were displayed. The variability was ranged from 8.27 (EC-305612) to 10.87 cm (Prabhani Kranti) for parents and 8.33 (IIVR-198 × Pusa Sawani) to 11.83 cm (IC-140934 × Pusa Sawani) for hybrids. The genetic advance for parents (0.95%) and for hybrids (1.25%) was low with genetic gain of 9.56 per cent for parents and 12.61 per cent for hybrids.



IC – 218844 × Arka Anamika

Plate II: Fruit length in okra

4.4.11 Fruit diameter

In Rainy season crop, the variability for this trait ranged from 1.30 (IIVR-401) to 1.70 cm (IC-140906) for parents and 1.30 (IIVR-342 × Prabhani Kranti) to 1.80 cm (IC-218844 × Arka Anamika) for hybrids were found. The coefficient of variation were 5.29 (GCV) and 8.08 (PCV) for parents while 4.64 (GCV) and 7.91 (PCV) for hybrids with high heritability of 42.8 per cent for parents and 34.4 per cent for hybrids. The genetic advance was quietly low in both hybrids (0.09%) and parents (0.11%) with genetic gain of 7.05 per cent for parents and 5.73 per cent for hybrids.

In Summer season crop, the coefficient of variation for parents were 5.04 (GCV) and 7.84 (PCV), while for hybrids 5.52 (GCV) and 8.45 (PCV). The variability ranged from 1.40 (VRO-6) to 1.70 cm (IC-43720) in parents and 1.30 (IC-45806 × Prabhani Kranti) to 1.80 cm (IC-218844 × Arka Anamika) were observed. The heritability was high in both parents (42.6%) and hybrids (41.3%) with low genetic advance of 0.21 per cent for parents and 0.10% for hybrids with the genetic gain of 6.45 per cent in parents and 13.46 per cent in hybrids.

4.4.12 Fruit yield per plant

In Rainy season crop, the variability ranged from 66.03 g (IC-43720) to 168.90g (VRO-6) in parents and 74.70 g (IC-218844 × Pusa Sawani) to 182.97 g (VRO-5 × Pusa Sawani). The heritability was higher in parents (70.2%) and hybrids (72.8%) with high genetic advance 33.99% parents and 34.50% in hybrids and high genetic gain in parents (31.03%) and hybrids (29.91%) were found.

In Summer season crop, the GCV and PCV for parent were 28.13 (GCV) and 30.05 (PCV) and for hybrids were 18.50 (GCV) and 20.28 (PCV) found. The variability ranged from 26.33 g (IC-43720) to 97.26 g (VRO-6) in parents and 45.43 g (SA-2 × Prabhani Kranti) to 108.91 g (Arka Abhay × Arka Anamika) **(Plate III)** were found.

Arka Abhay

Arka Anamika

Arka Abhay × Arka Anamika

Plate III: Fruit yield in okra

The heritability is high for parents (87.6%) and hybrids (83.3%) with high genetic advance of parents (32.68) and hybrids (26.07%). The genetic gain was also expressed in higher amount for parents (54.24%) and hybrids (34.79%).

4.4.13 Number of seeds per fruit

In Rainy season crop, number of seeds per fruit were ranged from 39.00 (IC-218844) to 70.77 (Pusa Sawani) for parents and 37.53 (SA-2 × Arka Anamika) to 74.13 (IC-140934 × Prabhani Kranti) for hybrids. The coefficient of variability were 15.03 (GCV) and 17.51 (PCV) for parents, while 12.67 (GCV) and 14.69 (PCV) for hybrids. However, the heritability were observed in high magnitude for parents (73.7%) and hybrids (74.4%) with moderate genetic advance for parents (15.04%) and hybrids (12.73%) and high genetic gain in parents (26.60%) and hybrids (22.51%).

In Summer season crop, the heritability were also expressed in higher magnitude for parents (84.4%) as well as for hybrids (75.7%) with moderate genetic advance of 17.89 per cent for parents and 13.14 per cent for hybrids with high genetic gain of 30.58 per cent for parents and moderate genetic advance 21.66 per cent for hybrids. The variability among parents ranged from 43.20 (IC-218844) to 75.70 (Arka Anamika) and in hybrids 44.57 (IC-45806 × Pusa Sawani) to 74.43 (IC-218883 × Arka Anamika). The coefficient of variation for parents were 16.16 (GCV) and 17.59 (PCV) while for hybrids 12.08 (GCV) and 13.88 (PCV) observed.

4.4.14 Number of ridges per plant

In Rainy season crop, number of ridges was 5.00 for all parents except for IIVR-198 (5.92). While in hybrids maximum number of ridges was observed in IC-43720 × Prabhani Kranti (6.00) and rest were 5.00. The coefficient of variation of parents were 4.06 (GCV) and 4.07 (PCV) with high heritability of 99.3 per cent and low genetic advance (0.42%) and genetic gain (8.32%). While in hybrids the GCV was 3.6 and PCV were 3.73 with high heritability (95.8%) and low genetic advance (0.37%) as well as genetic gain (7.34%).

In Summer season crop, the heritability of parents (99.9%) and hybrids (96.3%) were higher as compared to Rainy season and characters under studied. However, lower magnitude of genetic advance in parents (0.46%) and hybrids (0.37%) were expressed with lower genetic gain in both parents (9.11%) and hybrids (7.33%). The coefficient of variation of parents were equal i.e. 4.43 while for hybrids were 3.63 (GCV) and 3.70 (PCV). Whereas the variability were 5.00 for all parents except IC-43720 (6.00). While in hybrids the maximum number of ridges was observed in IC-43720 × Prabhani Kranti (5.93) and rest were 5.00.

4.4.15 Ascorbic acid content

In Rainy season crop, the coefficient of variation of parents were 17.31 (GCV) and 17.83 (PCV) with high magnitude of heritability (94.2%) and low genetic advance (3.48%) but high genetic gain (34.63%) had observed. However, in hybrids coefficient of variance were 12.95 (GCV) and 15.30 (PCV) with high level of heritability (71.6%) and low genetic advance (2.32%) but high genetic gain (22.55%) had found. The variability ranged from 6.80 (IIVR-342) to 12.87 mg/100g (VRO-5) in parents while 7.30 (IIVR-435 × Pusa Sawani) to 13.67 mg/100g (VRO-5 × Prabhani Kranti) in hybrids were expressed.

In Summer season crop, the coefficient of variance were 17.29 (GCV) and 18.27 (PCV) in parents while 12.53 (GCV) and 15.14 (PCV) in hybrids. The parents (89.5%) and hybrids (68.5%) expressed high heritability for this trait with low genetic advance 3.32 per cent and 2.17 per cent for parents and hybrids, respectively. However, the high magnitudes of genetic gain were observed in both parents (33.67%) and hybrids (21.38%). The variability ranged from 6.97 (IIVR-342) to 12.57 mg/100g (VRO-6) in parents while 7.10 (IIVR-435 × Pusa Sawani) to 12.80 mg/100g (VRO-5 × Arka Anamika).

4.5 Correlation and path coefficient analysis

4.5.1 Phenotypic and genotypic correlation coefficients

The phenotypic and genotypic correlation coefficients computed between the fifteen characters under study are presented in Table 4.5.1a for Rainy season parents, Table 4.5.1b for Rainy season F_1's, Table 4.5.1c for Summer season parents and Table 4.5.1d for Summer season F_1's (hybrids).

The genotypic correlation coefficients were higher in magnitude than phenotypic correlations for most of the characters barring few exceptions indicating inherent genetic association. Genotypic as well as phenotypic correlation coefficients between any two traits had in general same sign whether negative or positive.

In Rainy season crop, from parents only 13 pairs of combinations show positive significant correlation and 4 pairs showed negative significant correlation coefficient. The plant height had positive significant correlation with stem diameter (P = 0.529, G = 0.684) but negative significant genotypic correlation with single fruit weight (G = 0.633) and fruit yield per plant (G = 0.533). Stem diameter exhibited positive significant genotypic correlation with days to first flowering (G = 0.525). Number of branches per plant had negative significant genotypic correlation with internodal length (G = 0.486) but positive significant genotypic correlation with fruit diameter (G = 0.535). Number of nodes per plant also had high negative and significant correlation with internodal length (P = -0.777, G = 0.818) at both genotypic and phenotypic levels. Internodal length had high positive and significant genotypic correlation with ascorbic acid content (G = 0.561). Days to first flowering had positive significant genotypically correlated with number of fruits per plant (G = 0.441)

Table 4.5.1a: Phenotypic and genotypic correlation coefficients of parents for 15 characters in okra during Rainy season.

Characters		Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Fruit yield per plant (g)
Plant height (cm)		**rp**	0.529*	-0.131	0.233	0.195	0.302	0.202	0.091	-0.411	-0.162	-0.140	-0.145	0.190	-0.010	-0.416
		rg	0.684**	-0.223	0.118	0.412	0.429	0.346	0.172	-0.633**	-0.256	-0.370	-0.239	0.215	-0.022	-0.533*
Stem diameter (cm)			**rp**	-0.127	0.050	0.161	0.361	-0.012	0.041	-0.390	-0.076	-0.249	-0.258	-0.021	0.059	-0.311
			rg	-0.146	0.047	0.323	0.525*	-0.087	0.050	-0.501	-0.082	-0.266	-0.403	0.021	0.074	-0.471
Number of branches/plant				**rp**	0.232	-0.386	-0.068	-0.027	-0.068	-0.075	-0.367	0.315	-0.116	0.142	-0.290	-0.202
				rg	0.248	-0.486*	-0.101	0.006	-0.064	-0.096	-0.398	0.535*	-0.119	0.148	-0.307	-0.220
Number of nodes/plant					**rp**	-0.777**	-0.148	-0.098	0.038	0.197	0.122	0.074	0.179	-0.053	-0.318	-0.236
					rg	-0.818**	-0.177	-0.067	0.081	0.272	0.120	0.080	0.247	-0.114	-0.375	-0.253
Inter nodal length (cm)						**rp**	0.271	0.136	0.067	-0.260	-0.059	-0.139	-0.115	0.241	0.411	0.182
						rg	0.430	0.145	0.211	-0.408	-0.079	-0.259	-0.110	0.433	0.561**	0.192
Days to first flowering							**rp**	0.353	0.332	-0.209	0.173	-0.468*	-0.026	0.151	-0.001	0.147
							rg	0.359	0.441*	-0.308	0.195	-0.750**	-0.060	0.210	-0.010	0.181
Days to 50 % flowering								**rp**	0.023	-0.182	0.128	-0.013	-0.062	0.163	-0.247	-0.013
								rg	0.089	-0.250	0.168	-0.004	-0.040	0.239	-0.303	-0.072
Number of fruits/plant									**rp**	0.099	0.285	-0.369	0.642**	0.294	-0.091	0.497*
									rg	0.298	0.446*	-0.578	0.722**	0.557*	-0.117	0.654**
Single fruit weight (g)										**rp**	0.198	0.201	0.720**	0.188	0.044	0.518**
										rg	0.152	-0.098	0.826**	0.024	0.047	0.636**
Fruit length (cm)											**rp**	-0.138	0.248	0.020	0.246	0.475*
											rg	-0.388	0.271	-0.054	0.252	0.511*
Fruit diameter (cm)												**rp**	-0.018	0.278	0.081	-0.158
												rg	-0.284	-0.008	0.116	-0.248
Number of seeds/fruit													**rp**	0.351	-0.013	0.634**
													rg	0.349	-0.025	0.772**
Number of ridges/fruit														**rp**	0.266	0.300
														rg	0.304	0.376
Ascorbic acid (mg/100g)															**rp**	-0.190
															rg	-0.194

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

Table 4.5.1b: Phenotypic and genotypic correlation coefficients of hybrids (F_1's) for 15 characters in okra during Rainy season.

Characters	Plant height (cm)	Stem diameter (cm)	Number of branches/ plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Fruit yield per plant (g)
Plant height (cm)	**rp**	0.707**	0.084	0.591**	-0.128	0.019	-0.017	-0.066	-0.197	-0.320*	-0.121	-0.112	-0.005	0.014	-0.222
	rg	0.880**	0.045	0.609**	-0.119	0.054	0.013	-0.133	-0.244	-0.359**	-0.295*	-0.159	0.023	0.018	-0.288*
Stem diameter (cm)		**rp**	0.010	0.444**	-0.156	0.003	0.017	-0.080	0.013	-0.158	-0.039	-0.014	0.130	-0.079	0.037
		rg	-0.044	0.545**	-0.134	0.049	0.112	-0.174	0.042	-0.190	-0.066	-0.061	0.252	-0.120	-0.089
Number of branches/plant			**rp**	0.247	-0.223	-0.016	0.043	0.045	0.022	-0.022	-0.065	0.029	-0.008	0.010	-0.149
			rg	0.259	-0.296	-0.007	0.055	0.015	0.140	-0.004	-0.096	0.096	0.042	0.006	-0.144
Number of nodes/plant				**rp**	-0.745**	0.041	0.026	0.001	-0.186	0.020	-0.037	-0.126	0.041	-0.072	0.021
				rg	-0.829**	0.067	0.043	-0.006	-0.158	0.045	-0.097	-0.105	0.072	-0.078	0.019
Inter nodal length (cm)					**rp**	0.022	0.008	0.053	-0.027	-0.294*	-0.072	0.083	-0.016	0.104	-0.124
					rg	0.021	-0.009	0.046	-0.093	-0.418**	-0.044	0.060	-0.027	0.134	-0.157
Days to first flowering						**rp**	0.474**	0.314*	0.053	-0.073	0.075	0.232	0.046	-0.263	0.027
						rg	0.436**	0.465**	0.010	-0.097	0.126	0.287*	0.052	-0.297*	-0.024
Days to 50 % flowering							**rp**	0.206	0.097	0.070	-0.008	0.214	0.139	-0.313*	-0.030
							rg	0.319*	0.092	0.068	-0.073	0.282*	0.160	-0.355**	-0.045
Number of fruits/plant								**rp**	0.070	0.063	-0.020	0.652**	0.045	-0.051	0.217
								rg	0.151	0.096	-0.143	0.658**	0.125	-0.084	0.392**
Single fruit weight (g)									**rp**	0.407**	0.298*	0.700**	-0.098	-0.119	0.196
									rg	0.422**	0.390**	0.762**	-0.300*	-0.156	0.282*
Fruit length (cm)										**rp**	0.179	0.236	-0.039	-0.067	0.220
										rg	0.189	0.249	-0.121	-0.073	0.276*
Fruit diameter (cm)											**rp**	0.177	0.046	-0.036	-0.064
											rg	0.197	-0.323*	-0.063	-0.031
Number of seeds/fruit												**rp**	-0.043	-0.108	0.279*
												rg	-0.131	-0.147	0.360**
Number of ridges/fruit													**rp**	-0.083	0.097
													rg	-0.104	0.170
Ascorbic acid (mg/100g)														**rp**	-0.211
														rg	-0.254

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

Table 4.5.1c: Phenotypic and genotypic correlation coefficients of parents for 15 characters in okra during Summer season.

Characters		Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Fruit yield per plant (g)
Plant height (cm)	rp		0.524*	0.082	0.361	0.204	-0.091	-0.053	0.273	-0.083	-0.221	-0.205	0.150	0.145	-0.182	-0.263
	rg		0.386	0.072	0.305	0.393	0.044	-0.102	0.361	-0.028	-0.489	-0.473	0.232	0.212	-0.246	-0.389
Stem diameter (cm)	rp			0.160	0.303	0.069	-0.202	-0.106	0.358	-0.339	-0.246	-0.367	0.107	0.198	0.068	-0.259
	rg			0.175	0.251	0.123	-0.197	-0.271	0.387	-0.359	-0.393	-0.654	0.126	0.284	0.088	-0.361
Number of branches/plant	rp				0.422	-0.338	0.050	-0.107	0.112	-0.060	0.142	0.177	0.070	0.353	0.106	-0.134
	rg				0.436	-0.334	0.059	-0.160	0.084	-0.069	0.189	0.345	0.045	0.429	0.111	-0.150
Number of nodes/plant	rp					-0.709**	-0.278	-0.202	0.391	0.159	0.079	-0.156	0.411	0.129	-0.189	-0.037
	rg					-0.777**	-0.325	-0.360	0.427	0.201	0.040	-0.403	0.459*	0.174	-0.206	-0.045
Inter nodal length (cm)	rp						0.131	0.106	-0.226	-0.217	-0.307	0.003	-0.326	-0.018	0.137	-0.243
	rg						0.142	0.235	-0.272	-0.246	-0.392	0.131	-0.383	-0.064	0.151	-0.273
Days to first flowering	rp							0.294	-0.040	0.114	0.162	0.024	0.031	-0.035	-0.060	0.334
	rg							0.487*	-0.106	0.073	0.384	0.055	-0.050	-0.073	-0.075	0.383
Days to 50 % flowering	rp								-0.262	-0.140	0.208	0.258	-0.258	-0.129	0.084	0.204
	rg								-0.418	-0.206	0.444*	0.139	-0.393	-0.083	0.112	0.206
Number of fruits/plant	rp									0.229	-0.151	-0.578**	0.872**	0.378	-0.469*	0.255
	rg									0.274	-0.194	-0.848**	0.878**	0.473*	-0.508*	0.290
Single fruit weight (g)	rp										0.260	-0.143	0.663**	0.077	-0.235	0.511**
	rg										0.427	-0.298	0.694**	0.117	-0.256	0.574**
Fruit length (cm)	rp											0.195	0.045	-0.008	0.214	0.301
	rg											0.275	0.103	-0.148	0.261	0.401
Fruit diameter (cm)	rp												-0.511*	-0.025	0.301	-0.209
	rg												-0.780**	-0.010	0.469*	-0.401
Number of seeds/fruit	rp													0.330	-0.441	0.455*
	rg													0.415	-0.471*	0.511*
Number of ridges/fruit	rp														-0.083	0.099
	rg														-0.091	0.111
Ascorbic acid (mg/100g)	rp															-0.162
	rg															-0.167

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

Table 4.5.1d: Phenotypic and genotypic correlation coefficients of hybrids (F₁'s) for 15 characters in okra during Summer season.

Characters	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Fruit yield per plant (g)
Plant height (cm)	**rp**	0.719**	0.164	0.717**	-0.240	-0.076	-0.122	0.285*	-0.030	-0.190	0.016	0.214	-0.060	-0.052	-0.048
	rg	0.641**	0.030	0.761**	-0.158	-0.098	-0.187	0.440**	0.015	-0.230	0.159	0.367**	-0.109	-0.078	-0.031
Stem diameter (cm)		**rp**	0.201	0.603**	-0.357	0.048	-0.002	0.323*	-0.006	-0.007	-0.005	0.250	0.087	-0.150	0.129
		rg	0.072	0.611**	-0.336	0.068	0.012	0.599**	0.059	0.037	0.141	0.505**	0.091	-0.228	0.254
Number of branches/plant			**rp**	0.479**	-0.515**	-0.174	-0.151	0.164	-0.067	0.009	-0.173	0.093	0.035	-0.060	-0.025
			rg	0.472**	-0.515**	-0.188	-0.173	0.233	-0.040	0.036	-0.152	0.165	0.029	-0.062	-0.004
Number of nodes/plant				**rp**	-0.720**	-0.227	-0.260	0.294*	0.022	-0.071	0.048	0.244	0.004	-0.088	0.045
				rg	-0.734**	-0.289*	-0.380**	0.422**	0.093	-0.075	0.201	0.388**	-0.022	-0.110	0.094
Inter nodal length (cm)					**rp**	0.231	0.148	-0.198	-0.178	-0.206	-0.053	-0.263	-0.182	0.161	-0.193
					rg	0.264	0.196	-0.258	-0.244	-0.247	-0.155	-0.346*	-0.209	0.182	-0.291*
Days to first flowering						**rp**	0.648**	0.112	-0.068	-0.206	-0.115	0.037	0.016	-0.005	-0.112
						rg	0.674**	0.125	-0.119	-0.238	-0.191	0.020	0.028	0.000	-0.196
Days to 50 % flowering							**rp**	-0.036	0.016	-0.074	-0.043	-0.024	0.036	-0.027	0.065
							rg	-0.059	-0.029	-0.077	-0.200	-0.073	0.054	-0.023	0.082
Number of fruits/plant								**rp**	0.052	-0.045	-0.065	0.813**	0.083	-0.075	0.069
								rg	0.063	-0.060	-0.134	0.831**	0.103	-0.084	0.097
Single fruit weight (g)									**rp**	0.243	0.106	0.618**	-0.084	-0.119	0.130
									rg	0.274*	0.169	0.604**	-0.104	-0.141	0.182
Fruit length (cm)										**rp**	0.239	0.110	0.135	-0.129	0.079
										rg	0.240	0.111	0.070	-0.150	0.127
Fruit diameter (cm)											**rp**	0.005	-0.161	-0.038	0.023
											rg	-0.018	-0.378**	-0.065	0.006
Number of seeds/fruit												**rp**	0.026	-0.117	0.141
												rg	0.037	-0.132	0.195
Number of ridges/fruit													**rp**	-0.153	0.119
													rg	-0.173	0.177
Ascorbic acid (mg/100g)														**rp**	-0.145
														rg	-0.176

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

but negative significantly correlated with fruit diameter (P = -0.468, G = -0.750) at both genotypic and phenotypic levels. Number of fruits per plant had positive significantly correlation with number of seeds per fruit (P = 0.642, G = 0.722) and fruit yield per plant (P = 0.497, G = 0.654) at both the levels but had only genotypic positive significant correlation with fruit length (G = 0.446) and number of ridges per fruit (G = 0.557). Single fruit weight had significant positive correlation with number of seeds per fruit (P = 0.720, G = 0.826) and fruit yield per plant (P = 0.518, G = 0.636). Fruit length was positive significantly correlated with fruit yield per plant (P = 0.475, G = 0.511). Number of seeds per fruits had high positive and significant correlation with fruit yield per plant (P = 0.634, G = 0.772).

However, in Rainy season F_1's plant height showed highly significant positive correlation with stem diameter (P = 0.707, G = 0.880) and number of nodes per plant (P = 0.591, G = 0.609) but negative significantly correlated with fruit length (P = -0.320, G = -0.359) while negative significant genotypic correlation with fruit diameter (G = -0.295) and fruit yield per plant (G = -0.288). Stem diameter was highly positive significantly correlated with number of nodes per plant (P = 0.444, G = 0.545). Number of nodes per plant exerted negative and high significant correlation with internodal length (P = -0.745, G = -0.829). However, internodal length had negative significant correlation with fruit length (P = -0.294, G = -0.418). The days to first flowering was positive significantly correlated with days to 50 per cent flowering (P = 0.474, G = 0.436) and number of fruits per plant (P = 0.314, G = 0.465) but at only genotypic level with number of seeds per fruit (G = 0.287), while negative significant correlation with ascorbic acid content (G = 0.297) at genotypic level. Days to 50 per cent flowering was positive significantly correlated with number of fruits per plant (G = 0.319) and number of seeds per fruit (G = 0.282) at genotypic level while, negative significant correlated with ascorbic acid content (P = -0.313, G = -0.355) at both genotypic and phenotypic level. Number of fruits per plant had high positive significant correlation with number of seeds per fruit (P = 0.652, G = 0.658) at both levels and with fruit yield per plant (G = 0.392) at genotypic level. Single fruit weight exerted positive significant correlation with fruit length (P = 0.407, G = 0.422), fruit diameter (P = 0.298, G = 0.390) and number of seeds per fruit (P = 0.700, G = 0.762) at both levels and only at genotypic level positive significant correlation with fruit yield per plant (G = 0.282) while expresses negative significant genotypic correlation with number of ridges per fruit (G = -0.300). Fruit length had positive significant genotypic correlation with fruit yield per plant (G = 0.276).

Whereas, the fruit diameter showed negative significant correlation with number of ridges per fruit (G = -0.323) at genotypic level. Number of seeds per fruit expressed positive significant correlation with fruit yield per plant (P = 0.279, G = 0.360). Among all the combination of hybrids only 16 and 5 combinations were found to expressed positive and negative significant correlations, respectively.

In Summer season crop, the parents were expressed 9 and 6 combinations significantly correlated at positive and negative levels, respectively. Plant height had positive significant correlation with stem diameter (P = 0.524) at phenotypic level only. While number of nodes per plant exerted high negative significant correlation with internodal length (P = -0.709, G = -0.777) but positive significant correlation at genotypic level with number of seeds per fruit (G = 0.459). Days to first flowering expressed positive significant correlation with days to 50 per cent flowering (G = 0.487) at genotypic level. However, days to 50 per cent flowering was positive significantly correlated with fruit length (0.444) at genotypic level. Number of fruits per plant had high positive significant correlation with number of seeds per fruit (P = 0.872, G = 0.878) at both the levels and positive significant genotypically correlated with number of ridges per fruit (G = 0.473) while, negative significant correlation were expressed with fruit diameter (P = -0.578, G = -0.848) and ascorbic acid content (P = -0.469, G = -0.508). Single fruit weight exhibited positive significant correlation with number of seeds per fruit (P = 0.663, G = 0.694) and fruit yield per plant (P = 0.511, G = 0.574). Fruit diameter showed negative significant correlation with number of seeds per fruit (P = -0.511, G = -0.780) but positive significant genotypic correlation with ascorbic acid content (G = 0.469). Number of seeds per fruit expressed positive significant correlation with fruit yield per plant (P = 0.455, G = 0.511) but had negative significant correlation at genotypic level with ascorbic acid content (G = -0.471).

Whereas in hybrids of Summer season crop, only 12 and 5 combinations were expressed significant positive and negative correlations, respectively. Plant height exhibited highly significant and positive correlation with stem diameter (P = 0.719, G = 0.641), number of nodes per plant (P = 0.717, G = 0.761) and number of fruits per plant (P = 0.285, G = 0.440) at both the levels while with number of seeds per fruit (G = 0.367) at genotypic level only. Stem diameter showed significant positive correlation with number of nodes per plant (P = 0.603, G = 0.611) and number of fruits per plant (P = 0.323, G = 0.599) at both the levels and at genotypic level with number of seeds per fruit (G = 0.505). Number of branches per plant had positive significant correlation with number of nodes per plant (P = 0.479, G = 0.472) but negative significant correlation with internodal length (P-0.515, G = -0.515). Number of nodes per plant was positive significant correlation with number of fruits per plant (P = 0.294, G = 0.422) at both levels, while with number of seeds per fruit (G = 0.388) at genotypic level only, whereas negative significant correlation with internodal length (P = -0.720, G = -0.734) at both the levels but with days to first flowering (G = -0.289) and days to 50 per cent flowering (G = -0.380) at genotypic level only. Internodal length had negative significant genotypic correlation with number of ridges per fruit (G = -0.346) and fruit yield per plant (G = -0.291). Days to first flowering showed high positive significant correlation with days to 50 per cent flowering (P = 0.648, G = 0.674). Number of fruits per plant exerted high positive significant correlation with number of seeds per fruit (P = 0.813, G = 0.831). Single fruit weight was positive significantly correlated with fruit length (G = 0.274) at genotypic level and number of seeds per fruit (P = 0.618, G = 0.604) at both genotypic and phenotypic levels. Fruit diameter showed negative significant correlation with number of ridges per fruit (G = -0.378) at genotypic level.

4.5.2 Path coefficient analysis

The phenotypic and genotypic correlation coefficients between yield and other traits have been partitioned into direct and indirect effects by path coefficient analysis. The results are presented in Table 4.5.2a for Rainy season parents, Table 4.5.2b for Rainy season hybrids (F_1's), Table 4.5.2c for Summer season parents and Table 4.5.2d for Summer season hybrids (F_1's) are explained at genotypic level in the following paragraph.

In Rainy season parents, number of fruits per plant (1.114) followed by plant height (0.704), single fruit weight (0.628), fruit diameter (0.231), number of ridges per fruit (0.192), ascorbic acid content (0.029) and internodal length (0.027) exerted positive direct effects on fruit yield per plant. However, stem diameter (-0.644), number of seeds per fruit (-0.499), days to first flowering (-0.228), number of nodes per plant (-0.203), ascorbic acid content (-0.148), fruit length (-0.116) and number of branches per plant (-0.004) exerted negative direct effects on fruit yield per plant. Whereas, high positive indirect effects were found in ascorbic acid content (0.728)

Table 4.5.2a: Genotypic path of parents for 15 characters in okra during Rainy season.

Characters	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Genotypic correlation coefficient with yield
Plant height (cm)	**0.704**	-0.440	0.001	-0.024	0.011	-0.098	-0.038	0.192	-0.397	0.030	-0.085	-0.107	-0.004	0.079	-0.533
Stem diameter (cm)	0.481	**-0.644**	0.001	-0.009	0.009	-0.120	0.010	0.055	-0.315	0.010	-0.061	-0.010	0.014	0.070	-0.471
Number of branches/plant	-0.157	0.094	**-0.004**	-0.050	-0.013	0.023	-0.001	-0.071	-0.060	0.046	0.124	-0.074	-0.059	0.032	-0.220
Number of nodes/plant	0.083	-0.030	-0.001	**-0.203**	-0.022	0.040	0.007	0.090	0.171	-0.014	0.018	0.057	-0.072	0.037	-0.253
Inter nodal length (cm)	0.290	-0.208	0.002	0.166	**0.027**	-0.098	-0.016	0.235	-0.256	0.009	-0.060	-0.216	0.108	-0.028	0.192
Days to first flowering	0.302	-0.338	0.000	0.036	0.012	**-0.228**	-0.039	0.491	-0.194	-0.023	-0.173	-0.105	-0.002	-0.027	0.181
Days to 50 % flowering	0.244	0.056	0.000	0.014	0.004	-0.082	**-0.110**	0.099	-0.157	-0.019	-0.001	-0.119	-0.058	0.011	-0.072
Number of fruits/plant	0.121	-0.032	0.000	-0.016	0.006	-0.101	-0.010	**1.114**	0.187	-0.052	-0.133	-0.278	-0.023	-0.097	0.654
Single fruit weight (g)	-0.445	0.323	0.000	-0.055	-0.011	0.070	0.028	0.332	**0.628**	-0.018	-0.023	-0.012	0.009	-0.094	0.636
Fruit length (cm)	-0.181	0.053	0.002	-0.024	-0.002	-0.044	-0.018	0.496	0.096	**-0.116**	-0.090	0.027	0.048	-0.076	0.511
Fruit diameter (cm)	-0.260	0.171	-0.002	-0.016	-0.007	0.171	0.000	-0.644	-0.062	0.045	**0.231**	0.004	0.022	0.037	-0.248
Number of seeds/fruit	0.152	-0.013	-0.001	0.023	0.012	-0.048	-0.026	0.620	0.015	0.006	-0.002	**-0.499**	0.058	-0.056	0.772
Number of ridges/fruit	-0.015	-0.048	0.001	0.076	0.015	0.002	0.033	-0.131	0.030	-0.029	0.027	-0.152	**0.192**	-0.039	0.376
Ascorbic acid (mg/100g)	-0.375	0.303	0.001	0.051	0.005	-0.041	0.008	0.728	0.399	-0.059	-0.057	-0.188	0.050	**-0.148**	-0.194

Residual effect = -0.0624
Bold lines indicates direct effect

Table 4.5.2b: Genotypic path of hybrids (F_1s) for 15 characters in okra during Rainy season.

Characters	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Genotypic correlation coefficient with yield
Plant height (cm)	**1.981**	1.383	0.021	-4.120	0.636	-0.011	0.003	-0.219	0.243	0.245	-0.226	-0.014	0.005	-0.100	-0.288
Stem diameter (cm)	1.743	**1.572**	-0.021	-3.682	0.720	-0.010	0.022	-0.286	-0.041	0.130	-0.050	-0.159	-0.034	-0.031	-0.089
Number of branches/plant	0.088	-0.069	**0.470**	-1.754	1.587	0.001	0.011	0.025	-0.139	0.003	-0.073	-0.027	0.002	-0.050	-0.144
Number of nodes/plant	1.207	0.856	0.122	**-6.760**	4.445	-0.014	0.008	-0.010	0.157	-0.031	-0.074	-0.045	-0.022	0.007	0.019
Inter nodal length (cm)	-0.235	-0.211	-0.139	5.606	**-5.360**	-0.004	-0.002	0.076	0.093	0.285	-0.034	0.017	0.037	-0.054	-0.157
Days to first flowering	0.108	0.077	-0.003	-0.456	-0.113	**-0.210**	0.084	0.767	-0.009	0.066	0.097	-0.033	-0.083	-0.008	-0.024
Days to 50 % flowering	0.026	0.176	0.026	-0.287	0.046	-0.092	**0.193**	0.526	-0.092	-0.046	-0.056	-0.101	-0.099	-0.016	-0.045
Number of fruits/plant	-0.263	-0.273	0.007	0.040	-0.246	-0.098	0.061	**1.651**	-0.150	-0.065	-0.110	-0.079	-0.023	0.136	0.392
Single fruit weight (g)	-0.484	0.065	0.066	1.065	0.500	-0.002	0.018	0.249	**-0.996**	-0.288	0.300	0.189	-0.044	0.097	0.282
Fruit length (cm)	-0.710	-0.298	-0.002	-0.303	2.239	0.020	0.013	0.158	-0.421	**-0.683**	0.145	0.076	-0.021	0.096	0.276
Fruit diameter (cm)	-0.584	-0.103	-0.045	0.655	0.235	-0.027	-0.014	-0.236	-0.389	-0.129	**0.768**	0.204	-0.017	-0.011	-0.031
Number of seeds/fruit	0.045	0.396	0.020	-0.484	0.147	-0.011	0.031	0.206	0.299	0.083	-0.248	**-0.630**	-0.029	0.059	0.360
Number of ridges/fruit	0.035	-0.189	0.003	0.527	-0.717	0.062	-0.068	-0.138	0.156	0.050	-0.048	0.066	**0.279**	-0.054	0.170
Ascorbic acid (mg/100g)	-0.570	-0.140	-0.068	-0.128	0.841	0.005	-0.009	0.647	-0.280	-0.189	-0.024	-0.107	-0.044	**0.346**	-0.254

Residual effect = 0.45083
Bold lines indicates direct effect

Table 4.5.2c: Genotypic path of parents for 15 characters in okra during Summer season.

Characters	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Genotypic correlation coefficient with yield
Plant height (cm)	**-0.036**	0.012	-0.004	0.039	0.021	0.000	0.003	0.265	-0.012	-0.044	-0.006	0.008	-0.003	-0.018	-0.389
Stem diameter (cm)	-0.014	**0.030**	-0.010	0.032	0.006	0.000	0.008	0.283	-0.151	-0.035	-0.008	0.011	0.001	-0.017	-0.361
Number of branches/plant	-0.003	0.005	**-0.057**	0.055	-0.018	0.000	0.005	0.062	-0.029	0.017	0.004	0.016	0.001	-0.007	-0.150
Number of nodes/plant	-0.011	0.008	-0.025	**0.126**	-0.041	0.000	0.010	0.313	0.084	0.004	-0.005	0.007	-0.002	-0.002	-0.045
Inter nodal length (cm)	-0.014	0.004	0.019	-0.098	**0.053**	0.000	-0.007	-0.199	-0.103	-0.035	0.002	-0.002	0.002	-0.013	-0.273
Days to first flowering	-0.002	-0.006	-0.003	-0.041	0.008	**-0.001**	-0.014	-0.077	0.031	0.034	0.001	-0.003	-0.001	0.018	0.383
Days to 50 % flowering	0.004	-0.008	0.009	-0.045	0.012	-0.001	**-0.028**	-0.306	0.087	0.040	0.002	-0.003	0.001	0.009	0.206
Number of fruits/plant	-0.013	0.012	-0.005	0.054	-0.014	0.000	0.012	**0.733**	0.115	-0.017	-0.011	0.018	-0.006	0.013	0.290
Single fruit weight (g)	0.001	-0.011	0.004	0.025	-0.013	0.000	0.006	0.201	**0.421**	0.038	-0.004	0.004	-0.003	0.026	0.574
Fruit length (cm)	0.018	-0.012	-0.011	0.005	-0.021	-0.001	-0.012	-0.142	0.180	**0.090**	0.003	-0.006	0.003	0.018	0.401
Fruit diameter (cm)	0.017	-0.020	-0.020	-0.051	0.007	0.000	-0.004	-0.622	-0.126	0.025	**0.012**	0.000	0.006	-0.018	-0.401
Number of seeds/fruit	-0.008	0.009	-0.024	0.022	-0.003	0.000	0.002	0.347	0.049	-0.013	0.000	**0.037**	-0.001	0.005	0.511
Number of ridges/fruit	0.009	0.003	-0.006	-0.026	0.008	0.000	-0.003	-0.372	-0.108	0.023	0.006	-0.003	**0.012**	-0.014	0.111
Ascorbic acid (mg/100g)	0.014	-0.011	0.009	-0.006	-0.014	-0.001	-0.006	0.212	0.242	0.036	-0.005	0.004	-0.004	**0.046**	-0.167

Residual effect = 0.0010
Bold lines indicates direct effect

Table 4.5.2d: Genotypic path of hybrids (F_1s) for 15 characters in okra during Summer season.

Characters	Plant height (cm)	Stem diameter (cm)	Number of branches/plant	Number of nodes/ plant	Inter nodal length (cm)	Days to first flowering	Days to 50 % flowering	Number of fruits/ plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of seeds/ fruit	Number of ridges/ fruit	Ascorbic acid (mg/100g)	Genotypic correlation coefficient with yield
Plant height (cm)	**-0.137**	-0.041	-0.001	0.224	-0.028	0.001	-0.008	0.363	0.008	-0.009	0.000	-0.004	-0.001	-0.001	-0.031
Stem diameter (cm)	-0.088	**-0.064**	-0.003	0.180	-0.058	-0.001	0.000	0.494	0.033	0.001	0.000	0.003	-0.002	0.009	0.254
Number of branches/plant	-0.004	-0.005	**-0.041**	0.139	-0.090	0.001	-0.007	0.192	-0.022	0.001	0.000	0.001	-0.001	0.000	-0.004
Number of nodes/plant	-0.105	-0.039	-0.019	**0.295**	-0.128	0.002	-0.016	0.348	0.052	-0.003	0.000	-0.001	-0.001	0.003	0.094
Inter nodal length (cm)	0.022	0.021	0.021	-0.216	**0.174**	-0.002	0.008	-0.212	-0.136	-0.010	0.000	-0.008	0.002	-0.010	-0.291
Days to first flowering	0.013	-0.004	0.008	-0.085	0.046	**-0.007**	0.028	0.103	-0.067	-0.010	0.000	0.001	0.000	-0.007	-0.196
Days to 50 % flowering	0.026	-0.001	0.007	-0.112	0.034	-0.005	**0.042**	-0.049	-0.016	-0.003	0.000	0.002	0.000	0.003	0.082
Number of fruits/plant	-0.060	-0.038	-0.010	0.124	-0.045	-0.001	-0.002	**0.825**	0.035	-0.002	0.000	0.004	-0.001	0.003	0.097
Single fruit weight (g)	-0.002	-0.004	0.002	0.027	-0.042	0.001	-0.001	0.052	**0.559**	0.011	0.000	-0.004	-0.001	0.006	0.182
Fruit length (cm)	0.032	-0.002	-0.002	-0.022	-0.043	0.002	-0.003	-0.049	0.153	**0.040**	0.000	0.003	-0.001	0.004	0.127
Fruit diameter (cm)	-0.022	-0.009	0.006	0.059	-0.027	0.001	-0.008	-0.110	0.094	0.010	**0.001**	-0.014	-0.001	0.000	0.006
Number of seeds/fruit	0.015	-0.006	-0.01	-0.006	-0.036	0.000	0.002	0.085	-0.058	0.003	0.000	**0.036**	-0.002	0.006	0.195
Number of ridges/fruit	0.011	0.015	0.003	-0.032	0.032	0.000	-0.001	-0.070	-0.079	-0.006	0.000	-0.006	**0.009**	-0.007	0.177
Ascorbic acid (mg/100g)	0.004	-0.016	0.000	0.028	-0.051	0.001	0.003	0.080	0.102	0.005	0.000	0.006	-0.002	**0.034**	-0.176

Residual effect = 0.0048
Bold lines indicates direct effect

followed by number of seeds per fruit (0.620), fruit length (0.496) and days to first flowering (0.491) via. number of fruits per plant. However, high negative indirect effects were expressed in single fruit weight (-0.445) via. plant height and plant height (-0.397) via. single fruit weight. The estimate of residual effect (-0.0624) was very low.

In Rainy season F_1's, plant height (1.981) had maximum positive direct effect followed by number of fruits per plant (1.651), stem diameter (1.572), fruit diameter (0.768), number of branches per plant (0.470), ascorbic acid content (0.346), number of ridges per fruit (0.279) and days to 50 per cent flowering (0.193). However, the high negative direct effects were observed in number of nodes per plant (-6.760), internodal length (-5.360) and single fruit weight (-0.996). The maximum positive indirect effect was found in internodal length (5.606) via. number of nodes per plant followed by number of nodes per plant (4.445) via. internodal length and fruit length (2.239) via. internodal length. The highest negative indirect effect was found in plant height (-4.120) via. number of nodes per plant, stem diameter (-3.682) and number of branches per plant (-1.754). The estimate of residual effect (0.4583) was low.

In Summer season parents, number of fruits per plant (0.733) expressed maximum positive direct effect followed by single fruit weight (0.421), number of nodes per plant (0.126), fruit length (0.090) and internodal length (0.050) while the highest negative direct effect was found in number of branches per plant (-0.057) followed by plant height (-0.036) and days to 50 per cent flowering (-0.028). The high positive indirect effects were found in number of seeds per fruits (0.347), number of nodes per plant (0.313) and stem diameter (0.282) via. number of fruits per plant but high negative indirect effect were also found in fruit diameter (-0.622), number of ridges per fruit

(-0.372) and days to 50 per cent flowering (-0.306) via. number of fruits per plant. The estimate of residual effect (0.0010) was too low.

In Summer season F_1's, the high direct effect on yield were found in number of fruits per plant (0.825), single fruit weight (0.559) and number of nodes per plant (0.295). However, the traits plant height (-0.137), stem diameter (-0.064) and number of branches per plant (-0.041) exhibited high negative direct effects. The stem diameter (0.494) had positive indirect effect followed by plant height (0.363) and number of nodes per plant (0.348) via. number of fruits per plant. Whereas, internodal length (-0.216) had maximum negative indirect effect via. number of nodes per plant followed by internodal length (-0.212) via. number of fruits per plant and number of nodes per plant (-0.128) via. internodal length. The estimate of residual effect (0.0048) in analysis was low.

The rest of the estimates of direct and indirect effects at genotypic level were not much important.

4.6 Incidence of yellow vein mosaic virus (YVMV)

Cultivation of resistant genotypes for commercial production is more economical than any control measure or integrated disease management. Yellow vein mosaic is most important and devasting viral disease of okra. Hence, efforts well made to screen the parents and the F_1's of different crosses against YVMV incidence in two different seasons (Rainy and Summer).

It is evident from the Table 4.6.1 that among the 20 parents under study, eight parental lines (VRO-5, VRO-6, AC-108, Arka Abhay, EC-305612, IIVR-435, IIVR-401 and SA-2) were found as highly resistant during both the seasons, excluding four, (IIVR-342, IC-140906, Arka Anamika and Prabhani Kranti) during Summer season were found highly resistant and also showed resistant response during Rainy season including IIVR-198. Five parents were found to show highly susceptible response (IC-128883, IC-45806, IC-218844, IC-140934 and Pusa Sawani) in both the seasons excluding two (IC-218877 and IC-43720) were showed highly susceptible response in Rainy season only. The line IC-43720 expressed moderately resistant response in Summer season only.

Out of 51 F_1's (Table 4.6.2) 30 crosses were expressed high resistant response during both the seasons while two crosses (VRO-6 × Arka Anamika and Arka Abhay × Arka Anamika) were expressed high resistant response during Summer season. However, 3 crosses (IC-218844 × Prabhani Kranti, Arka Abhay × Prabhani Kranti and IC-140934 × Prabhani Kranti) were reported resistant reaction during both the seasons excluding 7 crosses (IC-128883 × Arka Anamika, IC-128883 × Prabhani Kranti, IC-218877 × Arka Anamika, IC-218877 × Prabhani Kranti, IC-43720 × Arka Anamika, IC-140934 × Arka Anamika and IC-140934 × Pusa Sawani) in Summer season and 4 crosses (VRO-6 × Arka Anamika, VRO-6 × Pusa Sawani, IC-218844 × Pusa Sawani and Arka Abhay × Arka Anamika) in Rainy season. The hybrid IIVR-342 × Pusa Sawani showed moderately susceptible reaction during both the seasons while 11 and 1 (IC-218844 × Pusa Sawani) crosses were showed moderately susceptible response during Rainy and Summer season, respectively. Only 2 F_1's (IC-128883 × Pusa Sawani and IC-218844 × Pusa Sawani) were found to express susceptible reaction during Rainy season. The hybrid (F_1's) VRO-5 × Arka Anamika **(Plate IV)**, AC-108 × Arka Anamika and SA-2 × Prabhani Kranti were best cross combinations for resistance against YVMV. None of the hybrids were found to be highly susceptible in either of the season.

Disease susceptible crop (IC-140934)

Disease resistant crop (VRO - 5 × Arka Anamika)

Plate IV: Incidence of Yellow vein mosaic virus in okra

4.7 Nature of gene action for yield and yield attributing traits

The estimated of genetic component of variance due to additive, dominance and degree of dominance for various plant characteristics are presented below.

In Rainy season (Table 4.7.1), most of the characters except number of ridges per fruit and ascorbic acid content showed that the dominance genetic component of variance was higher than additive component of variance. The degree of dominance was maximum for days to first flowering (7.59) followed by plant height (7.28), number of branches per plant (4.69) and minimum was found in fruit length (-3.91).

Among Summer season (Table 4.5.2), all of the traits expressed more dominance genetic component of variance as compare to additive variance except for fruit diameter (0.01) and number of ridges per fruit (0.01) i.e. equal to dominance variance. The degree of dominance ranged from -3.79 (fruit length) to 8.34 (number of fruits per plant).

Table 4.7.1: Estimation of genetic component of variance (additive and dominance) and degree of dominance (DD) and for 15 characters of okra during Rainy season.

S.No.	Characters	Genetic component of variance		Degree of Dominance
		Additive	Dominance	
1	Plant height (cm)	2.83	150.11	7.28
2	Stem diameter (cm)	0.01	0.05	2.24
3	Number of branches / plant	0.01	0.22	4.69
4	Number of nodes / plant	1.89	7.29	1.96
5	Internodal length (cm)	0.54	1.81	1.83
6	Days to first flowering	0.10	5.27	7.59
7	Days to 50 % flowering	0.57	4.09	2.68
8	Number of fruits / plant	0.27	0.67	1.57
9	Single fruit weight (g)	0.29	0.88	1.74
10	Fruit length (cm)	-0.03	0.46	-3.91
11	Fruit diameter (cm)	0.01	0.02	1.41
12	Fruit yield / plant (g)	107.72	202.98	1.37
13	Number of seeds / fruit	5.08	42.92	2.91
14	Number of ridges / fruit	0.01	0.01	1.00
15	Ascorbic acid (mg / 100 g)	0.68	0.56	0.90

Table 4.7.2: Estimation of genetic component of variance (additive and dominance) and degree of dominance (DD) for 15 characters of okra during Summer season.

S.No.	Characters	Genetic component of variance		Degree of Dominance
		Additive	Dominance	
1	Plant height (cm)	-5.06	62.94	-3.53
2	Stem diameter (cm)	0.01	0.02	1.41
3	Number of branches / plant	0.01	0.18	4.24
4	Number of nodes / plant	0.91	5.88	2.54
5	Internodal length (cm)	0.15	0.99	2.57
6	Days to first flowering	1.45	4.32	1.73
7	Days to 50 % flowering	1.19	2.49	1.45
8	Number of fruits / plant	0.02	1.39	8.34
9	Single fruit weight (g)	0.08	0.70	2.96
10	Fruit length (cm)	-0.03	0.43	-3.79
11	Fruit diameter (cm)	0.01	0.01	1.00
12	Fruit yield / plant (g)	27.82	163.88	2.43
13	Number of seeds / fruit	22.39	27.26	1.10
14	Number of ridges / fruit	0.01	0.01	1.00
15	Ascorbic acid (mg / 100 g)	0.51	0.42	0.91

4.8 Pod colour of parents and hybrids (F_1's)

The pod colour of 20 parents and their 51 F_1's are presented in Table 4.8.1 (parents) and Table 4.8.2 (hybrids). The fruits were generally green (G) in colour with varied colour intensity. Some of the parents had light green (LG) or reddish green (RG) or purple green (PG) coloured fruits. Among 71 (20 parents & 51 F_1's) genotypes, 65 green, 4 reddish green (IIVR-342, IIVR-342 × Arka Anamika, IIVR-342 × Pusa Sawani **(Plate V)** and IIVR-342 × Prabhani Kranti), one light green (IC-218877) and rest one was purple green (Arka Abhay) coloured fruited.

Table 4.8.1: Pod color of okra parents.

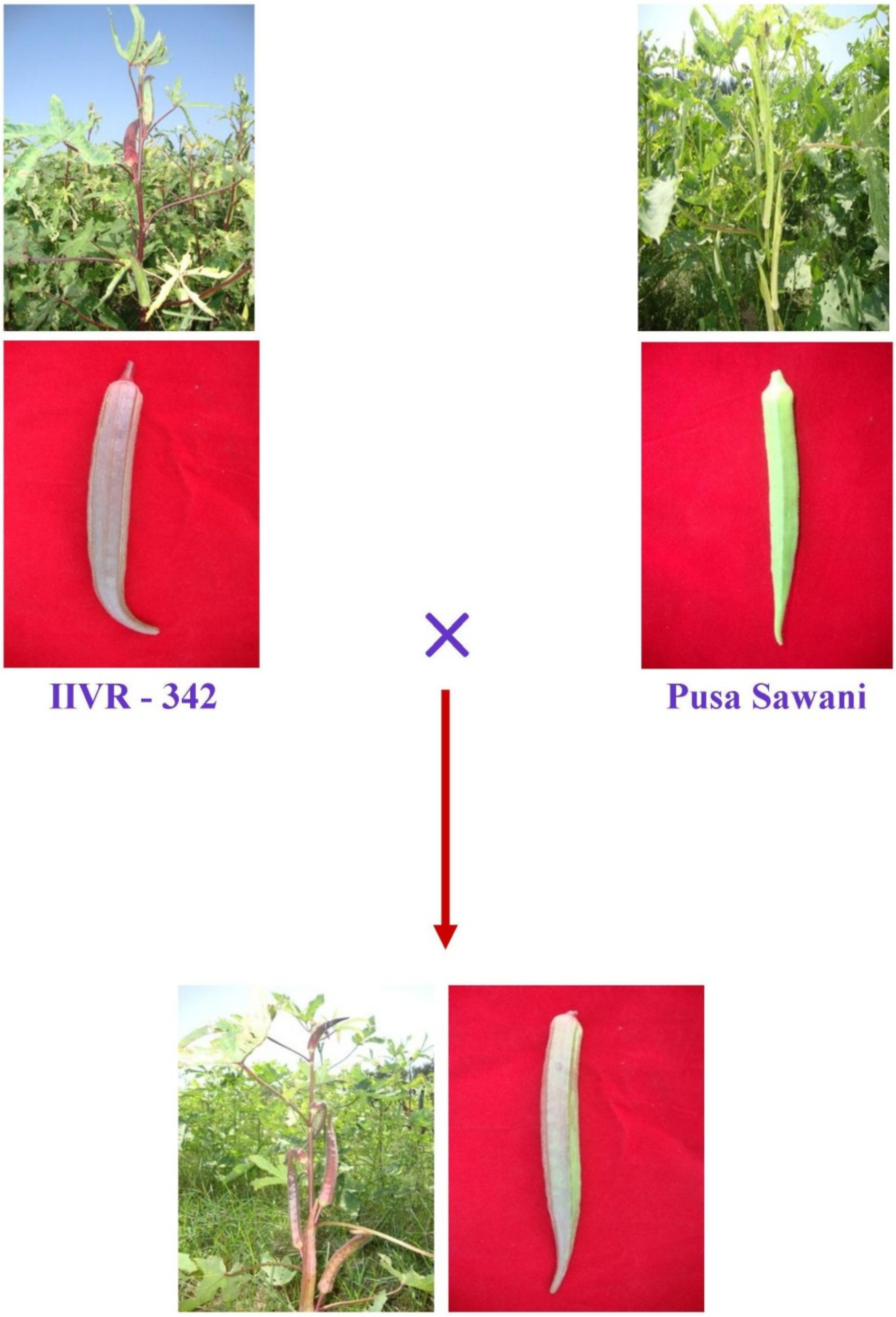
Parents	Pod color	Parents	Pod color	Parents	Pod color
IC – 128883	G	Arka Abhay	PG	IIVR-401	G
VRO-5	G	IC-43720	G	SA-2	G
VRO-6	G	IIVR-342	RG	IC-140934	G
AC-108	G	IC-140906	G	Arka Anamika	G
IC-45806	G	IIVR-198	G	Pusa Sawani	G
IC-218877	LG	EC – 305612	G	Prabhani Kranti	G
IC-218844	G	IIVR-435	G		

Where, G = Green, LG = Light green, PG = Purple green, RG = Reddish green.

Table 4.8.2: Pod color of okra hybrids (F_1's).

Hybrids	Pod color	Hybrids	Pod color	Hybrids	Pod color
IC - 128883 × AA	G	IC - 218877 × PK	G	IIVR-198 × PS	G
IC - 128883 × PS	G	IC - 218844 × AA	G	IIVR-198 × PK	G
IC - 128883 × PK	G	IC - 218844 × PS	G	EC - 305612 × AA	G
VRO - 5 × AA	G	IC - 218844 × PK	G	EC - 305612 × PS	G
VRO - 5 × PS	G	Arka Abhay × AA	G	EC - 305612 × PK	G
VRO - 5 × PK	G	Arka Abhay × PS	G	IIVR-435 × AA	G
VRO - 6 × AA	G	Arka Abhay × PK	G	IIVR-435 × PS	G
VRO - 6 × PS	G	IC - 43720 × AA	G	IIVR-435 × PK	G
VRO - 6 × PK	G	IC - 43720 × PS	G	IIVR-401 × AA	G
AC - 108 × AA	G	IC - 43720 × PK	G	IIVR-401 × PS	G
AC - 108 × PS	G	IIVR-342 × AA	RG	IIVR-401 × PK	G
AC - 108 × PK	G	IIVR-342 × PS	RG	SA - 2 × AA	G
IC - 45806 × AA	G	IIVR-342 × PK	RG	SA - 2 × PS	G
IC - 45806 × PS	G	IC - 140906 × AA	G	SA - 2 × PK	G
IC - 45806 × PK	G	IC - 140906 × PS	G	IC - 140934 × AA	G
IC - 218877 × AA	G	IC - 140906 × PK	G	IC - 140934 × PS	G
IC - 218877 × PS	G	IIVR-198 × AA	G	IC - 140934 × PK	G

*



IIVR - 342 × Pusa Sawani

Plate V: Pod colour in okra

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Chapter V

DISCUSSION

Development of high yielding variety is the major objective of any breeding programme. But, genetic architecture of yield is very complex. The breeder can not over look the possibility of obtaining genetic combination with greater yield potential than those available in the varieties under cultivation. Therefore, the data obtained from line × tester design were analysed for GCA of the parents and SCA of the hybrids by the method proposed by Kempthorne (1957). The heterosis was estimated as per cent increase or decrease over the better parent and standard variety as suggested by Fonseca and Petterson (1968). Hence, the nature and magnitude of gene action involved in the expression of particular quantitative traits provides a club about the type of breeding procedures that should preferably be adopted for the improvement of particular traits. The knowledge of heritability along with genetic advance is considered to be useful in predicting the response to selection in the offing generation. Therefore, the present investigation was undertaken by using 17 lines and 3 testers to develop set of 51 crosses for two different seasons (Rainy and Summer) to obtain genetic information on the above aspects by using relevant analysed and estimation of various genetic parameters. The important features of the findings are discussed in the light of pertinent literature in the subsequent sub-heads.

5.1 General and specific combining ability effects.

5.2 Heterobeltiosis and standard heterosis for yield and its component traits.

5.3 Studies on genetic parameters like variability, heritability and genetic advance.

5.4 Correlation and path coefficient analysis among the different economical traits.

5.5 Study on the genetics of resistance against yellow vein mosaic virus (YVMV).

5.6 Nature of gene action for yield and yield attributing traits.

5.7 Pod colour of parents and hybrids (F_1's).

5.1 Combining ability effects

The choice of parents for any crop improvement programme is an essential step in providing outstanding individual hybrids. During recent decades, the breeding methodology in autogamous crop has been mainly depending upon the selection of the parents for hybridization on the basis of *per se* performance followed by single plant selection in segregating populations. Combining ability is an effective tool to identify the suitable parents and crosses for their use in effective crop improvement programme (Sprague and Tatum, 1942). The concept of combining ability plays a pivotal role together with *per se* performance of parents, hybrids and heterotic response helps breeders in selecting potential parents, which combine well in producing promising hybrids for systematic breeding programme. It is also helpful to understanding the nature of genetic variations in the population, which is essential to workout appropriate breeding strategy. Evaluation of parents for combining ability also permits an indication of relative magnitude of additive or non-additive variance for characters under study. General combining ability (GCA) largely involves additive genetic effects, while specific combining ability (SCA) effects contain non-additive type of gene action (Griffing, 1956b; and Sprague and Tatum, 1942).

In present research work, the combining ability was carried out through line × tester techniques of Kempthorne (1957) in order to sort out good combiners that can be utilised in the production of commercial hybrids. In okra, several workers have used line × tester analysis to evaluate general and specific combining ability.

5.1.1 Analysis of variance for combining ability

The analysis of variance for combining ability indicated that mean sum of square due to lines (females) were highly significant for all the characters in both seasons indicating genetic diversify among the lines, this highest contribution by these characters towards combining ability. Variation in tester was also significant for 13 characters in Rainy season and 12 characters in Summer season. The female × male interaction component also emerged significant for all the 15 characters in both seasons, which proved that the combining ability contributed heavily in the expression of these traits. Similar findings were reported by Singh and Singh (2003), Kumar *et al.* (2005) and Singh *et al.* (2009).

5.1.2 General Combining Ability

The information regarding general combining ability (GCA) effects of parents is of prime importance as it helps in successful prediction of genetic potential of hybrids (F_1's), which yields desirable individuals in segregating population of crop. Estimates of GCA effects showed that it was difficult to pickup a good combiner for all the characters together as the combining ability effect were not consistent yield attributing traits. It was not possible because of low or negative association of characters, whereas overall results indicated that seven lines and one tester having positive significant GCA effects for fruit yield per plant in which VRO-5 and VRO-6 are most useful lines for both seasons. Among these, VRO-5 also emerged as good general combiner for internodal length, single fruit weight, fruit yield per plant and ascorbic acid content during Summer season, whereas for number of fruits per plant, fruit length, fruit yield per plant and ascorbic acid content during Rainy season. During Rainy season, IIVR-401 for plant height and stem diameter, IIVR-435 for number of branches per plant, VRO-5 for fruit yield per plant, ascorbic acid content and single fruit weight, IIVR-198 for number of nodes per plant and internodal length, IC-43720 for days to first flowering and days to 50 per cent flowering, IC-128883 for number of fruits per plant, IC-140934 for fruit length, IC-218844 for fruit diameter and AC-108 for number of seeds per fruit were most promising general combiners. Whereas during Summer season, IIVR-401 for plant height, stem diameter and single fruit weight, IIVR-435 for number of branches per plant, IIVR-198 for number of nodes per plant, internodal length and number of fruits per plant, SA-2 for days to first flowering and days to 50 per cent flowering, IC-140934 for fruit length, IC-218844 for fruit diameter, VRO-6 for fruit yield per plant, AC-108 for number of seeds per fruit and VRO-5 for ascorbic acid content were most desirable hybrids on the basis of GCA effects.

In an attempt to identify most desirable parents based on GCA effects as well as *per se* performance, 3 best parents were considered for each character (Table 4.2.3a, and Table 4.2.3b). Finally common parent(s), if any, was/were identified based on both criteria. Taking into account the above two criteria the Rainy season parent IIVR-401 was found to be the most desirable for plant height, EC-305612 was most desirable for stem diameter, IIVR-435 was most desirable for number of branches per plant, VRO-6 was most desirable for number of nodes per plant and fruit yield per plant, IC-218844 was most desirable for days to first flowering, days to 50 per cent flowering and number of seeds per fruit, IC-128883 was most desirable for number of fruits per plant and VRO-5 was most desirable for single fruit weight and ascorbic acid content. However in Summer season the most desirable parents were EC-305612 for stem diameter, IIVR-435 for number of branches per plant and days to 50 per cent flowering

VRO-5 for internodal length, EC-305612 for number of fruits per plant and VRO-6 for single fruit weight, fruit yield per plant and ascorbic acid content. Commonness of certain parents(s) both for GCA effects and *per se* performance suggests that mean value of parent for a particular character may have some predictive significance for its GCA effects for the characters. Many workers have reported similar findings in okra (Jawili and Rasco, 1990; Patel *et al.*, 1994; Nichal *et al.*, 2000; Sood and Kalia, 2001; Saini *et al.* 2005; Singh *et al.*, 2006; Dahake and Bangar, 2006; Eswaran *et al.*, 2007; Srivastava *et al.*, 2008 and Singh *et al.,* 2009).

5.1.3 Specific combining ability

The specific combining ability is associated with interaction effects, which may due to dominance and epistatic component of variation that are non-fixable in nature. Hence, it can be utilized in generation like F_1 in evolving of good F_1 hybrid. In the present study, none of the cross combination to have high SCA for all the characters under study.

In Rainy season the cross combinations, Arka Abhay × Arka Anamika for plant height and stem diameter, IIVR-401 × Prabhani Kranti for number of branches per plant, IIVR-198 × Prabhani Kranti for number of nodes per plant, IIVR-342 × Pusa Sawani for internodal length, IC-43720 × Arka Anamika for days to first flowering, AC-108 × Arka Anamika for days to 50 per cent flowering, EC-305612 × Pusa Sawani for number of fruits per plant and ascorbic acid content, IC-218844 × Arka Anamika for single fruit weight, VRO-5 × Arka Anamika for fruit length and IIVR-342 × Arka Anamika for fruit diameter, VRO-5 × Pusa Sawani for fruit yield per plant and SA-2 × Arka Anamika for number of seeds per fruit had high significant desirable SCA effects.

However in Summer season, the most promising hybrids on the basis of SCA effects were Arka Abhay × Arka Anamika for plant height and fruit yield per plant, VRO-5 × Pusa Sawani for stem diameter, IIVR-401 × Prabhani Kranti for number of branches per plant and number of nodes per plant, VRO-5 × Arka Anamika for internodal length, fruit length and ascorbic acid content, VRO-6 × Arka Anamika for days to first flowering, AC-108 × Pusa Sawani for days to 50 per cent flowering and fruit diameter, IIVR-198 × Prabhani Kranti for number of fruits per plant, IC-218844 × Prabhani Kranti for single fruit weight and IC-45806 × Pusa Sawani for number of seeds per fruit expressed high significant SCA effects in desirable direction.

In general, it is also interesting to note that the best cross, which expressed higher *per se* performance and SCA effects for particular trait was derived from such plant. In an attempt to identify most desirable cross combinations based on SCA effect and *per se* performance three best crosses were considered for each trait (Table 4.2.5a and Table 4.2.5b). Finally, common cross(s) if any was/were identified based on both criteria in both the seasons separately.

In Rainy season, taking into account to above criteria crosses, Arka Abhay × Arka Anamika was found to be the most desirable combination for plant height and stem diameter, EC-305612 × Arka Anamika for number of branches per plant, IIVR-198 × Prabhani Kranti for number of nodes per plant, VRO-5 × Arka Anamika for internodal length, IC-43720 × Arka Anamika for days to first flowering, EC-305612 × Pusa Sawani for number of fruits per plant, VRO-5 × Pusa Sawani for single fruit weight and fruit yield per plant, IC-218844 × Arka Anamika for fruit length and fruit diameter, SA-2 × Arka Anamika for number of seeds per fruit and Arka Abhay × Prabhani Kranti for ascorbic acid content.

However, during Summer season the most desirable cross combinations based on *per se* performance and SCA effects were, IIVR-198 × Arka Anamika was found to be the most desirable cross combination for plant height, IIVR-198 × Prabhani Kranti for stem diameter and number of fruits per plant, SA-2 × Pusa Sawani for number of branches per plant, VRO-5 × Arka Anamika for internodal length, VRO-6 × Arka Anamika for days to first flowering and fruit diameter, IIVR-342 × Prabhani Kranti for days to 50 per cent flowering, IC-218844 × Prabhani Kranti for single fruit weight, IC-140934 × Pusa Sawani for fruit length, Arka Abhay × Arka Anamika for fruit yield per plant and ascorbic acid content and IC-45806 × Pusa Sawani for number of seeds per fruit. Dahake and Bangar (2006) also reported that Arka Anamika is the best combiner and can be used as a parent in exploiting heterosis for fruit yield.

Some other crosses are found to have good common SCA effects and *per se* performance for one or two most desirable traits. Among the crosses, which has better *per se* performance and sca effects, involving high × high, high × low and low × low combiners. High × high combiners could be due to additive and additive × additive type of gene actions, which are fixable in nature (Griffing, 1956a). However, in majority of these cases the crosses exhibiting high sca effects were found to have either both or one of the parents as good general combiner for the character under study. The above area in conformity with the findings of Pratap *et al.* (1981), Dhankar *et al.* (1996) and Singh *et al.* (2005) revealing occurrence of high sca estimates not only in crosses involving high × high combiner parents but also from other combinations like high × low and low × low combiner parents.

Desirable sca effects for earliness yield and yield related traits were also reported by Sharma and Mahajan (1978) for assessing superiority of hybrid generally its sca effects. Further, it was also involved the best combination for most of the characters generally involved one good and one poor general combiner or both poor general combiners crosses with high sca where at least one of the parent was good combiner in these crosses. Poshiya and Vashi (1995); Pal and Hossain (2000); Sood and Kalia (2001); Kumar *et al.* (2005); Dahake *et al.* (2006); Adeniji and Kehinde (2007); Eswaran *et al.* (2007); Srivastava *et al.* (2008) and Weerasekara *et al.* (2008) observed specific combining ability (SCA) in okra for different crosses for different traits.

5.2 Heterobeltiosis and standard heterosis for different characters

Heterosis was computed as per cent increase or decrease in F_1's value over better parents (heterobeltiosis) and over the best commercial variety (standard heterosis). In the present investigation, the relative magnitude of heterosis over better parents and standard variety (VRO-6) were studied for 15 characters in 51 F_1's. The nature and magnitude of hybrid vigour differed for different traits in various hybrid combinations are discussed below.

Medium plant height is the desirable trait for okra crop. The better and standard parent heterosis for plant height ranged from -27.13 to 20.28 and -27.59 to 19.52 per cent, respectively for Rainy season crop and -33.47 to 11.03 and -33.02 to 11.79 per cent, respectively for Summer crop. Sood and Kalia (2001) and Singh and Syamal (2006) also found the similar pattern of heterosis for plant height in okra. Five hybrids were significantly taller than better parent and 7 hybrids showed significant positive heterosis over standard parent in Rainy season and one hybrid (IIVR-198 × Arka Anamika) showed positive significant heterosis over better and standard parent during Summer season. Present observations are close agreement with findings of several workers (Singh, 1983; Kumbhani *et al.*, 1993; Ahmed *et al.*, 1999; Pawar *et al.,* 1999b and Pitchaimuthu and Dutta, 2002).

More stem diameter is desirable traits because it is important traits for evolving of vigorous plants that produces more yield. The better parent heterosis was ranged from -32.81 to 36.54 per cent (VRO-5 × Pusa Sawani) and standard parent heterosis ranged from -29.39 to 23.15 per cent (Arka Abhay × Arka Anamika) for Rainy season crop. Whereas, better parent heterosis ranged from -24.59 to 28.26 per cent (IC-140906 × Pusa Sawani) for Summer season crop. Out of 51 F_1's, 4 and 6 hybrids showed better and standard parent heterosis, respectively during Rainy season and 19 hybrids showed negative heterosis for both better and standard parent heterosis during Summer season.

The heterosis for number of branches per plant ranged from -39.63 to 57.90 per cent (IIVR-435 × Pusa Sawani) over standard parent during Rainy season. Out of 51 hybrids only 7 hybrids showed positive heterosis with significant values over standard parent, during Rainy season crop but none were found for Summer season crop. Ahmed *et al.* (1999), Pawar *et al.* (1999b), Singh and Syamal (2006) and Desai *et al.* (2007) had also found heterosis for number of branches per plant.

For number of nodes per plant, the heterosis over better parent and standard variety ranged from -42.14 to 121.33 per cent (IIVR-198 × Prabhani Kranti) and -48.78 to 33.90 per cent (IIVR-198 × Prabhani Kranti), respectively for Rainy season crop. However, the better parent heterosis for Summer season crop ranged from -46.71 to 86.45 per cent (IIVR-401 × Prabhani Kranti). These findings are in line with those of Ahmed *et al.* (1999), Pawar *et al.* (1999b) and Desai *et al.* (2007).

Negative estimates were considered desirable for internodal length for which heterosis over better parent ranged from -44.93 (IIVR-198 × Prabhani Kranti) to 53.50 per cent (IIVR-435 × Pusa

Sawani) and heterosis over standard parent ranged from -32.98 (VRO-5 × Arka Anamika) to 49.76 per cent (IIVR-342 × Arka Anamika) during Rainy season. Hence, in Summer season crop better parent heterosis ranged from -42.67 (IIVR-401 × Pusa Sawani) to 155.00 per cent (VRO-5 × Prabhani Kranti). Among the hybrids (F_1's) 5 and 2 crosses during Rainy season expressed negative significant better and standard parent heterosis, respectively. However, only, 10 crosses showed negative significant better parent heterosis during Summer season. Kumbhnai *et al.* (1993); Ahmed *et al.* (1999) and Borgaonkar *et al.* (2005) have also been reported negative heterosis for internodal length.

For days to first flowering, negative heterosis is usually desirable because this will results the hybrids to mature earlier as compared to parents, there by increasing their productivity per day per unit area. Out of 51 F_1's, only 2 crosses exhibited for both significant negative better and standard parent heterosis during Rainy season. Whereas, 4 and 1 crosses exhibited negative significant better and standard parent heterosis, respectively during Summer season. Out of them the most desirable hybrids for this traits was IC-43720 × Arka Anamika (BPH = -12.82 %, SPH = -16.40 %) during Rainy season. However, IIVR-401 × Prabhani Kranti (BPH = -10.26 %, SPH = -7.89 %) was most promising hybrid during Summer season. Patil *et al.* (1996); Ahmad *et al.* (1999); Pitchaimuthu and Dutta (2002) and Singh and Syamal (2006) also reported negative heterosis for earliness.

The heterosis over better parents and standard variety for days to 50 per cent flowering ranged from -10.00 (IC-43720 × Arka Anamika) to 24.00 per cent and -6.25 (IC-43720 × Arka Anamika) to 29.17 per cent, respectively during Rainy season. However -7.84 (IC-128883 × Arka Anamika) to 12.50 per cent and -6.25 (SA-2 × Prabhani Kranti) to 12.50 per cent better and standard parent heterosis, respectively during Summer season. Heterosis for this trait has been reported by Muthukrishnan and Irulappan (1981) and Yadav *et al.* (2007).

Number of fruits per plant is one of the most important component of yield in respect of which hybrid with positive heterosis are desirable. The results revealed that 3 and 8 crosses expressed heterosis in desirable direction with significant value when tested against, better parent during Rainy and Summer season, respectively. The highest positive significant heterosis was found in EC-305612 × Pusa Sawani (26.10%) over better parent during Rainy season. In Summer season crop out of 51 crosses only 8 and 2 crosses were showed positive significant better and standard parent heterosis, respectively. The hybrid EC-305612 × Arka Anamika (15.32%) showed maximum positive significant standard parent heterosis, while the cross IIVR-198 × Prabhani Kranti (61.27%) had maximum positive significant better parent heterosis during Summer season. In general the hybrid with highest yield also expressed high heterosis for this trait. The work of Singh and Sharma (1990); Panda and Singh (1999); Borgaonkar *et al.* (2005); Jindal and Ghai (2005) and Desai *et al.* (2007) also supported the present findings that heterosis in yield was due to increased number of fruits per plant.

Heterosis in respect of single fruit weight was expressed in positive as well as negative direction, which is in conformity with the findings of Singh and Sharma (1990) and Sivagamasundhari *et al.* (1992). In the present study, heterosis for fruit weight was found up to 34.36 and 18.90 per cent over better parent and standard variety, respectively during Rainy season and 36.17 and 19.36 per cent over better and standard parent, respectively during Summer season. The high heterosis for yield seems to increase in size and weight of pods rather than increase in number of fruits. Singh and Syamal (2006) and Singh *et al.* (2009) have reported heterosis for yield in okra ranged from 27.32 to 71.84 per cent.

The hybrids with positive heterosis are desirable for fruit length. Heterosis for fruit length in general, was respectively low and it was expressed in negative direction. Heterosis for fruit length during Rainy season ranged from -15.58 to 26.26 per cent (IC-218844 × Arka Anamika) and -15.58 to 18.38 (VRO-5 × Arka Anamika) over better and standard parent, respectively. However, heterosis during Summer season ranged from -17.79 to 23.26 per cent (IC-140934 × Pusa Sawani) and -21.16 to 11.95 per cent (IC-140934 × Pusa Sawani) over better and standard parent, respectively. The present observations are in accordance with earlier findings of Singh (1983); Singh and Sharma (1990); Kumbhani *et al.* (1993) and Pawar *et al.* (1999b), who observed positive as well as negative heterosis for fruit length. They also viewed that heterosis in pod yield depended largely on the heterosis for fruit length.

The heterosis for fruit diameter ranged from -18.75 to 20.00 per cent over better parent and -13.33 to 20.00 per cent over standard parent during Rainy season. The hybrid IC-218844 × Arka Anamika was found the most promising hybrid for this trait during the both seasons. In Summer season, heterosis ranged from -18.75 to 20.00 per cent over better parent. Heterosis for this character has been reported by Singh (1983).

Fruit yield per plant being a complex trait, is a multiplicative product of several basic component traits of yield. The heterosis for fruit yield ranged from -39.79 to 37.80 per cent (VRO-5 × Pusa Sawani) over better parent during Rainy season. Whereas, the heterosis ranged from -42.78 to 55.00 per cent (Arka Abhay × Arka Anamika) and -5.29 to 11.98 per cent (Arka Abhay × Arka Anamika) over better parent and standard variety (VRO-6), respectively during

Summer season. Increased yield in heterotic hybrids in okra has been observed in the present investigation is in conformity with earlier workers (Singh, 1983; Poshiya and Shukla, 1986; Singh and Sharma, 1990; Panda and Singh, 1999; Nichal *et al.*, 2000; Desai *et al.*, 2007; Singh *et al.*, 2007; and Hosamani *et al.*, 2008).

The number of seeds per pod is undesirable character for edible fruit yield, negative significant heterosis is desirable for number of seeds per fruit. The heterosis ranged from -38.97 (SA-2 × Arka Anamika) to 60.20 per cent (Arka Abhay × Arka Anamika) over better parent and maximum negative and desirable heterosis was found in SA-2 × Arka Anamika (-46.33%) over standard parent (VRO-6) during Rainy season. However, better parent heterosis ranged from -30.94 (SA-2 × Pusa Sawani) to 62.18 per cent during Summer season, however the highest standard parent heterosis in desirable direction was found in IC-45806 × Pusa Sawani (-36.16%). Among 51 hybrids only 9 and 39 during Rainy season and 8 and 31 hybrids during Summer season expressed desirable negative heterosis over better and standard parent, respectively. Similar results for useful negative heterosis were observed by Wankhade *et al.* (1997) and Singh and Syamal (2006).

For number of ridges per fruit negative heterosis is desirable. Out of 51 crosses 3 expressed positive significant better and standard parent heterosis during both seasons. None of the hybrids expressed useful negative significant heterosis over better and standard parent in both seasons. The cross IC-43720 × Prabhani Kranti had maximum better and standard parent heterosis during both the seasons. Similar trend of heterosis also found by Pathak and Syamal (1997).

The positive heterosis is desirable and useful for ascorbic acid content. The heterosis ranged from -38.50 to 20.97 per cent (EC-305612 × Pusa Sawani) and -30.39 to 20.15 per cent (Arka Abhay ×

Arka Anamika) over better parent during Rainy and Summer season, respectively. Present finding is also in accordance with the observations made by Pawar *et al.*, 1999b; Indu Rani *et al.*, 2003; Jindal and Ghai, 2005 and Senthil Kumar *et al.*, 2007.

5.3 Variability, heritability and expected genetic advance

The genotypic variability is the raw material of plant breeding industry. Breeding strategy in any vegetable crop improvement depends upon the presence of biodiversity in plant population. Before aiming at an improvement in yield it is necessary to have knowledge of genetic variability present in the populations, heritability of various characters and probable genetic advance to be expected from selection of superior lines. Hence the present study was conducted with 20 parents and their 51 F_1's in two different season (Rainy and Summer) for estimating range, coefficient of variation (GCV and PCV), heritability, expected genetic advance and genetic gain for 15 characters in okra.

The information about the genetic variability is of paramount importance in a crop improvement programme. The extent of genotypic variability indicates the amenability of a given character for its improvement. Phenotypic coefficient of variation (PCV) is the result of genotypic (GCV) and environmental interaction. The magnitude of genotypic coefficient of variation in relation to phenotypic coefficient of variation is of interest to breeders as the variation on account of the former is only transmitted to progeny.

The amount of PCV was higher in magnitude than GCV for all the traits. Higher GCV was estimated in the present investigation for number of branches per plant, fruit yield per plant, internodal length and number of nodes per plant indicating that there is greater possibility of utilisation of variation for these traits for further improvement in yield and in contrast to this, there was very less chance of further improvement for days to 50 per cent flowering, days to first flowering, number of ridges per fruit, fruit diameter and fruit length as indicated by its low estimates of genotypic and phenotypic coefficients of variation. The findings are in line with those of Yadav (1986), Dhankar and Dhankar (2002), Bendale *et al.* (2003), Indu Rani *et al.* (2003), Bendale *et al.* (2004), Indu Rani and Veerangavathatham (2005), Mehta *et al.* (2006) and Singh *et al.* (2008).

The knowledge about heritability of traits is much important to the breeder since it indicated the possibility and extent to which improvement is possible through selection (Robinson *et al.*, 1949). It is a measure of genetic relationship between parents and progeny and has been widely used in determining the degree to which a character may be transmitted from parent to off-spring. High heritability alone is not enough to make efficient selection in the advanced generations unless accompanied by substantial amount of genetic advance and genetic gain. Burton (1952) pointed out that the heritability in combination with intensity of selection and amount of variability present in population influences the gains to be obtained from selection. Estimates of heritability and genetic advance are important for assessment of effectiveness of selection and expected genetic gain which could be realised by selection in a population of genetically variable individuals.

In the present study, high heritability were obtained for all traits specially for number of ridges per fruit, number of branches per plant, ascorbic acid content, number of fruits per plant, number of seeds per fruit, number of nodes per plant, fruit yield per plant and single fruit weight. A high estimates heritability would means that selection can be effectively made on phenotypic basis by mass selection, however, progeny testing would be required if heritability is low and environmental influence are high. High heritability for these traits has been reported by Bendale *et al.* (2003), Bello *et al.* (2006), Kumar *et al.* (2007) and Singh *et al.* (2007).

The genetic advance (GA) and genetic gain (GG) are another important selection parameter, which are although independent and present the expected genetic advance and genetic gain under selection. It measures the differences between the mean genotypic value of the selected lines and mean genotypic value of original population from which these were selected. The high genetic advance and genetic gain were recorded for fruit yield per plant, number of seeds per fruit and plant height. High heritability coupled with high genetic advance and genetic gain are in close agreement with the findings of Singh and Singh (1979); Indu Rani and Veerangavathatham (2005); Yadav *et al.* (2007); Kushwaha *et al.* (2007) and Singh *et al.* (2008).

5.4.1 Phenotypic and genotypic correlation coefficient

The phenotypic and genotypic correlation coefficients computed between fifteen characters under study for parents and their F_1's in two different seasons (Rainy and Summer) are presented in Table 4.5.1a (Rainy season parents), Table 4.5.1c (Summer season parents), Table 4.5.1b (Rainy season F_1's) and Table 4.5.1d (Summer season F_1's).

The genotypic correlation coefficients were higher in magnitude than phenotypic correlations for most of the traits barring few exceptions indicating inherent genetic association. Genotypic as well as phenotypic correlation coefficients between any two traits had in general same sign whether negative or positive. The agreement between the phenotypic and genotypic correlations indicates greater importance of genetic variability with common effects than environmental variability with common effects. They could occur if the environmental pertaining to the expression of the two traits has small and similar effect.

In Rainy season parents, only 13 and 4 combinations showed significant positive and negative correlation coefficients, respectively. The single fruit weight (P = 0.720, G = 0.826) had highest positive significant correlation followed by number of fruits per plant (P = 0.642, G = 0.722) with number of seeds per fruit and number of seeds per fruit (P = 0.634, G = 0.772) with fruit yield per plant. However, the highest negative significant correlation was found in number of nodes per plant (P = -0.777, G = -0.818) with internodal length. Among Rainy season F_1's, only 16 and 5 combinations were expressed positive and negative significant correlations, respectively. In all the combinations plant height (P = 0.707, G = 0.880) had maximum positive significant correlation with stem diameter followed by single fruit weight (P = 0.700, G = 0.762) and number of fruits per plant (P = 0.652, G = 0.658) with number of seeds per fruit. Whereas number of nodes per plant (P = -0.745, G = -0.829) expressed maximum negative and significant correlation with internodal length. Thus, these characters emerged as most important associates of fruit yield per plant in okra.

In Summer season parents, number of fruits per plant (P = 0.872, G = 0.878) had highest positive significant correlation followed by single fruit weight (P = 0.663, G = 0.694) with number of seeds per fruit. The highest negative significant correlation was found in number of nodes per plant (P = -0.709, G = -0.777) with internodal length. In all the parents of Summer season, only 9 and 6 combinations were observed to express significant correlation in positive and negative directions, respectively. Akinyele and Osekita (2006) also found that number of fruits per plant had highest genotypic correlation coefficient and it should be seen as major determiner of final yield.

For Summer season hybrids, only 12 and 5 combinations were expressed positive and negative correlations, respectively. The highest positive significant correlation were observed in number of fruits per plant (P = 0.813, G = 0.831) with number of seeds per fruit followed by plant height with number of nodes per plant (P = 0.717, G = 0.761) and stem diameter (P = 0.719, G = 0.641). However, the highest negative significant correlation were found in number of nodes per plant (P = -0.720, G = -0.734) with internodal length. Similar results for this trait had been observed by Dhall *et al.* (2000); Yadav and Dhankar (2001); Chhatrola and Monpara (2005); Bello *et al.* (2006); Patro and Sankar (2006), Singh *et al.* (2006) and Sazia Ali *et al.* (2008).

In order to take care of occurrence of negative as well as positive correlations between important yield components, a reasonable compromise is required for attaining their proper balance for maximum combined contribution towards manifestation of yield. Most of the correlation coefficients obtained in present study are in conforming to previous reports in okra (Dhankar and Dhankar, 2002; Jaiprakasnnarayan and Mulge, 2004; Patro and Sankar, 2004 and Singh *et al.*, 2007).

5.4.2 Path coefficient analysis

Path coefficient analysis is a tool to partition the observed correlation coefficient into direct as well as indirect effects of yield components or fruit yield per plant to provide more clear picture of character association for formulating efficient selection strategy. Path analysis differs from simple correlation in that it points out the causes and their relative importance. Whereas, the latter measures simply the mutual association ignoring the causation.

In the present study, the direct effect of several components on fruit yield per plant was estimates at genotypic level for parents and their F_1's in two different seasons Rainy as well as in Summer season.

In Rainy season parents, number of fruits per plant (1.114) had maximum positive direct effect on fruit yield per plant followed by plant height (0.704) and single fruit weight (0.628). Whereas, the highest negative direct effect was found in stem diameter (-0.644). However, high positive indirect effects were found in ascorbic acid content (0.728) followed by number of seeds per fruit (0.620), fruit length (0.496) and days to first flowering (0.491) via. number of fruits per plant. While, the highest negative indirect effect was found in plant height (-0.445) via. single fruit weight.

Among Rainy season hybrids, plant height (1.981) expressed maximum positive direct effect on fruit yield per plant followed by number of fruits per plant (1.651) and stem diameter (1.572). However, the highest negative direct effect was found in number of nodes per plant (-6.760). The highest positive indirect effect was found in internodal length (5.606) via. number of nodes per plant followed by number of nodes per plant (4.445) via. internodal length and fruit length (2.239) via. internodal length. The highest negative indirect effect was found in plant height (-4.120) via. number of nodes per plant. These characters have also been identified as major direct contributors towards fruit yield per plant in okra by earlier workers (Kamal *et al.*, 2003; Patro *et al.*, 2004; Bali *et al.*, 2005; Patro and Sankar, 2006 and Singh *et al.*, 2007).

In Summer season parents, the highest positive direct effect on fruit yield per plant was found in number of fruits per plant (0.733) followed by single fruit weight (0.421) and number of nodes per plant (0.126). However the highest negative direct effect was observed in number of branches per plant (-0.057). The high positive indirect effect were expressed in number of seeds per fruit (0.347) followed by number of nodes per plant (0.313) and stem diameter (0.283) via. number of fruits per plant. While highest negative indirect effect was observed in fruit diameter (-0.622) via. number of fruits per plant.

Among Summer season F_1's, the highest positive direct effect on yield was expressed in number of fruits per plant (0.825) followed by single fruit weight (0.559) and number of nodes per plant (0.295). Whereas, the highest negative direct effect was found in plant height (-0.137). The high positive indirect effect were expressed in stem diameter (0.494) followed by plant height (0.363), number of nodes per plant (0.348) via. number of fruits per plant. While, internodal length (-0.216) via. number of nodes per plant expressed high negative indirect effect. Such results have also been reported by Singh *et al.*, (2006); Akinyele and Osekita (2006) and Singh *et al.*, (2007) in okra.

5.5 Incidence of yellow vein mosaic virus (YVMV)

To evolve YVMV resistant variety is the major objective in okra breeding programme. Besides other adversities, the okra is very much susceptible to yellow vein mosaic disease which is caused by yellow vein mosaic virus (YVMV) and spread by white fly (*Bemesia tabaci*) (Chakraborty *et al.*, 1999). Due to the virus in abundance in common weed plants and easy access by the vector, its incidence remains often quite high varying from 30-100 per cent, there by inflicting much loss in fruit quality and yield of okra. The losses have been reported up to 93.3 per cent when the infected within 45 days after germination (Sastry and Singh, 1974). Now it has become the most serious disease of okra in India. In the humid and heavy rainfall areas, the plant fails to bears fruits when infected by this disease in early stage. However, Summer season crop gives reasonably good harvest and encouraging returns because the crop matures at the time the disease infects the crop.

Kulkarni (1924) first reported it in Bombay presidency. Later on, Uppal *et al.* (1940) established its virus nature. The search for genotypes resistance to yellow vein mosaic virus has been going for quite a long time. Efforts were made to transfer the resistance against this virus from the wild relatives to some exotic genotypes of the cultivated species of *Abelmoschus*. However, with the transfer of resistance to yellow vein mosaic virus, many undesirable characters were also transferred from the wild types to the cultivated types that hampered the breeding programme. Therefore, attempts were made for the vertical screening in *Abelmoschus esculentus* against the yellow vein mosaic virus and as a result some resistance/tolerant genotypes like Prabhani Kranti (Jambhale and Nerakar, 1986) and EMS-8 and Punjab Padmini (Arora *et al.*, 1992) were released for cultivation. Strictly immune or highly resistant varieties against this disease are rare. But now at this time some of the resistance varieties like Prabhani Kranti are going to be susceptible against YVMV disease due to evolution of new races of YVMV. Therefore, an effort has been made in the present study to explore the possibility of combating this disease by locating the source(s) of resistance to YVMV indifferent crosses (L × T) made and studied their field performance. The results of this field research work are being discussed below:

In 20 parental lines, 8 parents (VRO-5, VRO-6, AC-108, Arka Abhay, EC-305612, IIVR-435, IIVR-401 and SA-2) were found as highly resistant during both the seasons except four, (IIVR-342, IC-140906, Arka Anamika and Prabhani Kranti) during Summer season were found highly resistant and also showed resistant response during Rainy season including IIVR-198. Five parents were found to show highly susceptible response (IC-128883, IC-45806, IC-218844, IC-140934 and Pusa Sawani) in both the seasons excluding two (IC-218877 and IC-43720) were showed highly susceptible response in Rainy season only. The line IC-43720 expressed moderately resistant response in Summer season only. Bhagat (1999) also found that the variety Pusa Sawani expressed the highly susceptible response against yellow vein mosaic virus.

Among 51 crosses (F_1's), 30 were expressed high resistant response during both the season; two were expressed high resistant response during Summer season. Whereas, three crosses were expressed resistant reaction during both the season except six in Summer season and three in Rainy season. Only 2 F_1's were found to show susceptible reaction during Rainy season. The most promising three hybrids were VRO-5 × Arka Anamika, AC-108 × Arka Anamika and SA-2 × Prabhani Kranti against yellow vein mosaic virus disease. None of the hybrid was found to express highly susceptible reaction in either of the season.

Similar type of screening for disease incidence of yellow vein mosaic virus in okra has been reported by many workers (Bhagat, 2000; Ali *et al.*, 2000; Singh, 2000; Debnath and Nath, 2002, Singh *et al.*, 2002; Debnath and Nath, 2003; Vijaya, 2004; Prabhu and Warade, 2007; Anand *et al.*, 2007 and Bhattiprolu and Rahman, 2008).

It is remarkable to note that high resistance in the crosses is due to the present of resistance in respective parents for yellow vein mosaic. The incidence of the disease in a particular cross combination varied from season to season may be due to the influence in the environmental conditions.

5.6 Nature of gene action for yield and yield attributing traits

The information of nature and magnitude of gene action helps in formulating the effective breeding programme. In the present study the fruit yield per plant and various component traits influencing the expression of fruit yield were put to detailed genetic analysis using the line × tester mating approach and information obtained form the numerical estimates of gene action were discussed below:

The numerical analysis revealed that both additive and dominance gene action were important for the expression of the characters studied. A preponderance of dominance gene action over additive one was observed for all traits except for ascorbic acid content in both the seasons. In the present investigation, the predominant of non-additive gene action may be exploited by developing F_1 hybrid in okra. The importance of dominance gene effects in expression of yield per plant and other characters in okra had also been reported by Thaker *et al.*, 1981; Rani and Arora, 2003; Adeniji and Kehinde, 2004 and Arora and Ghai, 2007.

Whereas, additive component was found insignificant in most of the cases. The partial degree of dominance was expressed only in ascorbic acid content while other were found to expressed high (over dominance) degree of dominance. Similar gene effects have been reported in okra for different traits by Sood (2001) for fruit length, number of fruits per plant, fruit weight, plant height, number of nodes per plant, internodal length and fruit yield per plant while, Vishwakarma *et al.* (2002) for days to flowering, plant height, number of branches per plant, number of nodes per plant, length of internodes, fruit length, number of fruits per plant and fruit yield per plant. Dahake and Bangar (2006) and Singh *et al.* (2009) also reported that the both additive and non-additive (dominance) gene effects were important in the inheritance of quantitative characters in okra.

5.7 Pod colour of parents and hybrids (F_1's)

In okra the attractive green colour of pod is preferable. The pod colour of okra had simple inheritance (multiple allels) (Kalia and Padda, 1962). Among all 71 genotypes (20 parents and 51 F_1's), 65 were produce green colour pod, 4 reddish green (IIVR-342, IIVR-342 × Arka Anamika, IIVR-342 × Pusa Sawani and IIVR-342 × Prabhani Kranti), one light green (IC-218877) and rest one had purple green (Arka Abhay) pod colour. The green pod colour and reddish green pod colour had dominant gene effect. Present investigation is closed agreement with findings of several workers, Jasin (1967); Nath and Dutta (1970); Bhalekar *et al.* (2004) and Udengwu (2008).

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Chapter VI

SUMMARY AND CONCLUSION

The present investigation entitled "Hybrid breeding in okra [*Abelmoschus esculentus* (L.) Moench]" was carried out:

6.1 Analysis of variance of Line × Tester (17 female and 3 male) for 15 characters comprising parents and F_1 progenies.
6.2 Combining ability analysis.
6.3 Heterosis over better parent and standard variety.
6.4 Variability, heritability and expected genetic advance.
6.5 Correlation and path coefficient analysis.
6.6 Incidence of yellow vein mosaic virus (YVMV).
6.7 Nature of gene action for yield and yield attributing traits.
6.8 Pod colour of parents and hybrids (F_1's).

The study material for the present investigation composed of twenty genetically diverse parents (17 lines and 3 testers) and their 51 crosses for two seasons i.e. Rainy and Summer season.

The experiment consisted of a total of 71 treatments (17 lines, 3 testers & 51 F_1's) and was laid out in randomized block design with three replications during Rainy season, 2007 and Summer season, 2008. The observations were recorded for 17 characters namely, plant height, stem diameter, number of branches/plant, number of nodes/plant, internodal length, days to first flowering, days to 50 per cent flowering, number of fruits/plant, single fruit weight, fruit length, colour of pod, reaction to yellow vein mosaic virus and ascorbic acid content. The salient findings of the present investigations are summarized as follow:

1. The analysis of variance for treatments, parents and F_1's was highly significant for all the characters indicating that sufficient variability existed in the treatments, parents and F_1's for all the traits under study.

2. The analysis of variance for combining ability revealed significant differences due to female and female × male for all the traits during both the seasons while for males all the traits were significant except for days to 50 per cent flowering and number of fruits per plant during Rainy season and plant height, stem diameter and fruit length during Summer season indicating sufficient variability existed in the treatments, lines testers and their hybrids (F_1's) for all the traits during both the seasons i.e. Rainy and Summer.

3. Among the female parental lines, VRO-6 was found good general combiner for number of nodes/plant and fruit yield/plant. Other god combiner was VRO-5 noticed for single fruit weight and ascorbic acid content during Rainy season. However, during Summer season VRO-6 was also found good general combiner for single fruit weight, fruit yield/plant and ascorbic acid content followed by VRO-5.

4. Among male parental lines Arka Anamika was found to be good general combiner for most of the desirable traits.

5. Among 51 F_1's studied none of the crosses exhibited high sca effects for all the characters. However, the most promising combinations were Arka Abhay × Arka Anamika, VRO-5 × Pusa Sawani and IC-218844 × Arka Anamika for Rainy crop and Arka Abhay × Arka Anamika and VRO-6 × Arka Anamika for Summer season crop, expressed sca effects for fruit yield/plant as well as several other desirable traits, more commonly, plant height, stem diameter, internodal length, fruit length, fruit diameter fruit yield/plant and ascorbic acid content. These crosses can be exploited for isolating transgressive segregants in segregating generations.

6. Considering the estimates of gca effects and based on per se performance VRO-6 and VRO-5 were found the best parental lines for fruit yield/plant and several other its component traits.

7. Considering the estimates of sca effects and based on per se performance Arka Abhay × Arka Anamika, VRO-6 × Arka Anamika and VRO-5 × Pusa Sawani were found best hybrid during both the years for fruit yield/plant and several other its component traits. Therefore, due to exploitable yield potential these hybrids may be considered for future hybrid breeding programme.

8. In general, the magnitude as well as direction of heterosis over better parent and standard variety differed from two characters depending upon cross combinations.

9. The outstanding F_1 hybrid over better parents were IIVR-198 × Arka Anamika for plant height during both the season, Arka Abhay × Arka Anamika for stem diameter in Rainy and IC-140906 × Pusa Sawani in Summer season, IIVR-198 × Prabhani Kranti in Rainy season and IIVR-401 × Prabhani Kranti in Summer season for number of nodes per plant, IIVR-198 × Prabhani Kranti in Rainy season and IIVR-401 × Pusa Sawani in Summer season for internodal length, IIVR-401 × Prabhani Kranti in Summer season for days to first flowering, IC-43720 × Arka Anamika in Rainy season and IC-128883 × Arka Anamika in Summer season for days to 50 per cent flowering, EC-305612 × Pusa Sawani in Rainy season and IIVR-198 × Prabhani Kranti in Summer season for number of fruits per plant, IC-218844 × Arka Anamika in Rainy season and IIVR-401 × Arka Anamika in Summer season for single fruit weight, IC-218844 × Arka Anamika in Rainy season and IC-140934 × Pusa Sawani in

Summer season for fruit length, IC-218844 × Arka Anamika for fruit diameter in both season, VRO-5 × Pusa Sawani for fruit yield per plant, SA-2 × Arka Anamika in Rainy and SA-2 × Pusa Sawani in Summer season for number of seeds per fruit and EC-305612 × Pusa Sawani in Rainy season and Arka Abhay × Arka Anamika in Summer season for ascorbic acid content.

10. The outstanding F_1's over standard variety were IIVR-198 × Arka Anamika in both the seasons for plant height, IIVR-435 × Pusa Sawani in Rainy season and SA-2 × Pusa Sawani in Summer season for number of branches per plant, IIVR-198 × Prabhani Kranti in Rainy season and IIVR-401 × Prabhani Kranti in Summer season for number of nodes per plant, VRO-5 × Arka Anamika in Summer season for internodal length, IC-43720 × Arka Anamika in Rainy and IIVR-401 × Prabhani Kranti in Summer season for days to first flowering, IC-43720 × Arka Anamika in Rainy and SA-2 × Prabhani Kranti in Summer season for days to 50 per cent flowering, EC-305612 × Arka Anamika in Summer season for number of fruits per plant, VRO-5 × Pusa Sawani in Rainy season for single fruit weight, VRO-5 × Arka Anamika in Rainy season and IC-140934 × Pusa Sawani in Summer season for fruit length, IC-218844 × Arka Anamika in both the seasons for fruit diameter, Arka Abhay × Arka Anamika in Summer season for fruit yield per plant and SA-2 × Arka Anamika in Rainy season and IC-45806 × Pusa Sawani in Summer season for number of seeds per fruit.

11. Higher genotypic coefficient of variation (GCV) was observed for number of branches per plant, fruit yield per plant, internodal length and number of nodes per plant. Among the phenotypic coefficient of variation (PCV) was higher in magnitude than GCV for all the traits.

12. High broad sense heritability was estimated for all the traits especially for number of ridges per fruit, number of branches per plant, ascorbic acid content, number of fruits per plant, number of seeds per fruit, number of nodes per plant, fruit yield per plant and single fruit weight.

13. High expected genetic advance and genetic gain were recorded for fruit yield per plant, number of seeds per fruit and plant height.

14. Based on genotypic and phenotypic correlations single fruit weight, number of fruit per plant and number of seeds per fruit were identified as important fruit yield component in Rainy season. However, number of fruits per plant, plant height and stem diameter were most crucial yield component for Summer season.

15. Path coefficient analysis carried out at genotypic level revealed that number of fruit per plant exerted maximum positive direct effect on fruit yield per plant in Rainy parents, plant height in Rainy season F_1's, number of fruits per plant in Summer season parent and Summer season F_1's exerted maximum positive direct effect on fruit yield per plant. However, the highest positive indirect effect was found in ascorbic acid content via. number of fruits per plant for Rainy season parents, internodal length via. number of fruits per plant for Rainy season F_1's, number of seeds per fruit via. number of fruits per plant in Summer season parents and stem diameter via. number of fruits per plant in Summer season F_1's exerted maximum positive indirect effect on fruit yield per plant.

16. As yellow vein mosaic virus (YVMV) disease of okra has become a limiting factor in the successful cultivation of this crop, therefore an attempt was made to identify suitable breeding material would could be used for evolving varieties resistant to this virus. It has been observed that among 20 parents eight were found as highly resistant to YVMV during both the seasons and among 51 F_1's thirty were expressed as high resistant response to YVMV during both the seasons. The crosses VRO-5 × Arka Anamika, AC-108 × Arka Anamika and SA-2 × Prabhani Kranti were best cross combination for resistant against YVMV. It is remarkable to note that high resistance in the process is due to the presence in respective parents for this disease.

17. For most of the traits dominance gene action was more important than additive gene action especially fruit yield per plant, plant height and number of seeds per fruit showed slight over dominance.

18. The green pod colour and reddish green pod colour had dominant gene effect. Among all 71 genotypes green pod colour were found in 65 genotypes, reddish pod colour in 4 genotypes, 1 purple green colour and rest 1 was light green colour.

Based on the above findings following suggestions are made to plan efficient and effective breeding programmes for improving yield of okra:

(i) The lines like VRO-5, VRO-6, Arka Abhay, IC-218844 and testers like Arka Anamika prove to be the good general combiner and Arka Abhay × Arka Anamika, is the good specific combiner for most of the yield and yield attributing traits during both the seasons.

(ii) The selection of parents based on morphological variation and genetic diversity is expected to be reliable in order to get good heterotic hybrids.

(iii) High heritability were observed for all the traits with genetic advance i.e. much important for crop improvement programme.

(iv) Correlation coefficient and path coefficient were found in positive direction for yield and yield attributing traits and on the basis of this we can easily detect the traits that are much important for yield and yield attributing traits.

(v) As only two recessive genes for YVMV resistance are involved it should be possible to recover a large number of resistant plants, coupled with desirable traits.

(vi) In the crosses where dominance gene effect is significant heterosis breeding would be most effective.

(vii) The pod colour of okra had simple inheritance (multiple alleles). Most of the genotypes produced attractive green colour of pod that is a desirable quality traits in okra.

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Appendix I: Mean performance of parents and hybrids (F_1's) during Rainy season 2007

S. No.	Genotypes	Plane height (cm)	Stem diameter (cm)	Number of branches / plant	Number of nodes / plant	Internodal length (cm)	Days to first flowering	Days to 50% flowering	Number of fruits / plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield / plant (g)	Number of seeds / fruit	Ascorbic acid (mg / 100 mg)	Yellow vein mosaic infection (%)
		1	2	3	4	5	6	7	8	9	10	11	12	13	16	15
1	IC - 128883	106.00	1.83	2.63	9.93	9.75	40.00	50.00	13.83	8.83	10.67	1.60	122.06	61.93	12.47	95.67
2	VRO-5	85.03	1.73	3.60	11.53	6.28	40.00	48.00	11.63	11.40	10.40	1.50	132.78	52.23	12.87	4.33
3	VRO-6	112.00	2.03	2.47	16.53	7.65	40.67	48.00	14.93	11.27	10.70	1.50	168.90	69.93	12.73	6.67
4	AC-108	100.83	1.97	3.70	13.87	6.67	39.00	46.00	9.43	8.53	9.67	1.70	79.42	46.77	8.07	4.00
5	IC-45806	106.07	1.80	2.40	10.53	9.60	41.00	50.00	12.03	9.63	9.70	1.50	116.17	44.27	10.83	99.00
6	IC-218877	112.73	1.97	2.70	11.63	8.57	37.00	46.00	11.43	9.13	8.90	1.57	103.92	55.10	8.30	95.00
7	IC-218844	109.67	2.10	2.40	12.37	8.13	39.00	46.00	10.97	9.70	9.90	1.50	106.68	39.00	9.13	97.67
8	Arka Abhay	113.33	2.13	2.43	14.63	6.87	44.00	51.00	11.43	9.73	11.07	1.50	111.50	42.47	10.40	8.33
9	IC-43720	111.83	2.03	3.37	12.40	8.28	39.00	50.67	8.60	7.67	9.60	1.60	66.03	50.67	7.97	97.33
10	342.00	119.13	2.30	2.33	12.40	8.99	41.00	51.00	8.93	9.33	8.67	1.60	92.62	53.77	6.80	16.67
11	IC-140906	98.37	1.67	2.77	10.97	8.74	39.00	53.00	9.90	9.67	10.67	1.70	104.61	56.13	10.20	19.67
12	198.00	109.47	2.07	1.93	8.90	11.92	41.00	47.00	10.83	9.47	10.70	1.60	107.73	67.60	11.97	39.00
13	EC - 305612	116.10	2.50	3.27	9.53	10.73	43.00	49.00	11.37	8.70	8.33	1.60	106.82	61.13	10.07	15.33
14	435.00	117.03	2.10	5.20	14.90	6.81	41.00	50.67	12.23	8.57	9.60	1.70	107.57	62.17	8.23	15.67
15	401.00	122.93	2.17	1.70	11.63	9.78	46.00	51.33	12.67	7.80	10.60	1.30	98.34	56.77	9.97	15.00
16	SA-2	114.90	2.10	2.47	11.00	9.62	42.00	54.00	12.60	9.17	10.40	1.60	110.65	67.00	10.60	11.33
17	IC-140934	119.83	2.03	3.10	12.60	8.65	40.00	52.00	12.10	8.70	9.80	1.50	116.65	55.47	8.13	99.33
18	Arka Anamika	111.30	2.30	3.73	9.53	10.70	47.00	50.00	13.47	8.20	9.90	1.40	91.91	61.50	10.13	20.33
19	Pusa Sawani	110.80	1.63	3.93	13.13	7.78	41.00	50.00	11.20	10.17	8.73	1.60	115.37	70.77	10.33	81.67
20	Prabhani Kranti	104.40	1.40	3.30	10.00	9.59	40.67	50.67	11.33	9.87	9.07	1.60	130.80	56.23	11.83	19.33
21	IC - 128883 x AA	113.27	1.83	2.30	12.70	8.13	45.00	51.67	13.23	9.40	10.33	1.70	126.66	54.40	10.90	49.00
22	IC - 128883 x PS	110.10	1.87	2.30	9.43	10.95	43.00	53.00	13.50	9.37	10.60	1.70	126.89	59.33	7.67	52.67
23	IC - 128883 x PK	96.70	1.57	2.93	11.07	8.24	44.00	52.33	13.57	8.70	10.20	1.50	117.60	64.53	12.27	30.00
24	VRO - 5 x AA	81.10	1.63	2.87	16.20	5.13	44.00	54.00	13.53	10.50	12.67	1.60	129.05	54.87	12.93	4.67
25	VRO - 5 x PS	109.90	2.37	3.07	11.13	9.41	44.00	54.00	12.30	13.40	10.40	1.60	182.97	63.83	12.66	9.00
26	VRO - 5 x PK	93.23	1.90	2.33	9.47	9.17	44.00	51.00	13.70	10.30	10.10	1.60	112.35	61.63	13.67	4.00
27	VRO - 6 X AA	121.00	1.90	1.93	14.83	8.46	39.00	49.33	10.90	9.33	10.17	1.50	118.70	50.67	11.07	17.67
28	VRO - 6 X PS	110.50	2.00	2.73	12.60	7.96	43.00	53.67	12.70	11.50	11.23	1.60	151.79	58.20	12.23	18.33
29	VRO - 6 X PK	108.00	2.10	2.27	11.50	8.43	42.00	49.00	13.13	10.40	10.30	1.50	133.40	58.43	12.60	8.00
30	AC - 108 x AA	113.77	2.03	2.63	15.07	6.76	42.33	48.33	12.80	10.27	10.30	1.50	117.65	49.77	8.87	1.00
31	AC - 108 X PS	98.30	1.83	1.93	9.50	9.59	44.00	53.33	11.43	11.50	10.37	1.80	157.58	44.27	9.10	10.67

Contd…

S.No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13	16	15
32	AC - 108 x PK	106.07	1.97	1.77	11.43	8.27	45.00	53.33	13.67	9.53	10.53	1.60	114.72	52.27	9.90	1.67
33	IC - 45806 x AA	116.70	2.03	2.27	13.33	7.94	44.67	52.00	12.03	10.67	10.50	1.60	129.97	65.30	10.53	9.67
34	IC - 45806 x PS	97.27	1.70	2.03	11.00	8.45	42.67	49.67	12.23	9.60	10.20	1.60	119.60	47.63	9.73	7.00
35	IC - 45806 x PK	91.37	1.80	2.37	11.17	7.14	44.00	50.67	12.47	10.13	10.40	1.50	125.00	60.63	11.03	3.33
36	IC - 218877 x AA	109.73	1.90	2.70	11.33	8.72	41.00	49.67	10.93	9.60	10.17	1.70	105.68	54.50	9.63	41.33
37	IC - 218877 x PS	104.57	2.03	2.27	10.43	9.79	44.00	49.67	11.10	8.83	10.27	1.60	98.12	70.40	9.73	44.33
38	IC - 218877 x PK	112.13	1.90	3.23	11.93	8.58	44.00	50.67	9.27	8.50	9.90	1.60	78.76	63.87	9.63	38.67
39	IC - 218844 x AA	99.20	2.20	2.00	9.87	6.76	39.00	50.67	8.23	13.03	12.50	1.80	107.34	55.10	9.73	51.67
40	IC - 218844 x PS	117.80	2.27	2.27	11.37	9.29	42.00	48.00	8.53	8.77	9.60	1.60	74.70	47.90	10.27	58.67
41	IC - 218844 x PK	115.60	1.87	1.40	11.33	9.26	42.33	47.00	10.33	8.87	10.73	1.50	91.86	45.50	10.60	25.33
42	Arka Abhay x AA	132.73	2.50	2.20	17.23	6.83	44.00	52.33	13.37	8.90	10.23	1.60	119.19	68.03	9.60	23.67
43	Arka Abhay x PS	106.37	1.80	1.40	10.80	9.44	45.00	49.33	12.37	10.27	9.80	1.60	127.35	49.47	10.33	48.67
44	Arka Abhay x PK	87.00	1.43	2.30	8.47	9.59	41.00	48.33	13.03	11.03	10.35	1.60	143.94	61.10	12.80	24.33
45	IC - 43720 x AA	101.00	1.87	2.57	12.30	7.37	34.00	45.00	8.63	9.30	10.20	1.60	80.49	63.10	8.93	46.00
46	IC - 43720 x PS	112.67	1.97	3.00	11.13	9.79	45.00	46.00	12.10	9.30	10.60	1.60	113.09	52.70	9.23	48.67
47	IC - 43720 x PK	112.73	1.80	1.93	10.77	10.02	39.00	51.00	12.00	9.20	9.73	1.50	110.13	49.13	9.83	44.67
48	342 x AA	109.10	2.10	2.37	9.47	11.46	42.00	50.67	11.37	9.27	9.60	1.70	104.97	66.43	8.33	5.33
49	342 x PS	126.63	2.07	2.93	15.50	7.25	42.67	52.00	11.57	11.10	10.20	1.50	128.85	62.50	7.70	41.33
50	342 x PK	116.67	2.10	2.20	10.37	10.56	42.00	53.00	10.73	8.47	10.53	1.30	90.89	65.37	9.50	3.67
51	IC - 140906 x AA	106.20	1.80	2.23	11.70	8.71	45.00	53.00	9.63	9.20	9.80	1.50	88.95	55.40	9.67	9.67
52	IC - 140906 x PS	119.07	2.20	1.77	11.30	9.41	43.00	53.00	9.60	9.83	10.40	1.50	94.10	54.57	9.50	5.00
53	IC - 140906 x PK	107.07	2.00	1.47	9.63	10.79	43.00	55.00	11.33	8.77	10.10	1.50	99.82	63.57	9.77	12.33
54	198 x AA	133.87	2.47	1.97	19.70	5.98	44.00	53.00	10.27	9.07	9.37	1.60	93.00	59.53	10.83	1.33
55	198 x PS	87.27	1.67	1.63	9.00	9.46	43.00	52.00	10.47	8.90	9.03	1.60	93.13	62.27	10.73	2.67
56	198 x PK	130.53	2.43	2.63	22.13	5.28	43.00	51.00	11.30	8.83	10.50	1.70	100.06	56.37	10.83	1.00
57	EC - 305612 x AA	125.00	2.30	3.57	16.97	6.56	44.00	50.67	11.47	10.60	9.47	1.50	121.54	56.40	10.07	1.33
58	EC - 305612 x PS	110.50	2.23	1.80	9.50	11.21	43.00	54.00	14.33	10.87	10.57	1.50	155.77	60.83	12.50	5.33
59	EC - 305612 x PK	111.07	2.07	2.37	10.90	9.68	41.67	55.00	11.33	9.70	9.43	1.70	110.13	54.73	9.67	0.33
60	435 x AA	111.57	1.83	3.70	14.27	7.01	39.33	52.00	11.97	9.47	10.03	1.50	112.31	57.53	8.73	2.67
61	435 x PS	104.00	1.73	4.03	9.50	10.45	45.00	55.00	11.43	9.40	9.43	1.50	107.19	52.17	7.30	8.33
62	435 x PK	115.90	2.10	2.57	12.17	8.36	41.00	52.00	11.50	9.87	10.27	1.40	113.60	45.80	8.77	4.00
63	401 x AA	132.73	2.37	2.03	12.73	9.15	41.00	51.67	12.23	10.23	10.37	1.50	125.02	47.67	11.00	3.00
64	401 x PS	100.83	1.93	2.33	9.90	9.58	43.00	52.00	10.73	12.43	10.37	1.70	134.05	46.67	10.77	4.00
65	401 x PK	131.63	2.47	3.37	16.83	7.07	40.00	53.00	10.90	9.13	10.27	1.50	99.02	60.00	11.47	9.00
66	SA - 2 x AA	97.30	1.70	3.03	8.73	10.31	40.67	51.33	11.60	11.03	10.43	1.60	126.73	37.53	10.27	1.00
67	SA - 2 x PS	101.67	1.77	2.63	13.37	6.94	41.00	54.00	11.60	9.70	10.87	1.60	112.09	46.40	10.47	7.00
68	SA - 2 x PK	112.73	2.07	2.27	10.67	10.07	40.00	55.00	12.00	9.03	9.70	1.50	108.09	63.80	11.03	0.67
69	IC - 140934 x AA	115.73	2.03	2.37	13.60	7.71	51.00	62.00	13.27	10.03	10.23	1.60	132.91	57.20	8.40	43.33
70	IC - 140934 x PS	87.43	1.43	2.70	11.67	7.06	42.00	54.00	10.77	10.40	12.07	1.60	111.52	50.83	10.57	51.67
71	IC - 140934 x PK	91.07	1.87	1.93	11.23	7.58	40.33	54.67	11.33	9.23	10.93	1.50	104.60	74.13	11.27	22.33

Appendix II: Mean performance of parents and hybrids (F_1's) during Summer season 2008

S. No.	Genotypes	Plane height (cm)	Stem diameter (cm)	Number of branches / plant	Number of nodes / plant	Internodal length (cm)	Days to first flowering	Days to 50% flowering	Number of fruits / plant	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield / plant (g)	Number of seeds / fruit	Ascorbic acid (mg / 100 mg)	Yellow vein mosaic infection (%)
		1	2	3	4	5	6	7	8	9	10	11	12	13	16	15
1	IC - 128883	95.07	1.77	1.80	10.53	6.27	45.00	51.00	5.97	7.67	10.50	1.60	45.77	56.97	12.27	78.00
2	VRO-5	69.83	1.67	2.03	15.23	2.67	41.00	49.00	8.50	9.70	10.57	1.50	82.56	53.17	12.53	2.67
3	VRO-6	102.07	2.10	1.63	20.40	2.80	38.00	48.00	9.77	9.97	10.57	1.40	97.26	70.30	12.57	3.00
4	AC-108	93.10	1.97	1.97	16.73	4.47	39.00	49.33	4.17	7.17	9.97	1.60	30.18	45.93	7.87	3.33
5	IC-45806	97.70	1.63	1.17	10.73	7.67	39.00	49.00	6.07	7.67	9.40	1.60	46.52	44.07	10.60	79.00
6	IC-218877	105.23	1.87	1.70	11.87	7.13	40.00	49.33	7.47	8.37	9.43	1.60	62.47	55.77	8.20	74.00
7	IC-218844	105.67	2.03	1.27	16.43	4.97	39.00	49.00	6.87	9.00	9.90	1.50	61.75	43.20	9.07	82.00
8	Arka Abhay	92.47	2.03	1.30	14.33	5.23	38.67	48.00	8.00	8.57	9.90	1.40	68.56	44.03	10.40	1.67
9	IC-43720	85.77	2.00	2.10	10.77	6.83	39.00	49.33	3.70	7.13	10.57	1.70	26.33	54.87	7.60	38.00
10	342.00	103.03	2.10	1.00	12.80	7.00	39.00	47.00	9.07	7.77	9.77	1.50	70.57	60.13	6.97	8.33
11	IC-140906	72.17	1.43	1.70	10.17	4.47	38.00	48.00	5.90	7.67	10.40	1.70	45.03	56.17	9.97	15.67
12	198.00	81.90	1.97	1.47	10.07	7.03	38.00	50.00	6.43	9.10	9.97	1.60	58.50	67.73	11.70	17.33
13	EC - 305612	99.07	2.40	2.07	12.77	6.83	39.00	45.00	8.87	7.50	8.27	1.40	66.47	65.00	9.40	14.33
14	435.00	108.77	2.03	3.93	20.77	4.17	38.00	47.67	8.57	7.67	9.97	1.60	65.60	67.63	8.17	12.67
15	401.00	102.53	2.07	0.67	10.97	7.80	39.00	51.00	7.83	6.83	9.63	1.40	53.03	56.33	10.33	8.67
16	SA-2	96.77	2.10	2.27	13.57	5.67	40.00	47.67	7.60	8.50	10.47	1.60	64.33	67.67	10.07	6.33
17	IC-140934	98.63	1.93	1.70	12.20	7.10	39.00	49.00	5.20	8.17	9.60	1.60	42.47	59.70	7.63	85.33
18	Arka Anamika	102.77	2.13	2.67	12.70	6.47	40.67	51.00	8.67	7.83	9.93	1.50	70.27	75.70	9.93	1.33
19	Pusa Sawani	99.60	1.53	1.37	15.03	5.40	39.00	48.00	7.03	9.63	9.17	1.60	67.77	71.83	10.20	76.00
20	Prabhani Kranti	99.33	1.60	1.83	11.07	7.50	41.00	48.00	6.80	11.67	10.87	1.50	79.40	53.97	11.77	7.00
21	IC - 128883 x AA	86.33	1.67	1.63	12.93	6.13	39.00	47.00	7.80	8.00	9.80	1.50	62.27	74.43	10.80	23.33
22	IC - 128883 x PS	92.03	1.87	1.37	11.83	6.23	42.00	50.67	6.43	8.03	10.67	1.70	51.70	69.33	11.07	32.00
23	IC - 128883 x PK	85.17	1.90	1.20	12.53	5.13	43.00	52.00	6.93	7.63	9.73	1.50	52.03	70.07	12.10	25.33
24	VRO - 5 x AA	68.37	1.70	1.67	12.00	2.60	42.00	51.00	8.30	11.83	11.30	1.60	98.17	71.47	12.80	0.33
25	VRO - 5 x PS	86.93	2.13	1.77	12.03	6.20	44.00	53.67	7.60	9.67	9.27	1.40	73.33	67.10	11.53	2.33
26	VRO - 5 x PK	87.80	1.83	1.30	11.10	6.80	42.00	54.00	8.77	9.63	10.30	1.60	84.47	64.33	11.93	3.00
27	VRO - 6 X AA	94.23	1.87	1.40	12.30	6.53	37.00	48.00	8.40	11.73	10.80	1.70	98.53	60.50	12.07	7.00
28	VRO - 6 X PS	97.00	1.93	1.73	14.17	5.97	44.00	51.67	9.73	9.83	10.23	1.50	95.80	59.20	12.43	11.00
29	VRO - 6 X PK	87.43	1.97	1.73	12.53	6.73	43.00	50.00	6.73	9.50	9.07	1.40	62.80	58.93	11.67	7.00
30	AC - 108 x AA	91.63	1.97	1.97	14.00	5.10	43.00	53.00	9.70	9.97	9.73	1.40	96.80	53.73	8.63	0.33
31	AC - 108 X PS	91.23	1.87	1.30	13.17	5.97	46.00	50.00	7.10	10.53	10.57	1.70	74.83	49.97	9.13	9.33
32	AC - 108 x PK	92.23	1.90	1.03	13.40	5.90	46.00	53.00	6.37	9.83	10.30	1.50	62.63	52.33	10.07	0.67
33	IC - 45806 x AA	96.67	1.87	1.33	11.63	7.13	47.00	51.00	7.73	10.20	9.87	1.50	78.97	67.53	10.33	4.33

Contd…

S.No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13	16	15
34	IC - 45806 x PS	87.17	1.90	1.63	11.37	7.03	42.33	52.00	7.53	8.93	9.80	1.60	65.20	44.57	9.87	3.33
35	IC - 45806 x PK	88.63	1.87	1.60	13.30	5.57	46.00	52.00	8.17	8.57	10.87	1.30	69.67	71.47	11.00	1.33
36	IC - 218877 x AA	91.50	1.83	1.67	12.90	6.27	45.00	51.00	6.87	8.63	9.60	1.60	59.32	60.67	9.50	19.67
37	IC - 218877 x PS	92.33	1.93	1.63	11.57	6.57	46.00	53.00	7.73	7.93	9.67	1.60	61.56	67.10	9.63	27.33
38	IC - 218877 x PK	95.40	1.87	2.13	14.00	5.70	40.00	50.67	8.20	7.87	9.03	1.40	64.40	71.30	9.87	20.33
39	IC - 218844 x AA	88.37	2.00	0.97	11.77	6.60	45.00	51.00	8.37	8.07	11.13	1.80	67.61	57.00	9.53	28.33
40	IC - 218844 x PS	97.87	1.73	1.27	14.50	5.77	45.00	54.00	7.30	8.53	9.50	1.50	62.17	48.90	10.03	41.33
41	IC - 218844 x PK	96.23	1.90	0.97	12.57	6.33	44.00	53.00	6.80	11.90	10.57	1.70	81.08	68.43	10.53	16.67
42	Arka Abhay x AA	108.00	2.03	1.50	16.90	5.20	44.00	51.33	9.90	11.00	9.67	1.50	108.91	68.33	12.60	12.33
43	Arka Abhay x PS	92.30	1.77	1.00	11.53	7.20	45.00	52.00	7.63	8.77	9.50	1.60	66.92	50.10	10.37	28.67
44	Arka Abhay x PK	77.53	1.53	1.67	10.90	6.67	42.67	49.00	6.77	10.17	10.30	1.50	68.93	59.53	11.07	16.33
45	IC - 43720 x AA	81.90	1.90	2.20	15.23	4.90	42.67	47.67	7.77	8.80	9.97	1.60	68.44	61.80	8.43	25.33
46	IC - 43720 x PS	93.97	1.77	1.40	11.83	6.73	45.00	50.00	9.27	9.37	9.83	1.40	86.87	54.27	8.83	26.00
47	IC - 43720 x PK	93.80	1.60	0.60	10.93	7.87	40.00	51.00	6.23	8.43	8.93	1.60	52.75	52.07	9.70	28.00
48	342 x AA	90.33	1.67	1.03	11.23	6.93	44.67	52.00	8.00	8.83	9.40	1.57	70.67	64.37	7.90	4.00
49	342 x PS	105.77	1.97	1.67	17.50	4.97	42.00	49.00	8.20	10.23	9.53	1.50	84.08	67.13	7.40	42.67
50	342 x PK	99.70	1.90	1.10	15.10	6.03	40.67	46.00	7.73	8.57	10.13	1.40	66.12	69.30	9.67	1.67
51	IC - 140906 x AA	90.30	1.80	1.63	12.60	6.20	42.00	46.67	8.63	9.27	9.33	1.50	80.02	58.97	9.40	2.00
52	IC - 140906 x PS	93.20	1.97	0.70	11.00	7.03	44.00	50.00	7.77	8.87	10.33	1.60	68.92	50.10	9.70	7.67
53	IC - 140906 x PK	90.37	1.97	0.73	11.57	7.07	46.00	49.67	10.17	8.97	9.53	1.53	91.21	65.90	9.63	15.00
54	198 x AA	114.10	2.23	1.40	20.87	4.03	45.33	51.00	8.43	8.73	8.70	1.70	73.56	64.00	10.63	2.67
55	198 x PS	76.70	1.47	0.73	9.50	7.03	44.00	50.67	8.60	8.53	8.33	1.50	73.33	66.97	10.47	7.00
56	198 x PK	109.67	2.27	1.70	20.33	4.47	40.00	48.00	10.97	9.10	9.83	1.70	99.84	58.07	10.53	0.67
57	EC - 305612 x AA	105.83	2.17	2.00	18.70	4.70	46.00	50.00	11.27	9.23	8.97	1.60	104.13	56.27	11.73	1.00
58	EC - 305612 x PS	93.73	1.97	1.03	10.87	7.23	43.00	48.00	9.30	9.37	10.23	1.50	87.24	63.13	10.07	6.00
59	EC - 305612 x PK	94.03	1.90	1.40	12.93	6.20	41.67	49.00	7.33	8.80	9.50	1.60	64.52	62.60	9.70	0.67
60	435 x AA	92.50	1.70	2.50	18.30	4.20	39.33	46.67	7.13	9.57	10.50	1.70	68.02	58.97	8.40	1.33
61	435 x PS	86.77	1.60	1.73	11.07	7.13	42.33	51.00	7.07	9.63	9.50	1.50	67.90	54.07	7.10	5.33
62	435 x PK	91.80	1.83	1.40	13.83	6.20	40.00	45.67	9.40	9.97	10.00	1.60	93.47	53.00	8.60	1.67
63	401 x AA	107.73	2.10	0.70	15.50	6.10	38.67	47.00	8.10	10.67	9.53	1.60	86.52	55.63	10.80	2.00
64	401 x PS	87.97	1.70	0.97	13.27	5.77	42.00	50.00	6.47	11.50	8.67	1.70	74.20	46.90	10.63	6.33
65	401 x PK	112.33	2.27	2.03	20.63	4.30	35.00	46.00	8.60	9.57	10.20	1.50	82.38	59.60	11.33	4.33
66	SA - 2 x AA	93.03	1.70	1.90	15.23	5.10	38.00	47.33	7.50	9.67	10.13	1.50	72.39	60.50	10.13	0.67
67	SA - 2 x PS	95.57	1.77	2.30	15.40	5.13	37.00	47.33	8.33	8.57	10.80	1.70	71.58	46.73	10.67	5.67
68	SA - 2 x PK	89.07	1.70	1.10	12.40	6.53	38.00	45.00	5.43	8.40	9.37	1.60	45.43	55.37	11.20	0.33
69	IC - 140934 x AA	94.53	1.93	1.13	13.77	5.80	40.67	50.67	8.33	8.77	10.33	1.60	73.10	72.20	8.23	19.33
70	IC - 140934 x PS	85.07	1.83	0.70	12.63	5.37	38.00	50.00	6.97	10.50	11.83	1.60	73.06	59.53	10.27	24.00
71	IC - 140934 x PK	87.57	1.90	1.07	12.90	5.40	39.00	48.33	7.60	9.73	10.47	1.60	74.02	70.57	11.03	7.00