

**GENETIC STUDIES FOR YIELD AND
YVMV RESISTANCE IN OKRA
[*Abelmoschus esculentus* (L.) Moench]**

Thesis

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By

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“Real life isn't always going to be perfect or go our way, but the recurring acknowledgement of what is working in our lives can help us not only to survive but surmount our difficulties”.

With limit less humanity, I would like to praise and thank ‘God’ the almighty, the merciful compassionate who bestowed me with all the favourable circumstances to go through this crucial juncture.

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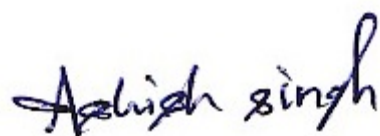
I dedicate this thesis to my most respected and ever loving member of QJV family and dearest love Pihu, Ananya, Mahi and Shivansh, who have been an infinite and constant source of inspiration and values, which encouraged my scholastic achievement and inculcated cognitive sense to me. Their uncompromised sacrifice, relentless efforts and tremendous patience spared no pain to see me get the best of everything in this world. They are truly the wind beneath my wings. I bow down my head before my adorable parents whose efforts, affection, sacrifice and encouragement enabled me to reach this horizon.

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Pantnagar
February, 2020



(Ashish Kumar Singh)
Author

CERTIFICATE

This is to certify that the thesis entitled “**GENETIC STUDIES FOR YIELD AND YVMV RESISTANCE IN OKRA [*Abelmoschus esculentus* (L.) Moench]**”, submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** with major in **Horticulture (Vegetable Science)** and minor in **Genetics and Plant Breeding** of the College of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, India, is a record of bonafide research carried out by **Mr. Ashisk Kumar Singh, Id. No. 51243** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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

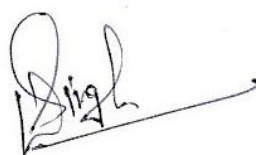
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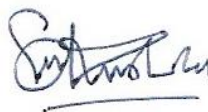
We, the undersigned, members of the Advisory Committee of **Mr. Ashisk Kumar Singh, Id. No. 51243**, a candidate for the degree of **Doctor of Philosophy** with major in **Horticulture (Vegetable Science)** and minor in **Genetics and Plant Breeding**, agree that the thesis entitled "**GENETIC STUDIES FOR YIELD AND YVMV RESISTANCE IN OKRA [*Abelmoschus esculentus* (L.) Moench]**" may be submitted in partial fulfillment of the requirements for the degree.



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Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] commonly known as bhindi or lady's finger is a fast-growing warm and rainy season annual herb whose immature green pods are used as a common vegetable. It belongs to the family Malvaceae and is believed to be native of tropical Africa. It is an important vegetable crop throughout the tropics and subtropics (Hammon and Van Stoles, 1989) and is also well distributed in the Indian subcontinent and East Asia (Kochhar, 1986).

Okra is an often cross-pollinated vegetable crop with somatic chromosome number $2n = 130$ and is considered to be an amphidiploid of *Abelmoschus tuberculatus* $2n = 58$ and an unknown species with $2n = 72$ (Datta and Naug, 1968). Flower bud appears in the axil of each leaf node at 6th to 8th leaf depending upon the cultivars. The time of anthesis ranges from 8 to 10 am which varies with cultivar, temperature and humidity (Purewal and Randhawa, 1947).

Okra is extensively cultivated for its tender immature fruits, which are largely used as a fresh vegetables. The fruits are fairly good in nutritive value and 100 g edible fruit contains dry matter (10.4 g), water (89 g), protein (2-4 g), fat (0.3 g), carbohydrate (7.6 g), calcium (92 mg), phosphorus (51 mg), iron (0.6 mg) and potassium (249 mg). Green fruits are also a rich source of iron and vitamin A, B and C (Aykroyd, 1963). Besides fancy dishes, it is also gaining popularity as pickled, frozen, boiled or fried vegetables. Dry seeds of okra contain 18 to 20 per cent oil and 20 to 30 per cent crude protein and are used to prepare vegetable curd or roasted and ground to be used as coffee additive or substitute. The roots and stems are used for clarification of sugarcane juice before it is converted into jaggery and brown sugar (gur). Carbohydrate is present in the form of mucilage and is used in the paper industries. The stem of the plant is used for the extraction of fiber. Besides these, different plant parts of okra have got a lot of medicinal properties. Fruits of okra are useful for the control of goiter disease due to high iodine content (Chaudhary, 1979).

Okra prefers warm-moist climatic season and thrives successfully both in the region of plains and hills. It is a short duration vegetable crop and grown as spring-summer and rainy season in northern India. In south India, where winter is mild and frost-free, it is possible to grow okra throughout the year. It is an important vegetable

crop for both internal market and export purposes. It has great potential for foreign exchange and accounts for about 60 per cent of the export of fresh vegetables. Its quick growth, short duration and photo-insensitive nature enable the geneticists and plant breeders to raise two crops in a year viz., spring-summer crop and rainy season crop and reduce the period of genetic advancement (Gondane, 1989). However, *Kharif* season is the main growing season because in this season the plants grow tall, vigorous and bear more number of pods that contribute to high yield per unit area. But in the summer season crop, the germination of seeds is generally poor, plants are dwarf producing comparatively lower yield because of unfavorable environmental conditions than that prevailing in *Kharif* season and realizing the potential of okra cultivars.

India is the largest producer of okra in the world. The total area in the country under okra cultivation is 0.51 million hectares with the production of 6.21 million tonnes of green fruits, whereas the productivity of the crop is 12 tonnes per hectare. Among the vegetables, the contribution of okra is 5.9 per cent in area and 3.9 per cent in production. Andhra Pradesh is the leading state in area 13.40 lakh hectare, production 233.82 MT and productivity 17.45 MT/ha (Anon., 2017).

Among the various constraints that are responsible for low productivity in okra, susceptibility to yellow vein mosaic virus (YVMV) is the most important and destructive viral disease. YVMV is a species of genus Begomovirus, family Geminiviridae (Fauquet and Stanley, 2005). Okra YVMV is believed to have originated in India and it was first identified by Kulkarni in 1924 (Usha, 2008). The disease infects at all the stages of crop growth and severely reduces growth and yield by 50 to 94 per cent. The YVMV disease is transmitted through the vector, white fly. The use of synthetic pesticides for managing pests and diseases is the immediate and most practiced method adopted by the farmers but, okra is a vegetable with shorter harvesting intervals, poses residual hazards to the consumers. Therefore, the emphasis is now shifting in favor of host plant resistance, particularly insect and disease resistant/tolerant varieties are more economical and environmentally safe (Sanford and John, 1994). However, there has been a pressing demand for a higher-yielding variety coupled with resistance to YVMV. Therefore, there is a need to develop YVMV resistant varieties or hybrids.

Before starting any crop improvement programme, it is necessary to assess the nature and magnitude of genetic variability, heritability and genetic advance in the initial

parental material. Genetic variability is a very important component of plant breeding which is a major tool being used to cope with the ever-increasing pressure of expanding the world population on food production (Ariyo, 1990). The extent of genetic and non-genetic components of variation formulates the proper breeding programme to reach the goal. Higher mean accompanied by higher genetic variability affords scope for selection. Selection based on multiple traits is always better than selection based on yield alone. As we know that yield is a quantitative character controlled by different characters, therefore, adequate knowledge about the magnitude and degree of association of yield with its attributing characters is of great significance to the breeder, through which breeder can clearly understand the strength of correlated traits, when they have to exercise selection for simultaneous improvement of more than one character.

Despite its recognized potential in the country, it is being neglected crop because of the non-availability of high yielding cultivars. Yield plateau seems to have been reached in open-pollinated cultivars of okra. To break the yield barriers in existing open-pollinated cultivars of okra, a hybridization-based breeding strategy would be desirable. Heterosis breeding has been the most successful approach in increasing productivity in cross-pollinated vegetable crops. Okra is an often-cross pollinated vegetable crop where the presence of heterosis was demonstrated the first time by Vijayaraghavan and Warriar (1946).

In okra, so many cultivars have been developed but a considerable increase in productivity potential could not be realized probably due to ceiling in the genetic potential of the genotypes. Therefore, there is an urgent need for genetic improvement of the crop for yield which can be done by the exploitation of hybrid vigor (heterosis), breeding for efficient plant type and component breeding. The choice of the right type of parents to be used in the hybridization programme is a crucial step for the plant breeder. It is a self-pollinated crop but some amount of cross-pollination has also been recorded hence kept under often cross-pollinated crop. The breeding method suitable for improving self-pollinated crops may be employed in this crop.

The main objectives of okra improvement include the development of early maturing, high yielding, insect and disease resistant cultivars with a long time, thin, tender, spineless and light green pods are considered to be pre-requisites of a good okra cultivar. F_1 hybrid cultivars of okra are cultivated on the commercial scale instead of open-

pollinated cultivars in most of the developed countries like Japan and the USA. The exploitation of hybrid vigour by inter-varietal hybridization has been a very promising attempt to increase the production of many vegetable crops in India, but success has not been made so far in this crop. However, during the past decade, much work has been done on hybrid vigour in okra and high heterosis has been reported by many workers (Desai *et al.*, 2007).

Since, yield, which is generally a polygenically inherited character, is the main consideration in heterosis breeding. The heterosis breeding programme intending to develop a hybrid cultivar involves the analysis of combining ability, identification of desirable parents producing F₁ hybrid having a high level of economic heterosis and determining the nature and magnitude of gene action through the estimation of genetic components. Out of several biometrical methods available for studying the inheritance of metric traits, the line $\times$ tester analysis is widely adopted. It also formulates appropriate breeding procedures that could be applied for achieving the desired objectives in the improvement of a particular crop. A great extent of natural variation present in the various characters among the cultivars of okra suggests a good scope of improvement in the economic traits through conventional breeding techniques. The genetic improvement of yield and its contributing characters require the selection of appropriate breeding procedures which is dependent upon the general combining ability (GCA) of parents and specific combining ability (SCA) of crosses. The general combining ability is the manifestation of additive gene action for the selection of parents, while the specific combining ability in respect of a particular character in the hybrid is the capitalization of non-additive gene action.

Combining ability analysis is useful for the study and comparison of homozygous inbred lines in hybrid combination (Sprague and Tatum, 1942). Line $\times$ tester mating design (Kempthorne, 1957) is one of the best techniques that provide information about general and specific combining ability of the parents and at the same time it helps estimate heterosis. It is also helpful in understanding the nature of gene action involved in the expression of various traits. The study of general combining ability (GCA) effects help in the selection of superior parents and specific combining ability (SCA) effects for superior hybrids.

An understanding of the mode of gene action, knowledge of genetic variances, levels of dominance, and the importance of genetic effects may help plant breeders to enhance yield potentials (Wolf and Hallauer, 1977). In a polygenic system underlying a quantitative character, the allelic and non-allelic interactions play a greater role in the manifestation of gene effects and inheritance patterns. Although line $\times$ tester analysis is useful in imparting the knowledge about additive variance, dominance variance, GCA, SCA variances and effects but they do not provide the estimates of non-allelic interactions. However, partitioning of total genetic variance into all its components *i.e.* additive, dominance and all types of epistasis concerning individual crosses will be of immense value in formulating an effective breeding programme. Generation mean analysis is one important method permitting the estimation of epistatic components in addition to additive and dominance effect, especially in partitioning the epistatic effect (Bernardo, 2002). The method involves measuring the mean of different generations and intermating the mean in terms of different genetic effects (Hayman, 1958; Gamble, 1962 and Bernardo, 2002). All the genetic effects can be estimated simultaneously and because they are estimated from the generation means rather than variances their sampling errors are inherently smaller than the variances for additive, dominance and epistatic interactions (Bernardo, 2002). All these parameters help to identify superior genotypes with high yielding ability to increase productivity. The present investigation was, therefore undertaken to understand the magnitude and extent of genetic variability, heritability, and genetic advance and to understand the inheritance of YVMV resistance for developing high yielding YVMV resistant varieties.

Therefore, given the above facts and considering the importance of okra, the present investigation was planned and executed by involving the potential parental lines with the following objectives:

1. To find out genetic variability, heritability and expected genetic advance for different quantitative traits.
2. To estimate the heterosis and combining ability for yield and its contributing traits.
3. To work out the nature and magnitude of gene action.
4. To study the gene effects and inheritance of resistance to YVMV through generation mean analysis.

*Review
of
Literature*

The relevant literature on the different aspects studied during this investigation has been reviewed here briefly under the following headings:

2.1 Genetic parameters

2.2 Heterosis

2.3 Combining ability and gene action

2.4 Inheritance of YVMV resistance

2.1 Genetic parameters

In the varietal improvement programme, the prime objective of the plant breeder is to breed varieties better than the existing ones. The knowledge of the genetic architecture of different traits, genetic variability, heritability and genetic advance helps in formulating effective breeding strategies. Crop improvement depends on the magnitude of genetic variability and the extent to which the desired characters are heritable. It attracted the attention of plant breeders to study the genetic aspects of economically important plant characters such as yield and its contributing characters. Therefore, it is necessary to understand the genetic architecture of various characters of importance and interrelationship among them. The literature on genetic variability (GV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (broad sense) and genetic advance (GA) towards fruit yield of okra are outlined under the following subheadings.

2.1.1 Genetic variability, heritability and genetic advance

The first and foremost step for improvement in any crop is to study the variation in different traits of its available germplasm. The variability observed in any population could be due to two factors, the genetic and environmental. Genetic variability concerning environmental variability was first studied by Fisher (1918) and partitioned it into three components namely, additive, dominant and epistatic. Coefficients of variation allow a meaningful comparison of the variation of several traits of plants belonging to the same population, as well as a comparison of the variation of the same trait as expressed by

different populations (of the same or different crops). The efficacy of selection depends upon the existence and magnitude of genetic variability for yield and yield contributing traits in the breeding material. For yield improvement selection of superior parents possessing better heritability tied with high genetic advance for yield contributing traits is an essential prerequisite. Heritability in conjunction with genetic advance is more useful than heritability alone in predicting the resultant effect of selection (Johnson *et al.*, 1955). Therefore, it is very much needed to characterize the genetic variability, which is a heritable difference among cultivars, and it is required in an appreciable level within a population to facilitate and sustain an effective long-term plant breeding program.

Many researchers earlier reported a wide range of variation in okra accessions for yield and yield components characters and some are reviewed below.

Dhankhar and Dhankhar (2002) studied sixty-two inbred lines of okra during the rainy and spring-summer season and reported broader range of variation and high mean values in rainy season for number of fruits per plant, days to 50 per cent flowering and number of branches per plant and in spring-summer season for fruit yield and plant height. The magnitude of PCV was almost similar to the corresponding GCV in both seasons for fruit yield and plant height indicating that environment had little effect in their expression. However, the characters such as number of fruits per plant, days to 50 per cent flowering and number of branches per plant were somewhat influenced by the environment. The GCV and PCV were high for number of branches per plant, fruit yield, number of fruit per plant and plant height in both seasons indicating high genetic variability. High heritability (bs) coupled with genetic advance was recorded for fruit yield, number of fruits per plant number of branches per plant and plant height in both season. While days to 50 per cent flowering in the spring-summer season showed low heritability (32.63 %) and genetic advance (1.00 %).

Hazra *et al.* (2002) evaluated twenty-two genotypes for 13 characters and observed the high PCV for primary branches per plant (41.23). Characters like fruit weight (11.37-23.70 g), number of fruits per plant (7.67-14.67) and fruit yield per plant (88.37-206.43 g) showed moderate variability (PCV) but wide ranges.

Bendale *et al.* (2003) observed the maximum phenotypic variance for yield per plant, plant height and seeds per pod. This indicated that these characters were highly

influenced by environmental factors. However, for first flowering node, primary branch per plant and 100 seed weight the phenotypic variance had been reported low.

Hussain *et al.* (2005) reported high phenotypic and genotypic variances for fruit yield, seed number, fruit number, node number, number of fruits/plant, number of seeds/fruit, node number and yield per plant.

Singh *et al.* (2006) observed significant differences among 19 diverse genotypes of okra for 15 quantitative characters. The phenotypic and genotypic coefficient of variations were high for internodal length, number of branches per plant, number of fruits per plant, number of seeds per pod and fruit yield per plant.

Magar and Madrap (2009) assessed the genetic variability in 41 genotypes of okra. The result revealed that phenotypic coefficient of variation was higher than the genotypic ones. High GCV and PCV were recorded for fruit yield per plant followed by number of fruits per plant, node at which the first flower appears, plant height and fruit weight. The magnitude of difference between PCV and GCV estimate was maximum for node at first flower appear and number of fruits per plant suggesting the influence of the environment on these traits.

Chaurasiya *et al.* (2010) reported high heritability for the characters viz., fruit length and number of ridges per fruit (100%) followed by days of first flowering (89%) and plant height (86%). However, these characters were coupled with varied genetic advance *i.e.* high, medium and low, respectively suggesting the complexity of genetic mechanism in expression of those traits.

Adiger *et al.* (2011) reported high heritability estimates (61.5%) coupled with high genetic advance for fruit yield per plant in okra. Adeoluwa and Kehinde (2011) observed high PCV (38.55%), GCV (37.30%), heritability (94.0%) and genetic advance (74.36%) for fruit yield per plant in okra.

Analysis of variance (mean square) revealed significant differences among genotypes for all the characters studied by (Kumar *et al.*, 2011). The results based on GCV and PCV indicated considerable genetic variability among the genotypes for height at first fruiting node, number of node at first pod appearance, plant height, number of nodes per plant, number of pods per plant and pod yield per plant.

Nwangburuka *et al.* (2012) observed high genotypic coefficient of variability, broad-sense heritability (%) and genetic advance in traits such as plant height (26.2, 90.7, 51.5), fresh pod length (23.9, 98.5, 48.8), fresh pod width (23.9, 98.5, 48.8), mature pod length (28.6, 98.5, 52.3), branching per plant (29.3, 82.3, 54.8) and pod weight per plant (33.9, 90.0, 63.3), which suggest the effect of additive gene action and reliability of selection based on phenotype of these traits for crop improvement.

Barche *et al.* (2014) studied on eight genotypes of okra including two checks collected from different parts of India were evaluated for nine yield and its attributing characters. The estimate of the phenotypic coefficient of variation (PCV) was also higher than the genotypic coefficient of variation (GCV) for all the traits. High PCV and GCV were observed for yield per plot and number of fruits per plant. High heritability values coupled with a high percentage of genetic advance were recorded for the weight of fruit per plant and plant height.

Bagwale *et al.* (2016) estimated high genotypic and phenotypic coefficient of variation for characters namely number of branches, yield per hectare, yield per plot and yield per plant. High heritability estimates were found for characters like number of branches, yield per plot, yield per plant, plant height, number of seeds per fruit (dry fruit), and fruit-bearing node indicated good inheritance of these characters. High heritability coupled with high expected genetic advance was observed for characters like plant height, yield per plant and yield per hectare, which indicate the presence of additive gene action and phenotypic selection may become more effective for desired genetic improvement.

Mahesh and Yadav (2018) studied on forty-four accessions from 6 different wild *Abelmoschus* species and 4 check cultivars from cultivated species during Kharif season to assess the genetic variability and character association. Estimates of genotypic coefficients of variability (GCV) and phenotypic coefficients of variability (PCV) ranged from 6.15–59.14 and 13.98–62.13, respectively. Heritability in broad sense (h^2) and genetic advance (GA) ranged from 19–98%, 0.40–84.20, respectively. Further classification revealed high GCV (>20.00%) and heritability (>60.00%) for most of the yield components and PDI of YVMV, except for first flowering node and stem diameter. Therefore, direct selection of traits will help in harnessing their positive direct effects on yield per plant in okra improvement programmes.

Priyanka *et al.* (2018) reported high magnitude of genotypic coefficient of variation (>20%) for number of marketable fruits per plant, marketable yield per plant and yellow vein mosaic virus infestation indicated a high degree of genetic variability suggesting great scope for selection of these characters. High heritability (>60%) coupled with high expected genetic advance (>20%) for number of marketable fruits per plant, marketable yield per plant and yellow vein mosaic virus infestation indicated the involvement of additive gene action and more chances of fixing by selection to improve such traits.

Raval *et al.* (2018) recorded twelve characters which showed considerable variability. PCV was higher than the respective GCV for all the traits. High magnitude of PCV and GCV was observed for number of branches/plant followed by fruit yield/plant, internodal length, number of fruits/plant and plant height at final harvest. High genetic advance coupled with high heritability was observed for most of the characters, which indicate additive gene action was more important for these characters.

Binepal *et al.* (2019) studied different parameters of genetic variability and performance of 18 genotypes namely Shakti, Jhilmil, No. 55, Sahiba, No. 64, Harita, Saarika, Ns-801, Arya Mohini, Shaan, Hissar Unnat, Panchwati, Panchali, Swati, Lakshmi, OH-102, Shankar Ganga and Parbhani Kranti collected from different regions. Analysis of variance revealed highly significant variation for all the characters indicating greater variability in the existing material. Phenotypic coefficient of variation (PCV) agreed closely with the genotypic coefficient of variation (GCV) however, the magnitude of PCV was higher than GCV for almost all the characters. The phenotypic coefficient of variations (PCV) was found highest for characters such as length of internodes, fruit yield per plot, fruit yield per ha and fruit yield per plant, while highest genotypic coefficient of variation (GCV) was noted for fruit yield per plant, length of internodes, fruit yield per plot and fruit yield per ha indicating greater diversity for these traits and their further improvement through selection.

Kumar *et al.* (2019) studied on sixty-eight genotypes of okra (pooled data analysis) revealed a high magnitude of genetic variability for the traits such as pod yield and plant height under study. High magnitude of GCV (>20%) for pod yield and plant height suggested a high degree of genetic variability offering great scope for selection of these characters. The genotypes under study showed moderate heritability (30-60%) due to

environmental influence. High heritability coupled with high genetic advance for the traits such as plant height and pod yield per plant revealed the involvement of additive gene action and more chances of fixing by selection to improve such traits. The genotypes B-02 and KS-442 are noticed with great potential and can be utilized for improvement of okra germplasm.

Maurya *et al.* (2019) studied on thirty genotypes of okra to estimate the extent of variability, heritability and genetic advance for different quantitative traits. The analysis of variance indicated highly significant differences among the genotypes for all the characters. High magnitude PCV were observed for unmarketable fruit yield per plant (31.34) followed by marketable fruit yield per plant (21.46), number of fruits per plant (20.78), total fruit yield per plant (19.70) and branches per plant (14.60). Moderate PCV along with with GCV were recorded for number of branches per plant (14.60, 9.57) followed by fruit circumference (12.86, 8.11), fruit length (12.26, 8.34), average fruit weight (10.23, 9.42) and plant height (10.88, 9.00). High heritability was estimated for total fruit yield per plant (93.82) followed by unmarketable fruit yield per plant (87.68), average fruit weight (84.86), days to 50% flowering (84.54) and marketable fruit yield per plant (81.13). High heritability coupled with high genetic advance was estimated for total fruit yield per plant (93.82, 38.08) followed by unmarketable fruit yield per plant (87.68, 56.60) and marketable fruit yield per plant (81.13, 35.87). However, based on the mean performance of genotypes NDO-33 (212.16) followed by NDO-31 (199.03), NDO-24 (195.50), NDO- 35 (190.20) and NDO-17 (189.23) were found most promising genotypes for fruits yield per plant which indicating opportunity for high selection response.

2.2 Heterosis studies

The term heterosis was first used by Shull in 1914. Heterosis may be defined as the superiority of an F_1 hybrid in one or more characters over its parents. Generally, heterosis is manifested as an increase in vigour, size, growth rate yield and resistance to disease and insect pests, but in some cases, the hybrids may be inferior to the weaker parent.

Heterosis breeding had led to a breakthrough in yield in several crop plants. For the exploitation of heterosis, it is imperative to study the magnitude of heterosis. The experiment of heterosis is greatly influenced by the magnitude of genetic differences

among parents involved in the crosses. The parents with optimal to intermediate genetic diversity will show maximum heterosis (Moll and Stuber, 1974).

Varying levels of heterosis in yield and yield components have been reported by several workers in okra. Vijayaraghawan and Wariar (1946) were the first to report hybrid vigour in okra concerning the number of fruits per plant, fruit length (cm), fruit diameter (mm) and weight of fruit (g).

In a set of 7 x 7 diallel crosses in okra, Poshia and Shukla (1986) studied heterosis and reported a higher degree of heterosis for number of pods per plant and yield per plant, medium for first fruiting node, number of nodes on the main stem and plant height, while relatively smaller for remaining traits. Hybrid New Selection × A.E. 91 manifested the highest heterosis over mid parent (29.94%) and better parent (27.77%) for yield per plant.

Kumbhani *et al.* (1993) attempted diallel cross using eight parents in okra. They observed that the magnitude of heterosis was higher for fruit yield per plant and moderate for pod length, pod girth, internodal length and plant height. The most heterotic hybrids for yield per plant were Padra 18-6 × KS-312, Punjab Selection × KS-312, Parbhani Kranti × Padra 18-6 and Punjab Selection × Padra 18-6.

Study on line × tester analysis in okra by Dhankhar *et al.* (1996) noted that the cross combination Raj-12 × Parbhani Kranti had the highest heterosis for fruit yield (166.16%), fruit number plant⁻¹ (113.36%) and number of branches plant⁻¹ (86.57%). During the study of heterosis in okra, Patil *et al.* (1996a) observed high degree of heterosis in crosses IHR-4 × PI-489782 and Pusa Sawani × Smooth Green for marketable yield, earliness and pod borer resistance, while Smooth Green × PI-48972 and Smooth Green × PI-496681 were excellent concerning earliness, pod borer resistance and pod length.

More and Patil (1997) studied a set of 8 × 8 Diallel crosses in okra. The highest heterosis and heterobeltiosis for fruit yield per plant was recorded 5.65% and 28.94%, respectively.

Wankhade *et al.* (1997) observed an appreciable amount of heterosis over standard parent Pusa Sawani for fruit yield per plant. Among the hybrids, Vaishali Vadhu × Local Akola, Local Akola × Sel. 2-2, IC-18960 × Sel. 2-2, IC-18960 × IC-3769 proved to be good and manifested significant heterosis for this character.

Panda and Singh (1999) studied heterosis in twenty crosses of okra. The highest values of heterosis were recorded for pod yield and number of pods per plant. The extent of heterosis was 45.62% for pod yield and 28.32% for number of pods plant.

Chauhan and Singh (2002) studied heterosis for yield and yield contributing characters in okra in line $\times$ tester analysis using twenty lines and four testers. The study revealed that heterosis over the better parent (BP), standard check 1 (Parbhani Kranti) and standard check 2 (Pusa Sawani) was recorded for all the traits studied. DC-97 $\times$ P-7 cross combination showed the highest magnitude of heterosis for yield over better parent and standard checks. Among other cross combinations, Arka Anamika $\times$ Arka Abhay, Shagun $\times$ Varsha Uphar, EMS-8 $\times$ P-7, DC-97 $\times$ Varsha Uphar, PSB-1 $\times$ Varsha Uphar, K-21 $\times$ P-7 and Punjab Padmini $\times$ Varsha Uphar exhibited higher heterosis over the better parent and standard check 1 (Parbhani Kranti), while Arka Anamika $\times$ Arka Abhay also exhibited higher heterosis over standard check 2 (Pusa Sawani). Thus, these can be considered as promising cross combinations for yield and can be tested further.

Singh *et al.* (2002) reported heterobeltiosis in okra ranging from -141% for fruit length (5709 $\times$ 6308) to 185% for number of fruits per plant (6305 $\times$ 6901). Maximum beneficial heterobeltiosis for yield per plant was observed in 6302 $\times$ 6308 (67.51%).

Kumar *et al.* (2005) studied relative heterosis, heterobeltiosis and standard heterosis for assessing hybrid value for eight characters. The cross Arka Abhay $\times$ Punjab Padmini showed significant positive heterosis over better parent and standard parent for number of nodes per plant, single fruit weight and fruit length.

Desai *et al.* (2007) reported the highest heterosis of 558% over mid parent and 447% over better parent for yield per plant. The study revealed that cross P. Kranti $\times$ Gold Finger showed superior performances for the plant height, fruits per plant and yield per plant. While the hybrid, Long Green Smooth Finger $\times$ Green Gold also showed superior performance for these characters except fruit weight. Considering the high magnitude of heterosis and *per se* performance, these hybrids were identified as promising hybrids in okra.

Sriram *et al.* (2007) estimated the highest heterotic value for seed yield per plant in a hybrid of Mohanoor Local $\times$ P. Kranti and TCR 2056 $\times$ P. Padmini. The hybrid

Mohanoor local × P. Kranti was found to be the superior among the eighteen hybrids studied.

Hosamani *et al.* (2008) studied heterosis over mid parent, better parent and standard check in okra. The cross IC-9004K × Parbhani Kranti exhibited 6.36% desirable heterosis over standard check which contributes to high yield. It is inferred that the magnitude of heterosis over standard check was high for most of the characters studied.

Heterosis for fruit yield and its components was studied by Dabhi *et al.* (2009) in a set of line × tester crosses. They recorded maximum heterosis of 20.04% and 32.08% for fruit yield over better parent and standard check, respectively. Maximum heterosis over better parent (66.67%) was observed for number of nodes at first flowering.

Khanpara *et al.* (2009) studied a set of line × tester crosses of 8 lines and 4 testers for the estimation of heterosis over better parent and standard check, respectively. They recorded pronounced heterotic effects for number of nodes per plant, inter-nodal length (cm), plant height (cm), number of branches per plant, number of fruits per plant and fruit yield per plant. The hybrid BO-13 × GO-2 exhibited highest heterobeltiosis (15.72%), whereas the hybrid Pant Bhindi × JOL-1 showed the maximum standard heterosis (60.18%) for fruit yield per plant.

Jindal *et al.* (2010) studied heterobeltiosis and economic heterosis for yield and earliness in okra. They reported that the magnitude of economic heterosis was higher for most of the characters studied. The hybrids Pusa A-4 × NDO-10, Pusa A-4 × PB-1, NDO-10 × HRB-108-2, VRO-3 × S-2 exhibited commercial importance in respect of earliness and yield.

Kumar and Sreeparvathi (2010) reported standard heterosis up to 65.23% from the hybrid MDU-1 × Hissar Unnath for fruit yield per plant. This hybrid also exhibited significant and negative standard heterosis for days to 50% flowering.

Heterosis over mid parent (MP), better parent (BP) and standard check (Parbhani Kranti) was calculated for fruit yield and its components in okra by Parmar *et al.* (2011). They revealed that significant heterosis over MP and BP was observed by cross Parbhani Kranti × Pusa Sawani for days to flowering, days to first picking, number of nodes on the main stem and plant height. The crosses Gujarat Okra 2 × JOL-04-08 for fruit yield per

plant and Pusa Sawani × Panjab-7 for fruit length showed significant heterosis over better parent and the crosses Gujarat Okra 2 × JOL-04-08 for fruit length, Arka Abhay × Pusa Sawani for fruit girth, Parbhani Kranti × Panjab-7 for fruit yield per plant.

Solankey and Singh (2011) manifested heterosis concerning seasonal variation by using 17 lines and 3 testers and reported that the outstanding hybrids for fruit yield were VRO-5 × Pusa Sawani during the rainy season and Arka Abhay × Arka Anamika during the summer season. Considering both the seasons together, the crosses IC 218844 × Parbhani Kranti and VRO 5 × Pusa Sawani were the better performers for most of the traits during both the seasons which can be exploited for commercial hybrid breeding.

Kumar and Singh (2012) reported highest plant height in parent (AC 177) and cross (KS 404 × AC 177), fruit length and pod numbers per plant in parent (AC 123) and cross (AC 123 × Parbhani Kranti) and fruit weight in parent (AC 45) and cross (AC 177 × Parbhani Kranti). Out of 22 crosses, thirteen crosses exhibited maximum heterobeltiosis, relative and standard heterosis in AC 174 × Parbhani Kranti (158.86%), AC 177 × Parbhani Kranti (136.67%) and K.S. 404 × Parbhani Kranti (165.23%), respectively for fruit yield per plant. Ten crosses showed the highest significant heterosis in which maximum heterobeltiosis, relative heterosis and standard heterosis was found in AC 123 × Parbhani Kranti (200.0%, 181.63% and 200.26%, respectively) followed by AC 177 × Parbhani Kranti for number of fruits per plant.

Medagam *et al.* (2012) reported high negative heterosis for days to 50 per cent flowering in cross IC 29119-B × IC 45732 (-4.35%) and days to first flowering in cross IC282248 × IC45732 (-15.22%). The crosses IC 89819 × IC 111447, IC 45732 × IC 89819 and IC89819 × IC899976 showed high standard heterosis and heterobeltiosis for total yield and marketable yield per plant.

Obiadalla-ali *et al.* (2013) found that the significant negative heterosis for day to 50 per cent flowering (-1.77% to -5.73%). The crosses Balady × P. Sawani was earliest among them and showed positive relative heterosis for the cross Balady × Pusa Sawani for plant height and fruit length. The hybrid Balady × Clemson Spineless, Balady × P. Sawani and Emerald × Pusa Sawani were best for fruit yield per hectare. While, hybrid Clemson Spineless × Pusa Sawani, Emerald × Pusa Sawani, Escandarany × White Valvate and

Emerald × White Valvate for number of branches per plant, number of fruits per plant, average fruit weight per plant and fruit length.

Solankey *et al.* (2013) recorded appreciable heterosis over better parents in 51 F₁'s of okra over both the seasons. It was confounded that rainy seasons were more yield productive seasons than summer. The high fruit yield potential recorded in the F₁ hybrid Arka Abhay × Arka Anamika has been directly attributed to increased number of fruit per plant during both climatic seasons.

Kumar *et al.* (2014) determined heterosis in 21 F₁ hybrids for fruit yield and its component traits in okra. They observed that cross NDO-10 × Arka Anamika gave maximum fruit yield while cross GB-1 × Pusa A-4 showed the lowest value for these attributes.

Nagesh *et al.* (2014) observed that appreciable heterosis in okra for all the traits studied in desirable direction over better parent and commercial check. The maximum positive heterosis was showed by cross KON-8 × IC90174 over better parent (107.90%) and the commercial check (92.42%) for total yield per hectare. The crosses KON-8 × IC90174 (92.42%), KON-5 × AAN (45.83%), KON-16 × AAN (40.52%), KON-12 × AAN (35.07%) and KON-7 × IC90174 (27.11%) showed significant heterosis over the commercial check for total yield per hectare.

Patel (2015) studied heterosis for fruit yield and its related traits in okra through line × tester mating design using 17 lines and 4 testers. They observed that cross combination viz., Local Red × P. Kranti (65.44%) and Sel. 2 × HRB-55 (57.05%) exhibited the highest heterosis over better parent and hybrid check, respectively. The other cross combinations viz. M-65 × GO-2 and VRO-6 × P. Kranti were also observed to be the most potent heterotic hybrids for fruit yield and related traits.

Verma and Sood (2015) studied the heterosis in 28 F₁ hybrids of okra developed through 8 × 8 half diallel mating fashion involving the inbred lines P-20, 9801, Parbhani Kranti, VRO-4, P-8, Hisar Unnat, Tulasi-1 and SKBS-11. They observed that maximum heterosis over the standard check "Hybrid Tulsi" was found for the traits like number of fruits per plant and fruit yield per plant. Heterosis for yield was generally accompanied by heterosis of yield components. Based on heterosis and mean performance, VRO-4 × Hisar

Unnat was the best cross combination followed by Tulasi-1 × SKBS-11, P-20 × Tulasi-1 and VRO-4 × Parbhani Kranti for fruit yield per plant.

Bhatt *et al.* (2016) studied 8 parental lines of okra and their 28 F₁ hybrids obtained from half diallel to investigate the extent of heterosis for fruit yield and its attributes. Maximum positive heterosis for fruit yield per plant over better parent and standard check (JOH 2) was observed to be 62.12 and 44.11 per cent, respectively. The best hybrid AOL 09-25 × AOL 09-26 recorded 44.11 per cent heterosis for yield over standard check may be exploited for commercial cultivation.

Nimbalkar *et al.* (2017) studied heterosis over better parents and standard check (Mahyco-10) for fruit yield and its component traits. Five crosses Phule Utkarsha × Arka Abhay, Hisar Navin × Arka Abhay, Hisar Navin × HRB-142, HRB-142 × Arka Abhay and Pusa Sawani × Hisar Navin recorded high positive heterosis and high performance for green fruit yield per plant.

Hadiya *et al.* (2018) studied the magnitude of heterosis over standard check for fruit yield and its components. For total fruit yield per plant standard heterosis ranged from -31.36 to 35.01 per cent and a total of four hybrids showed positive direction heterosis over standard check. The cross AOL-10-22 × GAO-5 exhibited the highest magnitude of heterosis to the extent of 35.01 per cent over standard check for fruit yield per plant. Other best performing crosses based on merit are AOL-10-22 × VRO-6 (34.15%), HRB-55 × AOL-12-59 (7.94) and JDNOL-11-01 × Arka Anamika (2.78%) respectively and the crosses can be used for exploitation of hybrid vigour on a commercial scale.

Chowdhury and Kumar (2019) estimated the magnitude of heterosis for yield and its parameters. The extent of heterosis ranged for all the characters under study. Desirable heterosis for days to 1st flowering was observed in Annika X Rajini over both mid parent and better parent while the cross EC359637 X Arka Anamika showed significant desirable heterosis over standard check. For average fruit weight, the maximum heterosis was obtained in cross EC359637 X Arka Anamika over mid parent, Annika X IC014026 and Annika X EC359637 over better parent. Maximum desirable heterosis for yield per plant was observed in EC359637 X IC014026 over mid parent, a better parent and standard check followed EC359637 X IC013664 and EC359637 X EC305768. Higher magnitude of

heterosis observed in crosses revealed the presence of significant genetic diversity among the genotypes.

2.3 Combining ability and gene action

The concept of combining ability as a measure of gene action was proposed by Sprague and Tatum (1942) working on maize. Combining ability refers to the capacity or ability of a genotype to transmit a superior performance to its crosses. The value of inbred line depends on its ability to produce superior hybrids in combination with other inbreds. Combining ability analysis helps in the identification of superior hybrid combinations which may be utilized for commercial exploitation of heterosis. It also provides information about the gene action involved in the expression of various quantitative characters and thus helps in deciding the breeding procedure for genetic improvement of traits.

Combining ability are two types, viz., general combining ability (GCA) and specific combining ability (SCA). The general combining ability (GCA) is defined as the average performance of a line in hybrid combinations, which can be recognized as a measure of additive gene action whereas, specific combining ability (SCA) is the deviation in performance of a cross combination from that predicted based on the general combining ability of the parents involved in the cross and it is considered as a measure of non-additive gene action. Federer and Sprague (1947) were of the view that single tester provides the most efficient means of testing specific combining ability, whereas, more than one tester is needed for the estimation of general combining ability. Genetic information, especially about the nature and magnitude of gene action governing the inheritance of important quantitative characters, is of vital importance to a plant breeder in formulating the appropriate breeding programme.

The first attempt to partition the genetic variance into its components was made by Fisher (1918). He recognized the components of hereditary variance as:

- I. An additive portion describing the difference between homozygous at any single locus.
- II. A dominance component arising from the interaction of alleles (Intra -allelic interaction).
- III. An epistatic part associated with inheritance of non-alleles (inter allelic interaction or epistasis).

The method of line $\times$ tester analysis developed by Kempthorne (1957) is one such design which has been extensively used both in self as well as cross-pollinated crops. For selecting a line for hybridization-based on combining ability, it is found to be more suitable in many respects than other methods like poly-cross as given by Tysdal *et al.* (1942) and di-allele cross given by Hayman (1954) and Griffing (1956) as there is always uncertainty about the randomness of pollinators in poly-cross techniques whereas the number of crosses involved in Diallel method is too high.

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

The available literature on the combining ability analysis in okra has been reviewed as under:

Chaudhary *et al.* (1991) carried out line $\times$ tester analysis involving five lines and three testers in okra. The results revealed that the genotypes Pusa Makhamali and Punjab Padmini were good general combiners for yield and its components.

Patil *et al.* (1996b) studied combining ability through line $\times$ tester analysis in okra and result revealed that line PI 489782 was the best general combiner for marketable yield, the total number of pods per plant and plant height. They also reported high positive significant SCA effect in crosses viz., IHR4 $\times$ PI 489782, Pusa Sawani $\times$ Smooth green, Pusa Sawani $\times$ PI 496620 and IHR4 $\times$ Green velvet for marketable yield.

Ramesh *et al.* (1998) studied combining ability through line $\times$ tester analysis in okra and found A. Abhay, Pusa Makhamali, P. Kranti and Punjab Padmini as good combiners for yield per plant. They also reported significant and positive SCA effects for yield per plant in crosses IC-9275 $\times$ HB-55, A. Abhay $\times$ Punjab Padmini, A. Abhay $\times$ HB-55,

P. Kranti $\times$ HB-55, D-2 $\times$ EC-16511, P7 $\times$ P. Padmini, Pusa Makhmali $\times$ Punjab Padmini and Pusa Makhmali $\times$ EC-16511.

Rajani *et al.* (2001) revealed that the parent NBPGR/TCR 861 was the best general combiner for single fruit weight and length. Among hybrids, NBPGR/TCR 893 $\times$ NBPGR/TCR 864 exhibited outstanding SCA effect for yield while NBPGR/TCR 865 $\times$ NBPGR/TCR 438 and NBPGR/TCR 893 $\times$ NBPGR/TCR 861 were notable for single fruit weight, fruit length and fruit girth. The hybrid NBPGR/TCR 854 $\times$ NBPGR/TCR 865 showed maximum tolerance to YVMV.

Singh *et al.* (2001) revealed that the parental lines 7310 and 6313 were good combiners for plant height, length of internode and number of fruits per plant. The crosses 6305 $\times$ 6308, 6305 $\times$ 6308, 6305 $\times$ 6325, 6302 $\times$ 6308, 6325 $\times$ 7312, 6308 $\times$ 6325, 6313 $\times$ 7312 and 67308 $\times$ 7312 had significant and positive specific combining ability effects for fruit yield per plant. They also revealed the predominance of non-additive gene action for plant height (cm), first fruiting node, length of internode (cm), number of branches per plant, length of fruit (cm), number of fruits/plant and fruit yield/plant (g).

Combining ability through half diallel analysis in okra was carried out by Borgaonkar *et al.* (2003) observed general, as well as specific combining ability variances, were significant for all characters studied. Parents HRB-55 and No.-41 were found good general combiners for yield and most of the traits. Specific combining ability effects indicated that top three yielding hybrids viz., JNDO-5 $\times$ No.-41, No.-74 $\times$ JNDO-5 and No.-129 $\times$ HRB-55 expressed average to high sca effects for yield and other characters. The GCA/SCA ratio signified the predominant role of additive variance for all the characters except inter-nodal length.

Kushwaha *et al.* (2007) studied diallel cross of 8 parents viz., AB-2, AB-1, KS-312, BO-2, P-7, VRO-3, VRO-5 and P. Kranti. Based on specific combining ability following crosses viz., VRO-3 $\times$ Parbhani Kranti, KS-312 $\times$ BO-2, AB-2 $\times$ BO-2, AB-2 $\times$ KS-312, P-7 $\times$ VRO-5 were found superior for commercial production.

Singh *et al.* (2009) studied twelve diverse best homozygous cultivars of okra which were crossed in a diallel fashion without reciprocal. The analysis of variance for combining ability revealed that GCA and SCA variance were highly significant for all the characters under study. Among the parents Pusa Makhmali, Pusa Sawani, 7D2 and Arka

Abhay were identified good general combiners for various characters viz., plant height (cm), pod size (cm), pod weight (g) and yield per plant (g). The cross Pusa Makhmali $\times$ P-7 was the best combiner for yield per plant and showed the highest positive SCA effect and a high degree of heterosis.

Singh and Sanwal (2010) reported that, high SCA effects in cross combinations of Pusa Sawani $\times$ A. Anamika, HRB-9-2 $\times$ P-7, HRB-55 $\times$ A. Anamika, VRO-5 $\times$ A. Anamika, VRO-5 $\times$ IIVR-11 and VRO-5 $\times$ A. Abhay among twenty-four hybrids. Whereas, P. Kranti, VRO-6, VRO-5 and IIVR-11 were identified as good general combiners. Hence, these parents may be used as one of the parents in okra hybrid programme. The gene action studies indicated that there was preponderance of non-additive (dominance) gene action for all the traits under study.

Combining ability effects were estimated by Adiger *et al.* (2013) for different characters in a line $\times$ tester crossing programme. They reported that majority of cross combinations had recorded high SCA effects and *per se* performance due to low $\times$ low, low $\times$ high or high $\times$ low parental GCA status. The tester P. Kranti was found to be the good general combiner followed by Pusa Sawani. The hybrids 38 $\times$ 3, 3 $\times$ 1 and 13 $\times$ 3 had higher significant SCA effects for fruit yield and its component characters like days to 50% flowering, plant height (cm), number of branches per plant, inter-nodal length (cm), fruit length (cm), fruit diameter (mm), fruit weight (g) and number of fruits per plant. They also reported that the magnitude of SCA variance was higher than the GCA variance. This shows the predominance of non-additive gene action for all the characters, which indicated the scope for heterosis breeding for crop improvement in okra.

Singh *et al.* (2015) identified that parents P. Kranti, KS404 and KS405 were good general combiners for fruit yield and other traits in both generations. Three hybrids viz., KS405 $\times$ KS404, P. Kranti $\times$ KS405 and P. Kranti $\times$ KS404 in both F₁ and F₂ were identified as most promising and their use in hybrid breeding programme in okra would be most advantageous. During the study of combining ability effects in okra, Patel *et al.* (2015) recommended that genotypes AOL 09 – 02, AOL 10 – 22 and JOL 12 – 02 can be used as one of the parents to generate high yielding hybrids, as well as in varietal improvement programme because of high GCA effects in many characters. Among 24 hybrids, JOL 12 – 02 $\times$ HRB-55 had significant sca effect in the desired direction for pod

yield per plant (g), number of branches per plant, pod diameter (mm) and pod weight (g). It is proposed to evaluate these hybrids over locations and seasons to confirm other potentiality for the exploitation of heterosis and combining ability in okra.

Singh and Goswami (2015) noted that higher GCA effect among the parent's under study, IC 218872 for plant height, VRO 5 for days to flowering, plant height, length of internode and yield per plant. Whereas, cross combinations IC 306053 $\times$ P. Kranti, C 7801 $\times$ P. Kranti, Azad Bhindi 2 $\times$ P. Kranti, BO 2 $\times$ Azad Krishna, FB 10 $\times$ P. Kranti and VRO 1668 $\times$ Azad Krishna showed a significant positive effect for more than one character indicating their utility in further breeding programme. The best parents and their crosses can be utilized in breeding programme for the improvement of yield components.

An experiment was conducted by Patel *et al.* (2015) to assess the magnitude of combining ability in line $\times$ tester cross material involving 24 hybrids developed by crossing eight lines with three testers and one commercial hybrid check (Hybrid Mahyco-28). The result revealed genotype AOL 09 – 02, AOL 10 – 22 and JOL 12 – 02 can be recommended for use as one of the parents to generate high yielding hybrids, as well as in varietal improvement programme due to high GCA effects in many characters. Among 24 hybrids, JOL 12 – 02 $\times$ HRB-55 has significant SCA effect in the desired direction for pod yield per plant, number of branches per plant, pod diameter and pod weight. It is proposed to evaluate these hybrids over locations and seasons to confirm other potentiality for the exploitation of heterosis and combining ability in okra. The gene action studies indicated that there was a preponderance of non-additive gene action for all the traits under study.

Paul *et al.* (2017) estimated the combining ability effects and suggested that parents HRB-55 (21.195), AOL-09-17 (30.008), AOL-09-2 (10.679) and JOL-09-7 (1.288) were good general combiners for fruit yield per plant and its related attributes in his study. The analysis of variance for specific combining ability indicates that sufficient variation was there among cross combinations for yield and its related traits. The estimates of specific combining ability effects indicated that cross combinations JOL-55-3 $\times$ HRB-55 (56.786), JOL-09-8 $\times$ JOL-09-7 (46.346) and JOL-09-8 $\times$ AOL-09-17 (46.110) were most significant for fruit yield per plant and related traits. Present investigation indicates sufficient scope for exploitation of heterosis using the parents and crosses. The σ^2 GCA

and σ^2 sca ratio indicated that both additive and non-additive gene action was predominant for the inheritance of different traits.

Punea and Garg (2019) studied line $\times$ tester analysis in okra with 6 lines and 3 testers to estimate the combining ability effects and variances. Kashi Kranti was identified as the best general combiner for most of the characters such as days to 50% flowering, days to maturity, plant height, number of branches per plant, number of fruits per plant, fruit length and fruit weight. Another line Kashi Pragati also emerged as good combiner for six characters viz., plant height, number of fruits per plant, fruit length, fruit weight and fruit yield per plant. The testers which emerged as good general combiner for yield and its contributing traits were Arka Anamika. The cross No. 315 $\times$ Hisar Unnat was identified as a best specific combiner for most of the characters viz., plant height, number of branches per plant, fruit length, fruit weight, biological yield and fruit yield per plant. The estimates of SCA variance was found higher than GCA variance for all characters except number of fruits per plant. The proportion of variance showed a preponderance of non-additive effects.

2.4 Inheritance of YVMV disease resistance

Only a few attempts have been made in the past to study the genetics of resistance/susceptibility to YVMV. All the reports are contradictory to each other and there is no definite report for the inheritance of resistance to YVMV. Okra geneticists across the world tried to understand the inheritance pattern of YVMV disease tolerance without much success. In India, the first attempt to understand the nature of inheritance was made by Singh *et al.* (1962) and they found that two recessive alleles at two loci confirmed resistance in inter-varietal crosses of okra. The discovery of this type of genetically controlled resistance led to the development of first resistance variety Pusa Sawani by utilizing IC-1542 which showed freedom from the resistance under field conditions. Inheritance studies by the same workers in the crosses between IC-1542 as the resistance parent and Pusa Makhmali, S-91 and S-72 as susceptible parent suggest that two loci are involved, the presence of dominant allele at both the loci being necessary for causing susceptibility to disease. The resistance variety IC-1542 was then assigned the genotypes Yv1, Yv1, Yv2, Yv2 and the susceptible parents Yv1, Yv1, Yv2, Yv2. They also reported the field resistance by Pusa Sawani was symptomless carrier type.

Crosses between *A. esculentus* (L.) Moench cv. Pusa Sawani and *A. manihot* ssp. *manihot* were attempted by Thakur (1976) and Sharma and Dhillon (1983), but only one way cross in which *A. esculentus* used as the female parent was found compatible. The F₁ plants were free from yellow vein mosaic throughout their growing period. Segregation ratios in back cross generations and BC₂ F₂ generations showed that the resistance was controlled by two complementary dominant genes. Further test showed that resistant plants carried the virus but were symptomless. On the contrary, inheritance studies from the crosses involving two wild forms of *A. manihot* and susceptible varieties of *A. esculentus* revealed that resistance to YVMV was controlled by a single dominant gene (Arumugam and Muthukrishnan 1980; Jambhale and Nerkar 1981; and Sharma and Sharma 1984). However, further studies by Sharma and Sharma (1984) indicated the probability of polygenic inheritance of YVMV in okra. Sadashiva (1988) reported that YVMV resistance in okra is imparted only when at least one of the genes is in homozygous condition.

The inheritance of resistance to YVMV in okra was studied in crosses involving three resistance parents (Arka Anamika, Punjab Padmini and Arka Abhay) and three susceptible parents (Pusa Sawani, Local and Pusa Makhmali). The inheritance pattern suggested that resistance to YVMV was controlled by two complementary dominant genes in susceptible $\times$ susceptible (S $\times$ S) and susceptible $\times$ resistance (S $\times$ R) crosses but in resistant $\times$ resistant (R $\times$ R) crosses by two duplicate dominant genes (Pullaiah *et al.*, 1998).

An okra variety, IPSA okra 1, tolerant to YVMV disease was crossed to three susceptible genotypes viz. Parbhani Kranti, SL-44 and SL-46 by Ali *et al.* (2000) to determine the nature of inheritance of tolerance of IPSA okra 1. From the segregation pattern for disease reaction in F₂ and BC₁ generations of the 3 crosses, it could be hypothesized that the tolerance to YVMV in IPSA okra 1 is quantitative, with possibly two major factors, and dependent on gene dosage with incompletely dominant gene action. Rattan and Bindal (2000) conducted a study on resistant $\times$ resistant (R $\times$ R), susceptible $\times$ susceptible (S $\times$ S) and susceptible $\times$ resistant (S $\times$ R) parents. The study revealed that resistant to disease was found to be monogenic and dominant.

Vashisht *et al.* (2001) revealed that there is complex genetic control of resistance to YVMV and through higher-order interactions, they reported that the inheritance of YVMV

was governed by epistatic gene action. Dhankhar *et al.* (2005) again confused the situation by reporting that the inheritance of resistance to YVMV is under the controlled of two complementary genes following Mendelian segregation.

The qualitative analysis for segregation of resistance and susceptible plants in F_2 and back cross-generation involving two resistance cultivars (Punjab-8 and Parbhani Kranti) and two susceptible cultivars (Pusa Sawani and Pusa Makhmali) indicated that the gene governing the resistance in different parents were different and when these genes were brought together in the F_1 their effect was duplicated. In the crosses involving resistant $\times$ susceptible parents, the presence of a single dominant gene controlling YVMV resistance was confirmed along with some minor genes (Arora *et al.*, 2008).

Boonsirichai *et al.* (2009) generated F_1 , F_2 and BC_1F_1 seeds from the cross between B4610, a B-21 derived YVMV disease-resistant mutant, and Pichit 03, a susceptible variety. Upon natural inoculation with YVMV in the field, F_1 individuals exhibited prolonged resistance compared to Pichit 03 but eventually developed YVMV disease symptoms. Therefore, YVMV disease resistant mutation is semi-dominant. The segregation of resistance: susceptible individuals for F_2 and BC_1F_1 population fit the expected ratios of 3:1 and 1:1 respectively, for a single dominant resistant gene.

In another study by Dhankhar and Kumar (2012), crosses were made between wild and cultivated types for transfer of YVMV disease-resistant gene. The studies indicated that the resistance to YVMV is controlled by two complementary genes whose track has been either from wild ssp. *manihot* or the symptomless carrier cultivar namely IC 1542. The concentrated efforts in this have led to the development of several promising recombinants inbred lines.

Senjam *et al.* (2018) studied the inheritance pattern of YVMV disease in okra by employing six generations (P_1 , P_2 , F_1 , F_2 , BC_1 , BC_2) of four selected crosses (one tolerant $\times$ tolerant, two tolerant $\times$ susceptible and one susceptible $\times$ susceptible) using two tolerant (BCO-1 and Lal Bhendi) and two susceptible (Japanese Jhar Bhendi and PAN 2127) genotypes. Qualitative genetic analysis was done based on segregation pattern of tolerant and susceptible plants in F_2 and backcross generations of all the four crosses. It revealed that a single dominant gene along with some minor factors governed the disease tolerant trait in both the tolerant parents used. However, it was observed that genes governing

disease tolerance in both the tolerant variety used were different. It could be concluded that the gene governing YVMV disease tolerance in okra was genotype-specific. Further, duplicate gene action as evident from an approximate ratio of 15:1 (tolerant: susceptible) in the F₂ population in the cross of two tolerant varieties gave a scope of increasing the tolerance level of the hybrid plants when both the tolerant genes are brought together. However, generation mean analysis revealed involvement of both additive and non-additive effects in the inheritance of disease tolerance. It confirms that a complicated genetic inheritance pattern is involved in the disease tolerance against YVMV trait. Thus, there exists a lot of confusion and variation regarding the genetics of resistance to YVMV which is listed below in table 1. The major tolerance genes could be transferred to other okra varieties, but the tolerance breaking virus strains might not allow them to achieve tolerance in stable condition. Therefore, the accumulation of additional genes may be needed for a sustainable tolerance phenotype in okra.

Table 1. Genetics of YVMV resistance in okra

Sr. No.	Resistant/Tolerant parent (R)	Susceptible parents (S)	Cross	Gene effects/Remark	References
1.	<i>A. manihot</i> (L.) Medik and <i>A. manihot</i> (L.) Medik ssp. <i>manihot</i>	<i>A. esculentus</i> cv. Pusa Sawani	F ₂ , BC, and subsequent generations	Single dominant gene	Jambhale and Nerkar, 1981
2.	<i>A. manihot</i> ssp. <i>manihot</i>	-	Different generations	Two dominant genes	Sharma and Dhillon, 1983
3.	<i>A. manihot</i>	<i>A. tetraphyllus</i>	Different generations	Single dominant gene	Dutta, 1984
4.	Arka Anamika, Punjab Padmini and Arka Abhay	Pusa Sawani, Local and Pusa Makhmali	S×S, S×R R×R	Two complementary dominant genes Two duplicate dominant genes	Pullaiah <i>et al.</i> , 1998
5.	IPSA Okra 1	Parbhani Kranti, SL-44 and SL-46	F ₂ and BC generations	Quantitative with two major factors dependent on gene dosage having incomplete dominant gene action	Ali <i>et al.</i> , 2000
6.	Parbhani Kranti	Punjab 8, Punjab Padmini, Pusa Makhmali, and Pusa Sawani	Nine generations	Additive gene effects more significant than dominance gene effects	Vashisht <i>et al.</i> , 2001
7.	<i>A. manihot</i> (L.) Medikus ssp. <i>manihot</i>	<i>A. esculentus</i> cv. Hisar Unnat	Different generations	Two complimentary dominant genes	Sharma and Sharma, 1984; Dhankhar <i>et al.</i> , 2005
8.	Punjab-8 and Parbhani Kranti	Pusa Sawani and Pusa Makhmali	F ₂ and back cross	Both single dominant gene and some minor genes; the presence of additive gene effects and duplicate epistatic gene action	Arora <i>et al.</i> , 2008
9.	BCO-1 and VNR Green	Pusa Sawani and Arka Anamika	Six generations (P ₁ , P ₂ , F ₁ , F ₂ , BC ₁ , BC ₂) of (T×T), (T×S) and (S×S) crosses	Two duplicate dominant genes in T×T, and 02 complimentary dominant genes in T×S cross	Seth <i>et al.</i> , 2017
10.	BCO-1 and Lal Bhendi	Japanese Jhar Bhendi and PAN 2127	Six generations (P ₁ , P ₂ , F ₁ , F ₂ , BC ₁ , BC ₂) of (T×T), (T×S) and (S×S) crosses	Both single dominant gene with some minor genes; the presence of additive gene effects and duplicate epistatic gene action	Senjam <i>et al.</i> 2018

BC - Back Cross

S×R- Susceptible × Resistant

R×R- Resistant × Resistant

T×S- Tolerance × Susceptible

S×S- Susceptible × Susceptible

T×T- Tolerance × Tolerance



*Materials
and
Methods*



The present study was carried out at Vegetable Research Centre (VRC) of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand in the summer and rainy seasons of the year 2017-18 and 2018-19, respectively. The material used in this investigation and methods followed has been described in this chapter.

3.1 Site of experiment and climate

Geographically Pantnagar is situated at the latitude of 29.5° North and longitude 79.2° East and at an elevation of 243.83 meters above the mean sea level. The weather conditions were quite favourable for the normal growth of the crop. The climate of Pantnagar is humid sub-tropical with maximum temperature ranging from 35.10°C to 45.40°C in summer and minimum temperature ranging from 4.80°C to 13.60°C in winter. Generally, monsoon starts from the third week of June and ends in September. The average annual rainfall is 1300 mm. The mean relative humidity remains almost 80-90 per cent from mid-June to the end of February and then it steadily decreases to 50 per cent by the first week of May and remains so till mid-June. The weekly average of various weather parameters that prevailed during the investigation was recorded at Meteorological Observatory of Norman E. Borlaug Crop Research Centre of the University and are presented in Appendix I, II and III. Considering the eco-geographical conditions, Pantnagar is located at the foothills of *Shivalik* range in the Himalayas and falls under the humid sub-tropical climate in a narrow belt called *Tarai*. The soil of the *Tarai* region has been developed from calcareous, medium to coarse-textured materials under the predominant influence of tall vegetation and moderate to well drain condition.

3.2 Estimation of genetic variability, heritability and genetic advance for yield and its contributing traits in okra

3.2.1 Experimental Material

The experimental material utilized for this study consists of 16 genotypes (11 lines, 4 testers and 1 check) which collected from N.B.P.G.R., New Delhi and I.I.V.R., Varanasi. During rainy season of 2017, all the breeding lines and tester were raised in a breeding block and prepared 44 crosses in line × tester mating design. In summer and rainy season of 2018,

these 44 crosses along with 15 parents and one check were evaluated in RBD design. The detail of the parental materials used in the study is given in Table 3.1.

Table 3.1: List of parental genotypes

S. No.	Lines (Female)	Source	Specific traits
1.	IC093655	NBPGR, New Delhi	Light green fruit, tender, moderately resistant to YVMV
2.	EC169430	NBPGR, New Delhi	Attractive dark green fruit, tender, smooth, good yield potential and resistant to YVMV
3.	EC169435	NBPGR, New Delhi	Dark Green fruit, 5 ridged, good yield potential and tolerance to YVMV
4.	EC169506	NBPGR, New Delhi	Green fruit, smooth, tender and moderately resistant to YVMV
5.	EC169400	NBPGR, New Delhi	Green fruit, long, slender moderately resistant to YVMV
6.	EC169408	NBPGR, New Delhi	Green fruit, smooth, moderately resistant to YVMV
7.	IC117123	NBPGR, New Delhi	Light green fruit, slender, smooth, susceptible to YVMV
8.	IC117245	NBPGR, New Delhi	Green fruit, smooth, moderately resistant to YVMV
9.	IC117351	NBPGR, New Delhi	Light green fruit, tender, moderately resistant to YVMV
10.	IC117355	NBPGR, New Delhi	Green fruit, long, slender moderately resistant to YVMV
11.	IC117328	NBPGR, New Delhi	Light green fruit, rough, moderately resistant to YVMV
	Tester (Male)		
1.	Pusa A-4	IARI, New Delhi	Attractive dark green fruit with 5 ridged, good shelf life, 12-15 cm long
2.	VRO-6 (Kashi Pragati)	IIVR, Varanasi	Green fruit, 8-10 cm long pods
3.	Parbhani Kranti	PCPGR, Pantnagar	Extremely dark green fruit, smooth, tender, slender, 5 ridged with a long and narrow tip
4.	15/RES-4	IIVR, Varanasi	Extremely dark green fruit, slightly hard, immune to YVMV
	Check		
1.	Arka Anamika (C)	PCPGR, Pantnagar	Medium green fruit, rough, 5 ridged, good yield potential

3.2.2 Experimental layout

The experiment was laid out in Randomized Block Design (RBD) with 15 parents (11 lines and 4 testers), 44 crosses and 1 check.

1. Site of the experiment: Vegetable Research Centre, G.B.P.U.A. & T., Pantnagar, U. S. Nagar, Uttarakhand
2. Number of parental genotypes: 15 (11 inbred lines and 4 testers)
3. Scheme of mating: Line $\times$ tester
4. Experimental material: 60 [15 parents + 44 F₁s + 1 check (Arka Anamika)]
5. Design of experiment: Randomized Block Design (RBD)
6. Number of replication: 3
7. Spacing: 60 $\times$ 30 cm
8. Number of plants/treatment: 20
9. Fertilizer doze (N.P.K kg/ha): 100:40:40
10. Number of rows per genotype: 2
11. Sowing season: Rainy and Summer

3.2.3 Field preparation and seed sowing

The field of the experiment was prepared by preparatory tillage operation *i.e.*, one deep ploughing followed by three harrowing. The field was levelled and divided into plots as per the layout. The seeds were sown with the help of hoe and after germination excess plants were thinned out to maintain ten plants at a spacing of 30 cm in each line.

3.2.4 Application of fertilizer

The NPK fertilizers were applied @ 100:40:40 kg/ha. Half dose of nitrogen and a full dose of phosphorus and potash were applied as basal dose and mixed into the soil thoroughly one day before seed sowing. Rest of nitrogen was applied in two split doses, one at 30-40 days after seed sowing and the remaining at 55-60 days after seed sowing as a top dressing in each block.

3.2.5 Observations recorded

44 F₁ crosses and their 15 parents with one check were sown in each block. After germination of the seeds, the thinning operation was done to maintain ten plants per line in

each block. Five plants were selected randomly and tagged to record all the vegetative and reproductive observations. The following 13 quantitative observations were recorded:

3.2.5.1 Days to 50 per cent flowering

The number of days taken from sowing to the date by which 50 per cent plants in each entry flowered was noted and their average in terms of days was worked out.

3.2.5.2 Plant height (cm)

The plant height was measured at the time of final harvesting from the ground level to the growing tip of the plant with the help of a meter scale.

3.2.5.3 Number of primary branches per plant

The numbers of primary branches per plant were counted at the time of final harvesting in each genotype in each block and average number of branches per plant was calculated.

3.2.5.4 Stem diameter (cm)

The stem diameter was measured at the base (crown portion) of the stem with the help of vernier caliper, at time of final harvesting and the mean diameter of stem per plant was calculated in centimetre.

3.2.5.5 Inter-nodal length (cm)

The inter-nodal length per plant was measured at the time of final harvesting stage from node to node with the help of meter scale. The average inter-nodal length per plant was calculated in cm.

3.2.5.6 First fruit-producing node

The node at which first fruit appears per plant was counted at the fruiting stage in each genotype line and average number of node per plant was calculated.

3.2.5.7 Fruit length (cm)

Five edible fruits were selected randomly in each genotype in each block and the length of these fruits, excluding fruit stalk, was measured in centimetres and the mean length per pod was computed.

3.2.5.8 Fruit diameter (cm)

The diameter of the five randomly selected edible fruits were measured at the base of fruits with the help of Vernier calliper and the mean was calculated in centimetres.

3.2.5.9 Average fruit weight (g)

Five edible fruits were selected randomly in each genotype, in each block and their weight was taken with the help of weighing balance and their weight was averaged in gram.

3.2.5.10 Number of fruits per plant

The numbers of edible fruit harvested from the five tagged plants in each entry and during all the pickings were added and average number of fruits per plant was calculated.

3.2.5.11 Fruit yield per plant (g)

Fruit yield per plant of tagged plants was computed by adding the fruit weight of all the pickings and by averaging and was expressed in grams per plant

3.2.5.12 Number of seeds per fruit

Ten dried fruits from tagged plants of each experimental plot were randomly picked and seeds were extracted. The numbers of seeds were counted and average number of seeds per fruit was worked out.

3.2.5.13 Total yield (q/ha)

Total yield q/ha was calculated by average fruit weight multiply with number of fruits per plant and number of plants per hectare.

3.2.6 Incidence of YVMV (%)

Under natural disease pressure condition, all the plants in each plot were observed for the appearance of yellow vein mosaic virus symptoms. The numbers of plants affected by YVMV were observed at 30, 45, 60 and 75 days after sowing of the crop in each genotype. YVMV was scored by using the scorecard given below. Per cent incidence was computed based on the total number of plants per plot.

$$\text{YVMV infestation on plants(\%)} = \frac{\text{Number of YVMV infected plants}}{\text{Total number of plants}} \times 100$$

Table 3.2: Scale for classifying reaction of okra genotypes to yellow vein mosaic virus disease (Senjan *et al.*, 2018)

Description	Severity grade	Reaction
Symptom absent	0	Highly Resistant/Immune
Mild symptoms <5% of plants infected	1	Resistant
5-25 per cent of plants affected	2	Moderately Resistant
26-50 per cent of plants affected	3	Moderately susceptible
51-75 per cent of plants affected	4	Susceptible
>75 per cent of plants affected	5	Highly Susceptible

3.2.7 Statistical analysis

The data collected on the quantitative characters were subjected for statistical analysis and following different statistical parameters were worked out.

3.2.7.1 Analysis of variance (ANOVA)

Analysis of variance was done separately for each character for all treatments.

The model of analysis of variance was given below.

Source	D.F	SS	MSS	Cal. F
Replications	r-1	RSS	RSS/(r-1)	TMSS/EMSS
Treatments	t-1	TSS	TSS/(t-1)	-
Error	(r-1) (t-1)	ESS	ESS/(r-1) (t-1)	-
Total	(rt-1)	-	-	-

Where,

t = Number of treatments (genotypes)

r = Number of replications

The standard error was calculated as,

$$SEm = \sqrt{EMSS/r}$$

The significance of treatments means squares and replication mean squares were tested by comparing with error mean squares referring to 'F' table values at 5 and 1 per cent level of probabilities.

3.2.7.2 Estimation of genotypic, phenotypic and environmental variances

The variance due to genotype, phenotype and environment were computed as follows.

$$\text{Genotypic variance } (\sigma_g^2) = \frac{\text{MS due to genotypes (adj)} - \text{MS due to error (intra block)}}{r \text{ (replication)}}$$

$$\text{Environmental variance } (\sigma_e^2) = \text{Error mean sum of squares}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \sigma_g^2 + \sigma_e^2 \text{ (MS due to error)}$$

Where, 'r' is number of replications.

Genotypic and phenotypic coefficient of variation

Genotypic and phenotypic coefficients of variance were estimated according to Burton and Devane (1953) based on the estimate of genotypic and phenotypic variance.

Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\text{Genotypic standard deviation}}{\text{Mean}} \times 100$$

Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\text{Phenotypic standard deviation}}{\text{Mean}} \times 100$$

Environment co-efficient of variation (ECV)

$$\text{ECV (\%)} = \frac{\text{Environmental standard deviation}}{\text{Mean}} \times 100$$

Where,

$$\bar{X} = \text{General mean}$$

$$\sigma_g = \text{Genotypic standard deviation}$$

σ_p = Phenotypic standard deviation

GCV and PCV were classified as suggested by Burton and Devane (1953)

<10% : Low

10-20% : Moderate

>20% : High

3.2.7.3 Estimation of heritability

The broad sense heritability (h^2_{bs}) was estimated by following the procedure suggested by Weber and Moorthy (1952) as indicated here below.

$$\text{Heritability } (h^2) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where, h^2 (%) = Heritability (Broad sense)

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Heritability (h^2) in broad sense was categorized as suggested by Hanson *et al.*, 1956 is given below.

< 50% - Low

50-75% - Moderate

> 75% - High

3.2.7.4 Genetic advance (GA)

The expected genetic advance was estimated by the method proposed by Johnson *et al.* (1955).

$$GA = h^2 \cdot K \cdot \sigma_p$$

Where,

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation of the given character

K = Selection differential at 5% selection intensity (2.06).

3.2.7.5 Genetic advance as per cent of mean ($\overline{GA\%}$)

$$G.A. (\%) = \frac{\text{Genetic advance}}{\text{Mean}} \times 10$$

Genetic advance as per cent of mean was categorized as low, moderate and high as given by Johnson *et al.* (1955). It is as follows:

<10%	- Low
10-20%	- Moderate
>20%	- High

3.3: Estimation of heterosis and combining ability for yield and its contributing traits in okra [*Abelmoschus esculentus* (L.) Moench]

3.3.1 Experimental material

The experimental material for the present study consisted of 15 genotypes (11 lines and 4 testers) which are selected based on their diversity for various traits. From these 15 genotypes, 44 crosses were made during *Kharif* 2017 using line x tester mating design. Thus, the 44 crosses and their 15 parents formed the experimental material for the present study.

3.3.2 Selfing and crossing techniques

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

3.3.3 Experimental design and layout plan

The experimental material, consisting fifty-nine entries including fifteen parents and their forty-four crosses, was laid out in a randomized block design (RBD) with three replications over two seasons *viz.*, summer and rainy (2018) at the Vegetable Research Centre (VRC) of the G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Each entry was presented by two-row plot of twenty plants. All recommended agronomic practices along with plant protection measures were followed uniformly and timely. The details of the experimental plan are given below:

Experimental site	:	Vegetable Research Centre, Pantnagar
Design	:	Randomized Block Design (RBD)
Replications	:	3
Treatments	:	59
Spacing	:	60 x 30 cm

3.3.4 Details of observations recorded

Five competitive plants were randomly selected from each entry in three replications. Average of the five plants in respect of different characters was recorded as given below: All the 14 quantitative characters studied were first flower producing node, first fruit-producing node, inter-nodal length (cm), fruit length (cm), fruit diameter (mm), number of seeds per fruit, 100 seed weight (g), days to 50 per cent flowering, plant height (cm), number of primary branches per plant, stem diameter (mm), number of fruits per plant, average fruit weight (g) and fruit yield per plant (g). These characters were studied as per details given in heading 3.2.5.

3.3.5 Statistical analysis

Analysis of variance of 15 parents and 36 F₁s replicated three times in randomized block design was done to find out differences between the parents and the hybrids for fourteen characters.



(A) Experimental field view during summer season (2018)



(B) Experimental field view during rainy season (2019)

Plate 1: Experimental field view

Source of variation	Degrees of freedom (d.f.)	Mean Sum of Squares (MSS)	F value
Replication	r-1	M_r	M_r/M_e
Treatments	t-1	M_t	M_t/M_e
Error	(r-1) (t-1)	M_e	

Where,

r = Number of replications

t = Number of treatments

MSS = Sum of squares/ d.f.

M_r = Mean sum of square due to replication

M_t = Mean sum of square due to treatments

M_e = Mean sum of square due to error

Critical Difference (CD) was calculated to test the significance of the difference between any two treatments as follows:

CD = SED x 't' value at error degrees of freedom

Where 'SED' is the standard error of the difference between two treatment means.

SED = $\sqrt{2MSE/r}$

Where,

MSE is the mean sum of square due to error

3.3.5.1 Estimation of heterosis

The magnitude of heterosis was estimated with mid-parent, a better parent and standard parent (Arka Anamika). They were, calculated as a percentage increase or decrease of F_1 s over the mid-parent (MP), better parent (BP) and standard parent (SP) using the methods of Turner (1953) and Hayes *et al.* (1956). The formula used for estimation of heterosis given by Fonseca and Patterson (1968) was used.

For the characters like days to 50 per cent flowering, first flower producing node, first fruit-producing node and inter-nodal length, low scoring parent was considered as a better parent in the estimation of heterobeltiosis. Whereas, high scoring parent was considered as a better parent for the rest of the traits.

Heterosis for each trait was computed and the significance of F_1 heterosis values was tested by comparing them with critical difference (CD) values obtained separately for MP and BP employing the formulae given below.

3.3.5.1.1 For mid-parent heterosis

$$\text{Per cent heterosis over mid-parent (MP)} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Where, mid-parent} = \frac{P_1 + P_2}{2}$$

Where P_1 and P_2 are parents of a hybrid combination.

The deviations for heterosis were tested for their significance by the following standard errors.

$$SE = \sqrt{\frac{3}{2} \frac{MSE}{r}}$$

Where,

MSE = Mean sum of square due to error obtained from a general analysis of variance

r = Number of replications

C.D. = S.E.(d) x 't' value at error df (P = 0.05 and P 0.01 levels of significance)

Significance of heterosis values was tested using 't' test:

$$t = \frac{\overline{F_1} - \overline{MP}}{\text{S.E. of heterosis over MP}}$$

Calculated 't' value was compared with table value at error degrees of freedom for significance.

3.3.5.1.2 For better parents heterosis

$$\text{Per cent heterosis over better parent (BP)} = \frac{F_1 - BP}{BP} \times 100$$

Per cent heterosis over a better parent is also called as heterobeltiosis (BH).

CD for better parents heterosis = SE x 't' value.

$$SE = \sqrt{\frac{2MSE}{r}}$$

Where,

MSE = Mean sum of square due to error obtained from a general analysis of variance

r = Number of replications

t = Table 't' value at error degrees of freedom

Significance of heterosis values was tested using 't' test:

$$t = \frac{\overline{F_1} - \overline{BP}}{\text{S.E. of heterosis over BP}}$$

Calculated 't' value was compared with table value at error degrees of freedom for significance.

3.3.5.1.2 For standard parents heterosis

$$\text{Per cent heterosis over standard parent (SP)} = \frac{F_1 - SP}{SP} \times 100$$

Per cent heterosis over a standard parent is also called as standard heterosis.

CD for standard parents heterosis = SE x 't' value.

$$SE = \sqrt{\frac{2MSE}{r}}$$

Where,

MSE = Mean sum of square due to error obtained from a general analysis of variance

r = Number of replications

t = Table 't' value at error degrees of freedom

Significance of heterosis values was tested using 't' test:

$$t = \frac{\overline{F_1} - \overline{SP}}{\text{S.E. of heterosis over SP}}$$

Calculated 't' value was compared with table value at error degrees of freedom for significance.

3.3.5.2 Combining ability analysis

Information about general combining ability (GCA) and specific combining ability (SCA) were obtained by subjecting the data to line x tester analysis as outlined by Kempthorne (1957). The following model was used for estimating the GCA and sca effects in combining ability analysis.

$$X_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$$

Where,

μ = General mean

g_i = GCA effect of i^{th} line

i = 1, 2,..... i (Number of lines)

g_j = GCA effect of j^{th} tester

j = 1, 2,..... j (Number of testers)

S_{ij} = sca effect of the ij^{th} combination

e_{ijk} = Error associated with the observation

k = 1, 2,..... r (Number of replications)

In the analysis of variance for combining ability, the components due to lines, testers and line x tester were calculated by splitting the cross sum of squares. The model of table showing analysis of variance for combining ability is given below.

3.3.5.2.1 Analysis of variances for combining ability

Source of variation	Degrees of freedom	Sum of squares	Mean sum of square (MSS)
Replication	(r - 1)	$\frac{X^2 \dots k}{lt} - \frac{X^2}{ltr}$	
Crosses	(lt - 1)	$\frac{X^2_{ij}}{r} - \frac{X^2}{ltr}$	M ₀
Lines	(l - 1)	$\frac{X^2_{i \dots}}{tr} - \frac{X^2 \dots}{ltr}$	M ₁
Tester	(t - 1)	$\frac{X^2_j}{lt} - \frac{X^2 \dots}{ltr}$	M ₂
Line x Tester	(l - 1) (t - 1)	$\frac{X^2_{ij}}{r} - \frac{X^2 \dots}{ltr} - \frac{X^2_j}{r} + \frac{X^2}{tr}$	M ₃
Error	(r - 1) (lt - 1)	By difference	M ₄
Total	(ltr - 1)	$X^2_{ijk} - \frac{X^2}{ltr}$	

3.3.5.2.2 Estimation of general and specific combining ability effects

The individual effects were estimated as follows:

$$\mu = \frac{X \dots}{ltr}$$

where,

X... = Total of all hybrid combinations

Estimation of GCA effects

For lines

$$g_i = \frac{X_{i \dots}}{tr} - \frac{X \dots}{ltr}$$

Where,

g_i = General combining ability effect of ith line

X_i = Total of the ith line overall testers and replications

For testers

$$g_j = \frac{X_{j...}}{tr} - \frac{X_{...}}{ltr}$$

g_j = Total of j^{th} tester overall lines and replications

Estimation of SCA effects

$$S_{ij} = \frac{X_{ij}}{r} - \frac{X_{i...}}{tr} - \frac{X_{j...}}{lr} + \frac{X_{...}}{ltr}$$

Where,

S_{ij} = Specific combining ability of the cross between i^{th} line and j^{th} tester

X_{ij} = Total of $(ij)^{\text{th}}$ combination overall replications

The expectation of mean squares in the above table for the analysis of variance of combining ability is presented below:

MSS	Expected mean squares
M_1	$\sigma^2_e + r [\text{Cov. (F.S.)} - 2\text{Cov. (H.S.)}] + tr \text{ Cov. (H.S.)}$
M_2	$\sigma^2_e + r [\text{Cov. (F.S.)} - 2\text{Cov. (H.S.)}] + lr \text{ Cov. (H.S.)}$
M_3	$\sigma^2_e + r [\text{Cov. (F.S.)} - 2\text{Cov. (H.S.)}]$
M_4	σ^2_e

Where,

r = Number of replications

l = Number of lines

t = Number of testers

$X_{.....k}$ = Sum of all the $(l \times t)$ crosses in k^{th} replication

$X_{.....}$ = Sum of all the $(l \times t)$ crosses over all combinations

X_{ij} = Sum of $(ij)^{\text{th}}$ cross combination over all the replications

$X_{j.....}$ = Sum of j^{th} tester over all the lines and replications

X_{ijk} = $(ij)^{\text{th}}$ observation in k^{th} replication

M_1 = Mean square due to lines

M_2 = Mean square due to testers

M_3 = Mean square due to line x tester interaction and

M_4 = Mean square of the error

- i. $SE(m) (g_i) \text{ for lines} = \left[\frac{l-1}{ltr} \times EMS \right]^{1/2}$
- ii. $SE(m) (g_j) \text{ for testers} = \left[\frac{t-1}{ltr} \times EMS \right]^{1/2}$
- iii. $SE(m) (S_{ij}) \text{ for testers} = \left[\frac{(l-1)(t-1)}{ltr} \times EMS \right]^{1/2}$
- iv. $SE(d) (g_i - g_j) \text{ for lines} = \left[\frac{l-1}{ltr} \times 2EMS \right]^{1/2}$
- v. $SE(d) (g_i - g_j) \text{ for testers} = \left[\frac{t-1}{ltr} \times 2EMS \right]^{1/2}$
- vi. $SE(d) (S_{ijk} - S_{jk}) \text{ for hybrids of same tester} = \left[\frac{t-1}{ltr} \times EMS \right]^{1/2}$
- vii. $SE(d) (S_{ijk} - S_{jk}) \text{ for hybrids of same line} = \left[\frac{t-1}{ltr} \times EMS \right]^{1/2}$

Where,

$SE(m)$ = Standard error of mean

$SE(d)$ = Standard error of the difference between two values

EMS = Error mean squares

Critical difference (CD) = $SE(d) \times t'$ value at error degrees of freedom

Testing the significance of GCA effects

Significance of gca was tested by 't' test using the following formulae,

For lines, $t' = \frac{g_i}{SE(m) g_i}$

For testers, $t' = \frac{g_j}{SE(m) g_j}$

Testing the significance of SCA effects

Significance of sca was tested by 't' test using the following formulae,

$$t' = \frac{S_{ij}}{SE(m) S_{ij}}$$

Where,

g_i = GCA of i^{th} line

g_j = GCA of j^{th} tester

$SE(m) g_i$ = Standard error of line

$SE(m) g_j$ = Standard error of tester

S_{ij} = sca of the cross between i^{th} line and j^{th} tester

$SE(m) S_{ij}$ = Standard error of crosses

The calculated value of 't' was tested against a value in the 't' table at error degrees of freedom at 5 and 1 per cent level of significance.

3.3 Estimation of gene effects and inheritance of resistance to YVMV through generation mean analysis

3.3.1 Study on the inheritance of yellow vein mosaic virus disease resistance

15/RES-4 was crossed to EC169430, IC117123 and IC117328 to produce F_1 seeds during *Kharif* 2017 and advanced to F_2 , as well as back cross to resistant parent 15/RES-4, EC169430 and susceptible parents IC117123 and IC117328 to produce B_1 and B_2 generations respectively during *Kharif* 2018. The sowing was done with a spacing of 60 cm between rows and 30 cm between plants with the row length of 3 meters. The F_2 populations were raised and 100 plants were selected from each replication for taking observations. All standard agronomic practices were followed to raise a good crop. At the time of harvest, observations were recorded on all the plants including the parents and F_1 s for quantitative traits. For better disease condition, a row of okra line Pusa Sawani, a highly susceptible variety was planted after every seven lines to provide sufficient epiphytotic condition in the field. Disease severity grade was recorded at 30 DAS, 45 DAS, 60 DAS and 75 DAS. Record the disease severity grade based on disease severity range given in table 3.3.

Table 3.3: Disease scale for YVMV (Senjan *et al.*, 2018)

Severity range %	Disease scale/grade	Disease reaction
0	0	Immune (I)
1-10	1	Highly resistant (HR)
11-25	2	Moderately resistant (MR)
26-50	3	Tolerant (T)
51-60	4	Moderately Susceptible (MS)
>60	5	Susceptible (S)

$$\text{PDI (\%)} = \frac{\text{Sum of all disease rating} \times 100}{\text{Maximum grade} \times \text{total number of plants of the entry examined}}$$

3.3.2 Six generation mean analysis

The experiment was conducted during *Kharif* 2019 and the details of statistical procedures adopted for analysis of six generations viz., P₁, P₂, F₁, F₂, B₁, B₂ of the selected cross on the nature and magnitude of various types of gene action are presented below.

Mather's scaling tests

The scaling tests viz., A, B, C and D were calculated by following methods of Mather (1949) to detect the presence or absence of epistasis as detailed below.

$$\begin{aligned} A &= 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1 \\ B &= 2\bar{B}_2 - \bar{P}_2 - \bar{F}_2 \\ C &= 4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2 \\ D &= 2\bar{F}_2 - \bar{B}_1 - \bar{B}_2 \end{aligned}$$

Where,

P₁, P₂, F₁, F₂, B₁ and B₂ are the mean values of the respective generations. A significant deviation of A, B and C values from zero indicates the presence of epistasis justifying the use of six parameter model.

Variances of means of the corresponding generations (squares of standard errors) were used to compute the variances of A, B and C as shown below.

$$\begin{aligned}
V_A &= 4 V \bar{B}_1 + V \bar{P}_1 + V \bar{F}_1 \\
V_B &= 4 V \bar{B}_2 + V \bar{P}_2 + V \bar{F}_1 \\
V_C &= 16 V \bar{F}_2 + 4 V \bar{F}_1 + V \bar{P}_1 + V \bar{P}_2
\end{aligned}$$

Where,

V_A , V_B and V_C are the variances of A, B and C, respectively. V_{P1} , V_{P2} etc. are the variances of means of the respective generations, 't' values for each of these three quantities were calculated to test their significance as follows.

$$t(A) = A/SE(A)$$

$$t(B) = B/SE(B)$$

$$t(C) = C/SE(C)$$

Where, standard error (SE) is the square root of respective variance for example $SE(A) = \sqrt{V_A}$.

Joint scaling test

In the Cavalli's (1952) joint scaling test, genetic parameters viz., mean (m), additive (d) and dominant (h) components are estimated from the observed means of three or more generations. When more than three generation means are available to estimate the above three parameters a weighed least-square analysis is employed which enables precise estimation of (m), (d) and (h), such that deviations of observed from expected values are least. In this approach, reciprocals of the variance of each of the means are used as a weight. Six equations from six generations viz., P_1 , P_2 , F_1 , F_2 , B_1 and B_2 would be available for estimation of (m), (d) and (h) that are obtained by equating the observed family means to their expectations in terms of three genetic parameters as detailed below.

Generation	Weight	Coefficients			Observed Generation mean
		M	(d)	(h)	
P_1	$1/V_{P1}$	1	1	0	P_1
P_2	$1/V_{P2}$	1	-1	0	P_2
F_1	$1/V_{F1}$	1	0	1	F_1
F_2	$1/V_{F2}$	1	0	0.5	F_2
B_1	$1/V_{B1}$	1	0.5	0.5	B_1
B_2	$1/V_{B2}$	1	-0.5	0.5	B_2

'P2' is regarded as a favourable parent and $VP2$ = variance of $P2/n$.

The six equations and their weights are combined to get three simultaneous normal equations yielding weighted least squares estimates of the three parameters (m) (d) and (h) as follows.

Each of the equation is multiplied by the coefficient, which it contains and by its weight and the six equations are then summed to get the first normal equation. The two further equations are obtained in a similar way using the coefficients of m, d and h and the weights as multiplier. The solution to these three simultaneous normal equations is obtained by way of matrix inversion, that is in the form of $M = J^{-1}S$.

Where,

M = Matrix of the estimations of the parameters viz., m, (d) and (h)

J^{-1} = Inverse of the information matrix (J) and is a variance-covariance matrix

S = Column matrix obtained by multiplying respective observed values by coefficients and weight and is matrix of score.

By using the inversion matrix, the values of m, (d) and (h) were computed. The adequacy of the additive-dominance model was next tested by predicting the expected family means from the estimates of the three genetic parameters and comparing with the observed generation means with the help of the chi-square test. Significance of calculated chi-square value depicts the inadequacy of the additive-dominance model and further analysis using Hayman's approach (1958) is required to determine the possible non-allelic interaction effects.

Estimation of gene effects using six-generation means

The generation means were analysed by the method suggested by Hayman (1958) to provide information on the inheritance of various traits. The generation means were used to estimate the six genetic parameters viz., (m), (d), (h), (i), (j) and (l) of digenic interaction model representing F_2 means, additive gene action, dominance genetic effect, additive $\times$ additive gene interaction effect, additive $\times$ dominance interaction effect and dominance $\times$ dominance gene effects, respectively assuming that no linkage and no higher-order gene interaction exists. Considering the generation means as reference values, the above six genetic parameters were calculated following the relationship between respective generation mean and genetic effects.

Components of generation means

$$P_1 = m + (d) + (i)$$

$$P_2 = m - (d) + (i)$$

$$F_1 = m + (h) + (1)$$

$$F_2 = m + \frac{1}{2}(h) + \frac{1}{4}(l)$$

$$B_1 = m + \frac{1}{2}(d) + \frac{1}{2}(h) + \frac{1}{4}(i) + \frac{1}{4}(j) + \frac{1}{4}(l)$$

$$B_2 = m - \frac{1}{2}(d) + \frac{1}{2}(h) + \frac{1}{4}(i) + \frac{1}{4}(j) + \frac{1}{4}(l)$$

Accordingly, by least squares computation method, the formulae for different gene effects are as follows.

Formulae for gene effects

$$\text{Mean } m = \bar{F}_2$$

$$\text{Additive effect } (d) = \bar{B}_1 - \bar{B}_2$$

$$\text{Dominance effect } (h) = 2\bar{B}_1 + 2\bar{B}_2 + \bar{F}_1 - 4\bar{F}_2 - \frac{1}{2}\bar{P}_1 - \frac{1}{2}\bar{P}_2$$

$$\text{Additive} \times \text{additive epistatic effect } (i) = 2\bar{B}_1 + 2\bar{B}_2 - 4\bar{F}_2$$

$$\text{Additive} \times \text{dominance epistatic effect } (j) = \bar{B}_1 + \frac{1}{2}\bar{P}_1 - \bar{B}_2 + \frac{1}{2}\bar{P}_2$$

$$\text{Dominance} \times \text{dominance interaction effect } (l) = \bar{P}_1 + \bar{P}_2 + 2\bar{F}_1 + 4\bar{F}_2 - 4\bar{B}_1 - 4\bar{B}_2$$

The variance of these gene effects involving the variances of means of the generations was calculated as follows.

$$V_m = \bar{V}_{F_2}$$

$$V_d = \bar{V}_{B_1} + \bar{V}_{B_2}$$

$$V_h = \bar{V}_{F_1} + 16\bar{V}_{F_2} + \frac{1}{4}\bar{V}_{P_1} + \frac{1}{4}\bar{V}_{P_2} + 4\bar{V}_{B_1} + 4\bar{V}_{B_2}$$

$$V_i = 4\bar{V}_{B_1} + 4\bar{V}_{B_2} + 16\bar{V}_{F_2}$$

$$V_j = 4\bar{V}_{B_1} + 4\bar{V}_{B_2} + \bar{V}_{P_1} + \bar{V}_{P_2}$$

$$V_l = \bar{V}_{P_1} + \bar{V}_{P_2} + 4\bar{V}_{F_1} + 16\bar{V}_{F_2} + 16\bar{V}_{B_1} + 16\bar{V}_{B_2}$$

Where,

V_m = Variance of mean effect

V_d = Variance of additive effect

V_h = Variance of dominance effect

V_i = Variance of additive $\times$ additive interaction effect

V_j = Variance of additive $\times$ dominance interaction effect

V_l = Variance of dominance $\times$ dominance interaction effect

Square roots of the variance provided respective standard errors. B_1 = Back cross 1 and B_2 = Back cross 2. The standard errors were used to calculate the 't' values for testing significance of the corresponding variances, for example.

$$t(d) = \frac{\bar{d}}{SE(d)}, \text{ where, } SE(d) = \sqrt{V(d)}$$



Results and Discussion



The present investigation on “Genetic studies for yield and YVMV resistance in okra [*Abelmoschus esculentus* (L.) Moench] was carried out at V.R.C., Pantnagar (Uttarakhand) during *Kharif* and summer season of 2018-19. The results obtained in respect of various aspects of the present investigation are described under the following heads

- 4.1 Analysis of variance and estimation of genetic parameters for yield and its component traits.
- 4.2 Evaluation of okra genotypes against yellow vein mosaic virus in parents and F₁ hybrids.
- 4.3 Analysis of variance for different characters, mean performance of parents and F₁ hybrids.
- 4.4 Estimation of heterosis.
- 4.5 Estimation of combining ability and gene action.
- 4.6 Inheritance of YVMV disease resistance in okra.

4.1 Analysis of variance and estimation of genetic parameters for yield and its component traits

4.1.1 Analysis of variance

Analysis of variance carried out for 13 yield and its contributing traits in randomized block design is presented in table 4.1. The analysis of variance showed that significant genetic differences were present among okra genotypes for all the character studied except number of primary branches per plant during rainy season. This suggested that there were adequate amounts of genetic variability among the experimental material for all thirteen quantitative characters viz. days to 50% flowering, first fruit producing node, fruit length (cm), fruit diameter (mm), average fruit weight (g), number of fruits per plant, stem diameter (mm), inter-nodal length (cm), plant height (cm), fruit yield per plant (g), total yield (q/ha.) and number of seeds per fruit. Similar finding were revealed by Hazra *et al.* (2002) and Patel *et al.* (2015).

Table 4.1: Analysis of variance (ANOVA) for thirteen quantitative characters of okra

		Source of variation					
		Replication		Treatment		Error	
		Summer	Rainy	Summer	Rainy	Summer	Rainy
	Degree of freedom	2	2	59	59	118	118
Mean sum of squares	Days to 50% Flowering	0.74	2.47	12.47**	2.06**	1.00	1.16
	First fruit producing node	0.69*	0.78	1.21**	1.00**	0.21	0.44
	Fruit length (cm)	3.77*	2.40	2.12**	2.56**	0.90	1.05
	Fruit diameter (mm)	25.33*	2.76	5.60**	2.22**	1.52	0.94
	Average Fruit weight (g)	1.19	4.94**	6.08**	4.24**	0.83	0.55
	Number of fruits per plant	1.22	1.31	43.81**	10.26**	2.69	1.17
	Number of primary branches per plant	0.16	0.03	0.55**	0.07	0.13	0.10
	Stem diameter (mm)	15.11**	4.32*	15.43**	3.90**	1.93	1.22
	Internodal length (cm)	0.78**	0.17	1.95**	0.49**	0.14	0.25
	Plant height (cm)	101.54	1,919.57**	486.03**	252.41**	67.60	127.79
	Fruit yield per plant (g)	665.54	2,455.80**	10,268.32**	4,100.97**	425.67	484.26
	Total yield q/ha.	295.88	758.02**	4,563.62**	1,265.72**	189.18	149.45
	Number of seeds per fruit	16.72	3.30	110.36**	156.72**	9.77	8.66

4.1.2 Parameters of variability

The assessment of variability parameters revealed that there was tremendous amount of variation among the okra genotypes for different characters. The estimates of different parameters of variability like mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance (as% of mean) are presented in table 4.2. Descriptions for genetic variability parameters for different traits are described as below:-

4.1.2.1 Days to 50% flowering

Across the genotypes, days to 50% flowering ranged from 46.67 days to 52.67 days, with a mean value of 48.08 days. The estimate of PCV and GCV were low with value of 4.76 and 4.24%, respectively. Days to 50% flowering had high heritability (79.20%) coupled with low genetic advance (7.77%).

4.1.2.2 First fruit producing node

First fruit producing node varied from 4.67 to 7.44 with an average of 5.90. The estimate of PCV and GCV were moderate with value of 17.54 and 13.73%, respectively. Heritability estimate was moderate (61.30%) coupled with high genetic advance (22.14%).

4.1.2.3 Fruit length (cm)

Fruit length ranged from 11.73 to 15.91 cm with an average of 13.38 cm. The estimate of PCV and GCV were moderate 12.14 and low 6.76%, respectively. Heritability estimate was also found low (31.10%) with low genetic advance (7.76%).

4.1.2.4 Fruit diameter (mm)

Fruit diameter ranged from 12.41 to 16.81 mm with an average of 14.79 mm. The estimate of PCV and GCV were moderate 12.83 and low 8.82%, respectively. Heritability estimate was also found low (47.30%) with moderate genetic advance (12.50%).

4.1.2.5 Average fruit weight (g)

Average fruit weight varied from 9.29 to 14.23 g with an average mean of 11.95 g. The estimates of PCV and GCV were moderate with values of 13.74 and 11.31%, respectively. Average fruit weight had moderate heritability (67.70%) coupled with moderate genetic advance as per cent of mean (19.16%).

4.1.2.6 Number of fruits per plant

In case of number of fruits per plant, the average value was 16.99 and ranged between 13.11 to 20.67. The estimate of GCV and PCV were high with values of 29.29 and 32.04%, respectively. The characters had high heritability (83.60%) coupled with high genetic advance (55.16%).

4.1.2.7 Number of primary branches per plant

The numbers of primary branches per plant varied from 1.78 to 2.56 with an average of 2.06. This trait had high PCV (21.74%) and GCV (15.52%) coupled with moderate heritability (50.90%) and high genetic advance (22.81%).

4.1.2.8 Stem diameter (mm)

Stem diameter ranged in between 15.19 to 20.29 mm with a general mean 17.91 mm. PCV and GCV estimates were moderate for this trait and values were 15.83 and 13.24%, respectively. The trait had moderate heritability (70.00%) coupled with high genetic advance (22.82%).

4.1.2.9 Inter-nodal length (cm)

The inter-nodal length varied from 5.16 to 7.11 cm with an average of 6.34 cm. The estimates of PCV and GCV were moderate with values of 15.87 and 14.27%, respectively. Inter-nodal length had high heritability (80.90%) coupled with high genetic advance as per cent of mean (26.43%).

4.1.2.10 Plant height (cm)

The average plant height across the genotypes was 92.32 cm and it ranged from 75.60 to 113.62 cm. The estimate of PCV and GCV were moderate and high with values of 21.69 and 17.80%, respectively. The character had moderate heritability (67.40%) coupled with high genetic advance (30.09%).

4.1.2.11 Fruit yield per plant (g)

Fruit yield per plant varied from 128.76 to 278.18 g with an average mean of 204.55 g. The estimates of PCV and GCV were high with values of 40.55 and 38.15%, respectively. Fruit yield per plant had moderate heritability (88.50%) coupled with high genetic advance as per cent of mean (73.94%).

4.1.2.12 Total yield (q/ha.)

Total yield q/ha ranged from 71.53 to 154.54 with an average of 113.64. The estimate of PCV and GCV were high with values of 40.55 and 38.15%, respectively. Heritability estimate was moderate (88.50%) coupled with high genetic advance (73.94%).

4.1.2.13 Number of seeds per fruit

In case of number of seeds per fruit, the average value was 54.90 and ranged between 39.40 to 74.59. The estimate of PCV and GCV were moderate with values of 11.90 and 10.47%, respectively. The characters had high heritability (77.40%) coupled with moderate genetic advance (18.98%).

Variability

The nature and magnitude of genetic variability is one of the paramount importance for a plant breeder for initiating a sound breeding programme. Variability in plant genetic resources (PGR) provides an opportunity for plant breeders to develop new and improved cultivars with desirable characteristics, which include both farmer-preferred traits (yield potential) and breeders preferred traits (disease and pest resistance and photosensitivity *etc.*). Effectiveness of any selection programme depends upon the existence of genetic variability present within the population. The variability at phenotypic level arises due to genotypic and environmental influences that contribute towards the development of phenotype. The assessment of genetic variability present in a given crop population can be determined by using the biometrical components such as range, variance, coefficient of variation, standard error and heritability. The relative magnitude of these components determines the genetic properties of the population, in particular, the degree of resemblance between germplasm, that is, various determinants of the phenotype.

Yield is a complex trait controlled by polygenes and is highly sensitive to environmental factors hence it is not an efficient character for selection. The efficacy of selection depends upon the existence and magnitude of genetic variability for yield and yield contributing traits in the breeding material. Though variability in population is an indispensable prerequisite for any crop improvement programme, it is not the only criterion for deciding as to which trait is showing the highest degree of variability. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are

the best criteria to measure available variability. An assessment of variability parameters revealed that there is a lot of variation among genotypes studied. In general, the value of the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the characters, indicating the considerable influence of environmental factors on the performance of genotypes for different characters. The similar result was also reported in okra by Singh *et al.* (2006); Jindal *et al.* (2010); Barche *et al.* (2014); Raval *et al.* (2018); and Binopal *et al.* (2019).

Moderate to high PCV and GCV estimates were observed for many traits *viz.* first fruit producing node, average fruit weight, number of primary branches per plant, stem diameter, inter-nodal length, plant height, number of seeds per fruit, number of fruits per plant and fruit yield per plant. Moderate to high PCV and GCV for these traits indicate ample scope for yield improvement in okra through selection due to the presence of sufficient variability among genotypes of okra under studied. The PCV and GCV were low for days to 50% flowering, fruit length and fruit diameter. The high PCV accompanied with moderate GCV was observed for number of primary branches per plant and plant height. The first fruit producing node, number of primary branches per plant, fruit length and fruit diameter and plant height were highly influenced by environmental factors as the difference between PCV and GCV value was higher. The result of the present study agreed with the finding of Dhankhar and Dhankhar (2002); Singh *et al.* (2006); Magar and Madrap (2009); Senapati *et al.* (2011); Kumar *et al.* (2016); and Singh (2018).

Heritability and Genetic advance as per cent of Mean

Heritability of a character is important in determining its response to selection. Genetic improvement of plants for quantitative traits requires reliable estimates of heritability to plan an effective breeding program. The broad sense heritability is the relative magnitude of genotypic and phenotypic variance for the traits and it gives an idea of the total variation accounted to genotypic effect (Allard, 1960). It is generally expressed in percentage. The heritability is the heritable portion of phenotypic variance. It is a good index of transmission of characters from parents to their offspring.

Broad sense heritability estimates ranged from 31.10 (Fruit length) to 88.50 (Fruit yield per plant) (table 4.2). Fruit yield per plant recorded maximum heritability (> 75%) followed by number of fruits per plant, inter-nodal length, days to 50% flowering and

number of seeds per fruit. The heritability estimates for these traits indicate that these characters are least influenced by the environment. Since the estimates of broad-sense heritability are based on total genetic variance which includes both fixable (additive and additive x additive type of epistasis) and non-fixable (dominance, additive x dominance and dominance x dominance type of epistasis) variance. Hence, the selection for improvement of these characters may not be useful.

Stem diameter, average fruit weight, plant height, first fruit producing node and number of primary branches per plant exhibited a moderate level of heritability (50 – 75%). However, low heritability was observed for fruit length and fruit diameter (< 50%). Low to moderate estimates of broad-sense heritability indicates that these characters are highly influenced by environmental effects and the genetic improvement through selection in these traits is difficult due to masking effect of environment on the genotypic effects.

High estimates of genetic advance as percentage of mean (> 20%) was observed for most of the characters under study viz, plant height, fruit yield per plant and number of seeds per fruit. High estimates of genetic advance as percentage of mean indicated that the preponderance of additive genetic effects in expression of these characters. Therefore, selection for these characters in segregating generations based on phenotypic performance would likely be more effective.

Low estimates of genetic advance as percent of mean (< 10%) were observed for first fruit producing node, fruit length, fruit diameter, days to 50% flowering, average fruit weight, number of primary branches per plant, inter-nodal length and stem diameter, whereas, number of fruits per plant exhibited moderate level of genetic advance as per cent of mean (10-20%). Low value of genetic advance suggested that non-additive gene action was involved in controlling the characters.

High heritability does not always mean high genetic advance. For yield improvement, selection of superior parents possessing better heritability and genetic advance for yield contributing traits is an essential prerequisite. Heritability in conjunction with genetic advance determines the best picture of the amount of progress to be expected from selection and also the selection method to improve a character (Johnson *et al.* 1955). For efficient selection we cannot solely rely on heritability. The combination of high

heritability along with high genetic advance will provide a clear base on the reliability of that particular trait in the selection of variable entries.

The GCV along with heritability provides a reliable estimate of the amount of genetic advance expected through phenotypic selection (Burton and Devane, 1953). Based on the underlying facts, the traits under study were categorized into three different groups as per the analysis: First group included majority of the characters under study viz. first fruit producing node, number of fruits per plant, number of primary branches per plant, stem diameter, inter-nodal length, plant height and fruit yield per plant recorded moderate to high estimates of broad sense heritability and high estimates of genetic advance as percentage of mean. High heritability estimates along with high genetic advance indicated that most likely heritability is due to additive gene effects and the selection may be effective. High heritability and low difference between PCV and GCV estimates for these characters indicated that these traits were less affected by environmental factors. This strongly indicated the preponderance of additive gene action involved in the expression of these characters, and hence, there exists an ample scope for the improvement of concerned traits through direct selection. For different characters, similar results were also observed by various researchers like Sharma *et al.* (2007); Adiger *et al.* (2011); Das *et al.* (2012); Barche *et al.* (2014); Bagwale *et al.* (2016); and Kumar *et al.* (2019).

The second group of traits included average fruit weight, fruit diameter and number of seeds per fruits which had moderate to high heritability estimates coupled with moderate genetic advance as per cent of mean. It revealed that average fruit weight, fruit diameter and number of seeds per fruits were governed with additive gene effects and selection will be effective for these traits. Similar results were also reported by Mehta *et al.* (2006); Osekita and Akinyele (2008) and Kumar *et al.* (2019).

The third group included only a few characters *i.e.* days to 50% flowering and fruit length which had moderate to low heritability coupled with low genetic advance. Moderate heritability coupled with low genetic advance was indicative of non-additive gene action. The high or moderate heritability is exhibited due to favourable influence of environment rather than genotype as GCV estimates were also low and direct selection for such traits may not be rewarding. So, progeny testing or heterosis breeding could be employed for the

Table 4.2: Genetic parameters of variability for yield and its component traits

Genetic Parameters Characters	Mean $\pm$ S.E	Range	GCV	PCV	h^2bs (%)	GA	GA % of Mean
Days to 50% flowering	48.08 $\pm$ 0.58	46.67 - 52.67	4.24	4.76	79.20	3.58	7.77
First fruit producing node	5.90 $\pm$ 0.27	4.67 - 7.44	13.73	17.54	61.30	0.93	22.14
Fruit length (cm)	13.38 $\pm$ 0.55	11.73 - 15.91	6.76	12.14	31.10	0.73	7.76
Fruit diameter (mm)	14.79 $\pm$ 0.71	12.41 - 16.81	8.82	12.83	47.30	1.65	12.50
Average fruit weight (g)	11.95 $\pm$ 0.53	9.29 - 14.23	11.31	13.74	67.70	2.24	19.16
No. of fruits/plant	16.99 $\pm$ 0.95	13.11 - 20.67	29.29	32.04	83.60	6.97	55.16
No. of primary branches/plant	2.06 $\pm$ 0.21	1.78 - 2.56	15.52	21.74	50.90	0.55	22.81
Stem diameter (mm)	17.91 $\pm$ 0.80	15.19 - 20.29	13.24	15.83	70.00	3.66	22.82
Inter-nodal length (cm)	6.34 $\pm$ 0.22	5.16 - 7.11	14.27	15.87	80.90	1.44	26.43
Plant height (cm)	92.32 $\pm$ 4.75	75.60 - 113.62	17.80	21.69	67.40	19.97	30.09
Fruit yield/plant (g)	204.55 $\pm$ 11.91	128.76 - 278.18	38.15	40.55	88.50	111.01	73.94
Total yield q/ha	113.64 $\pm$ 7.94	71.53 - 154.54	38.15	40.55	88.50	74.01	73.94
No. seeds/fruit	54.90 $\pm$ 1.81	39.40 - 74.59	10.47	11.90	77.40	10.50	18.98

improvement of these characters in okra. Such results were also reported by Hazra and Basu (2000); Chaurasiya *et al.* (2010); and Das *et al.* (2012).

4.2 Evaluation of okra genotypes against yellow vein mosaic virus in parents and F₁ hybrids

Evaluation of 60 genotypes including 15 parents (11 lines and 4 testers), their 44 F₁ hybrids and 1 check (Arka Anamika) was done for yellow vein mosaic virus under field conditions. The disease score for yellow vein mosaic virus is given in table 4.3. For yellow vein mosaic virus incidence, parent 15/RES-4 and there all 11 F₁ hybrid showed highly resistant reaction. Whereas, parents EC 169430, EC 169435 and their crosses EC 169430 × Pusa A 4, EC 169430 × VRO 6; EC 169435 × Pusa A 4, EC 169435 × VRO 6, EC 169435 × Parbhani Kranti and EC169408 × Pusa A 4 showed moderate resistant reaction at 75 days after showing. Moderately susceptible reaction was exhibited by parents IC 117355, IC 117328, Parbhani Kranti, Arka Anamika (Check), and F₁ hybrid such as EC 169430 × Parbhani Kranti and EC169408 × VRO 6 at 75 days after showing. The remaining 49 genotypes including parents and F₁ hybrids showed susceptible reaction. Therefore, 15/RES-4 genotypes and their F₁ hybrid studied in this investigation showed highly resistant reaction against yellow vein mosaic virus. So, these hybrids can be used as commercial scale.

Table 4.3: Incidence of YVMV on parents and their 44 F₁ hybrids

S.No.	F ₁ hybrid + Parent and Check	YVMV incidence per plant							
		30 days	Score	45 days	Score	60 days	Score	75 days	Score
1	IC 093655 × Pusa A 4	1.39	0	8.89	2	23.01	2	59.68	4
2	IC 093655 × VRO 6	3.52	1	14.59	2	30.37	3	64.24	4
3	IC 093655 × P. Kranti	0	0	18.16	2	41.36	3	68.75	4
4	IC 093655 × 15/RES-4	0	0	0	0	0	0	0	0
5	EC 169430 × Pusa A 4	0	0	2.14	1	20.00	2	20.00	2
6	EC 169430 × VRO 6	0	0	9.20	2	20.00	2	24.53	2
7	EC 169430 × P. Kranti	0	0	12.94	2	32.49	3	50.04	3
8	EC 169430 × 15/RES-4	0	0	0	0	0	0	0	0
9	EC 169435 × Pusa A 4	0	0	4.33	1	22.22	2	22.22	2
10	EC 169435 × VRO 6	0	0	7.05	2	20.00	2	25.00	2
11	EC 169435 × P. Kranti	0	0	7.50	2	15.00	2	20.00	2
12	EC 169435 × 15/RES-4	0	0	0	0	0	0	0	0
13	EC 169506 × Pusa A 4	0	0	4.77	1	22.89	2	56.28	4
14	EC 169506 × VRO 6	0	0	7.67	2	28.01	3	55.86	4
15	EC 169506 × P. Kranti	0	0	13.58	2	33.38	3	59.92	4

16	EC 169506 × 15/RES-4	0	0	0	0	0	0	0	0
17	EC 169400 × Pusa A 4	0	0	4.72	1	27.64	2	62.42	4
18	EC 169400 × VRO 6	1.51	1	14.09	2	34.85	3	61.67	4
19	EC 169400 × P. Kranti	2.89	1	22.77	2	44.71	3	69.97	4
20	EC 169400 × 15/RES-4	0	0	0	0	0	0	0	0
21	EC 169408 × Pusa A 4	0	0	8.56	2	22.14	2	25.00	2
22	EC 169408 × VRO 6	0	0	8.33	2	22.22	2	33.33	3
23	EC 169408 × P. Kranti	0	0	20.20	2	48.57	3	74.17	4
24	EC 169408 × 15/RES-4	0	0	0	0	0	0	0	0
25	IC 117123 × Pusa A 4	0	0	17.06	2	36.86	3	61.50	4
26	IC 117123 × VRO 6	0	0	17.92	2	48.69	3	78.25	5
27	IC 117123 × P. Kranti	1.67	1	18.64	2	41.72	3	64.69	4
28	IC 117123 × 15/RES-4	0	0	0	0	0	0	0	0
29	IC 117245 × Pusa A 4	2.56	1	13.59	2	36.19	3	60.68	4
30	IC 117245 × VRO 6	4.69	1	23.14	2	50.10	3	83.41	5
31	IC 117245 × P. Kranti	1.59	1	17.03	2	49.63	3	69.60	4
32	IC 117245 × 15/RES-4	0	0	0	0	0	0	0	0
33	IC 117351 × Pusa A 4	0	0	10.91	2	35.51	3	63.43	4
34	IC 117351 × VRO 6	6.41	2	21.11	2	45.83	3	77.79	5
35	IC 117351 × P. Kranti	7.33	2	27.50	3	51.67	4	83.33	5
36	IC 117351 × 15/RES-4	0	0	0	0	0	0	0	0
37	IC 117355 × Pusa A 4	1.85	1	12.59	2	41.85	3	65.25	4
38	IC 117355 × VRO 6	2.89	1	24.93	2	50.69	3	82.92	5
39	IC 117355 × P. Kranti	1.45	1	15.32	2	34.99	3	65.91	4
40	IC 117355 × 15/RES-4	0	0	0	0	0	0	0	0
41	IC 117328 × Pusa A 4	4.76	1	24.31	2	53.77	4	69.69	4
42	IC 117328 × VRO 6	8.73	2	23.20	2	48.32	3	80.37	5
43	IC 117328 × P. Kranti	3.17	2	19.06	2	41.89	3	67.39	4
44	IC 117328 × 15/RES-4	0	0	0	0	0	0	0	0
45	IC 093655	0	0	7.34	2	23.86	2	53.72	4
46	EC 169430	0	0	2.94	1	10.79	2	20.25	2
47	EC 169435	0	0	4.00	1	12.78	2	21.84	2
48	EC 169506	0	0	12.32	2	29.88	3	57.23	4
49	EC 169400	1.23	1.0	16.75	2	39.66	3	60.16	4
50	EC 169408	0	0	15.96	2	18.33	2	27.27	3
51	IC 117123	0.59	1	10.78	2	29.73	3	56.93	4
52	IC 117245	1.21	1	10.37	2	27.47	3	51.73	4
53	IC 117351	0	0	9.03	2	23.97	2	54.98	4
54	IC 117355	0	0	5.12	2	21.10	2	47.43	3
55	IC 117328	0	0	6.24	2	22.04	2	43.27	3
56	Pusa A 4	0	0	9.84	2	32.42	3	60.76	4
57	VRO 6	0	0	6.85	2	32.77	3	52.78	4
58	P. Kranti	0	0	0	0	17.58	2	37.78	3
59	15/RES-4	0	0	0	0	0	0	0	0
60	A. Anamika (Check)	0	0	0	0	20.00	2	33.33	3

4.3 Analysis of variance for different characters, mean performance of parents and F₁ hybrids

The analysis of variance for thirteen characters of okra during both summer and rainy seasons of 2018 is presented in table 4.4 and 4.5, respectively. The mean sum of squares due to treatment was found significant for all the quantitative traits during both the respective seasons.

The total variability among F₁ hybrids was further partitioned into different components and their significance was tested. It is evident from the table that the mean sum of squares due to crosses was significant for all thirteen characters studied during both the season except days to 50 per cent flowering, number of primary branches per plant and plant height which was found non-significant during rainy season. During summer season, the mean sum of squares due to lines was found significant for days to 50 per cent flowering, fruit diameter, stem diameter and number of seeds per fruit. Whereas, during rainy season it was significant for first fruit producing node and plant height. None of testers were found significant for all thirteen characters during both the season of 2018.

Mean sum of squares due to line $\times$ tester effect was significant for all the characters under study during summer season except for fruit diameter. However, during rainy season it was significant for average fruit weight, number of fruits per plant, stem diameter, fruit yield per plant, total yield, number of seeds per plant and fruit diameter.

Mean performance of parents and F₁ hybrids

The mean performance of parents and crosses for yield and its component traits during both summer and rainy seasons of 2018 is presented in table 4.6 and has been described here as follows.

4.3.1 Days to 50 per cent flowering

Mean values for days to 50 per cent flowering ranged from 44.00 to 52.33 and 46.67 to 52.67 during summer and rainy seasons, respectively. Among the parents, minimum days required for 50 per cent flowering were recorded in IC 117245, IC 117355 and Parbhani Kranti (44.67) during summer season and IC 117355 (46.67) during rainy season. Whereas maximum days required in 15/RES-4 (51.67 and 52.67) during both summer and rainy seasons, respectively. Among the crosses, EC 169400 $\times$ Parbhani

Table 4.4: Analysis of variance (ANOVA) for line × tester with respect to thirteen quantitative characters of okra during summer season of 2018

Mean Sum of Squares		Source of variation						
		Replications	Crosses	Line effect	Tester effect	Line × tester effect	Error	Total
	Degrees of freedom	2	43	10	3	30	86	131
	Days to 50% Flowering	2.273	13.627**	46.897**	1.828	3.717**	1.071	5.211
	First fruit producing node	0.070	1.531**	1.062	0.716	1.769**	0.226	0.652
	Fruit length (cm)	1.218	2.372**	4.033	0.716	1.984*	0.838	1.348
	Fruit diameter (mm)	15.292**	7.205**	24.367**	1.781	2.026	1.360	3.491
	Average Fruit weight (g)	1.910	6.845**	9.171	0.714	6.683**	0.853	2.836
	Number of fruits per plant	3.279	51.214**	73.262	42.786	44.708**	3.263	19.003
	Number of primary branches per plant	0.303	0.671**	0.845	0.377	0.642**	0.153	0.325
	Stem diameter (mm)	9.964	19.286**	52.944**	6.416	9.354**	2.050	7.829
	Internodal length (cm)	0.337	2.167**	2.087	0.168	2.393**	0.148	0.814
	Plant height (cm)	41.269	530.497**	837.551	94.186	471.777**	61.104	214.877
	Fruit yield per plant (g)	1367.514	12238.770**	20171.870	6499.965	10168.290**	492.471	4361.487
	Total yield q/ha.	607.877	5439.384**	8965.213	2888.850	4519.161**	218.871	1938.414
	Number of seeds per fruit	9.551	125.333**	274.101*	46.608	83.616**	10.158	47.954

Table 4.5: Analysis of variance (ANOVA) for line × tester with respect to thirteen quantitative characters of okra during rainy season of 2018

Mean Sum of Squares		Source of variation						
		Replications	Crosses	Line effect	Tester effect	Line × tester effect	Error	Total
	Degrees of freedom	2	43	10	3	30	86	131
	Days to 50% Flowering	0.758	0.952	0.618	2.028	0.956	1.161	1.086
	First fruit producing node	0.980	0.871*	2.769**	0.158	0.310	0.455	0.600
	Fruit length (cm)	1.767	2.131*	2.389	1.853	2.072	1.134	1.471
	Fruit diameter (mm)	1.996	1.862*	2.146	0.832	1.871*	0.911	1.240
	Average Fruit weight (g)	3.266*	4.784**	9.45	0.641	3.644**	0.559	1.987
	Number of fruits per plant	0.331	11.063**	16.225	3.427	10.106**	1.352	4.524
	Number of primary branches per plant	0.002	0.075	0.117	0.059	0.063	0.109	0.096
	Stem diameter (mm)	6.400*	4.167**	7.814	0.714	3.297**	0.986	2.113
	Internodal length (cm)	0.493	0.575*	1.163	0.078	0.428	0.267	0.372
	Plant height (cm)	2001.382**	154.980	413.308**	42.713	80.097	120.283	160.391
	Fruit yield per plant (g)	1125.117	5190.612**	9149.854	1291.064	4260.820**	516.158	2059.818
	Total yield q/ha.	347.277	1602.029**	2823.969	398.393	1315.079**	159.297	635.736
	Number of seeds per fruit	4.289	158.780**	327.239	67.654	111.739**	9.955	58.719

Kranti (44.00) recorded minimum days to 50 per cent flowering during summer season and EC 169435 × 15/RES-4 and EC 169400 × Parbhani Kranti (47.00) during rainy season. However, maximum days were noticed in IC 093655 × 15/RES-4 (52.33) during summer season and IC 093655 × Parbhani Kranti and EC 169506 × 15/RES-4 (49.33) during rainy season.

4.3.2 First fruit producing node

Perusal of data revealed that mean values for first fruit producing node ranged from 3.32 to 6.09 and 4.67 to 7.44 during summer and rainy season, respectively. Among the parents IC 117245 (3.67) and EC 169435 (5.56) recorded minimum mean value for first fruit producing node during both summer and rainy season, respectively. Whereas, maximum values were recorded in EC 169435 (4.66) during summer season and IC117328 (7.44) during rainy season.

Among the crosses, minimum values for same character was noticed in IC 093655 × Pusa A 4 (3.32) and EC 169506 × 15/RES-4 (4.67) during summer and rainy season, respectively. However, maximum mean value was recorded in EC169430 × Pusa A 4 (6.09) and EC 169408 × Pusa A 4 (6.67) during summer and rainy season, respectively.

4.3.3 Fruit length (cm)

During summer and rainy seasons, mean values for fruit length ranged from 7.83 to 11.61 cm and 11.73 to 15.91 cm, respectively. VRO 6 (10.00 cm) and IC 117351 (15.91 cm) recorded maximum fruit length among the parents, whereas minimum value was found in EC 169400 (8.08 cm) and IC 117328 (11.97 cm) during summer and rainy season respectively. Among the F₁s, maximum fruit length was recorded in EC 169430 × Parbhani Kranti (11.61 cm) and EC 169430 × 15/RES-4 (15.66 cm), while minimum values were found in EC 169408 × Pusa A 4 (7.83 cm) and IC 117355 × Parbhani Kranti (11.73 cm) during summer and rainy season, respectively.

4.3.4 Fruit diameter (mm)

Mean values for fruit diameter ranged from 9.52 to 15.09 and 12.41 to 16.81 mm, during summer and rainy seasons, respectively. IC 093655 (14.49 mm) and EC 169430 (16.50 mm) recorded maximum fruit diameter among the parents, whereas minimum value was found in IC 169400 (12.59 mm) and EC 169435 (13.11 mm) during summer and

Table 4.6: Mean performance of parents and their F₁ for different traits of okra during summer and rainy season of 2018

S. No.	Characters	Days to 50% Flowering		First fruit producing node		Fruit length (cm)		Fruit diameter (mm)	
	Treatments (F ₁ + Parents)	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	45.33	48.67	3.32	6.11	9.33	13.15	13.44	15.51
2	IC 093655 × VRO 6	46.00	48.67	4.33	5.89	9.48	12.46	14.48	14.47
3	IC 093655 × P. Kranti	46.00	49.33	3.88	5.89	10.41	13.65	13.67	15.82
4	IC 093655 × 15/RES-4	52.33	48.33	3.61	5.11	8.58	13.20	9.52	14.61
5	EC 169430 × Pusa A 4	45.67	48.33	6.09	5.89	10.44	13.69	13.55	14.71
6	EC 169430 × VRO 6	45.33	48.00	4.83	6.44	9.17	13.61	12.92	15.71
7	EC 169430 × P. Kranti	44.67	47.67	5.19	6.44	11.61	13.35	14.36	15.64
8	EC 169430 × 15/RES-4	48.67	47.33	4.72	5.45	9.79	15.66	12.90	16.22
9	EC 169435 × Pusa A 4	45.67	48.33	5.14	5.78	9.00	13.03	13.04	14.09
10	EC 169435 × VRO 6	45.00	47.67	4.87	6.56	9.73	13.20	13.51	15.40
11	EC 169435 × P. Kranti	45.00	48.00	5.67	6.11	10.38	14.91	13.79	14.93
12	EC 169435 × 15/RES-4	50.00	47.00	4.61	5.44	9.72	14.55	12.63	15.83
13	EC 169506 × Pusa A 4	45.67	48.33	3.98	6.56	10.38	11.97	15.09	13.32
14	EC 169506 × VRO 6	44.67	47.33	3.60	6.45	10.38	12.62	14.28	14.78
15	EC 169506 × P. Kranti	44.67	47.67	4.05	6.44	10.09	13.92	14.70	15.88
16	EC 169506 × 15/RES-4	48.67	49.33	3.58	4.67	8.70	13.01	12.05	13.52
17	EC 169400 × Pusa A 4	45.00	47.67	3.76	6.22	8.85	11.75	14.96	14.12
18	EC 169400 × VRO 6	45.00	47.67	4.07	6.45	8.88	13.36	12.88	14.75
19	EC 169400 × P. Kranti	44.00	47.00	3.75	6.22	11.39	13.29	14.59	14.82
20	EC 169400 × 15/RES-4	51.33	48.33	3.86	4.89	9.81	13.55	10.87	15.08
21	EC 169408 × Pusa A 4	45.67	48.67	4.97	6.67	7.83	13.40	14.38	15.37
22	EC 169408 × VRO 6	46.00	48.67	5.93	6.44	8.64	13.31	12.05	15.26
23	EC 169408 × P. Kranti	45.33	48.33	4.97	5.55	10.24	12.72	15.03	14.77
24	EC 169408 × 15/RES-4	47.67	47.33	4.73	5.22	9.75	15.56	11.18	16.81
25	IC 117123 × Pusa A 4	44.33	47.67	4.36	5.78	9.08	13.32	12.96	15.08
26	IC 117123 × VRO 6	45.33	48.33	5.13	5.56	8.95	12.45	13.34	15.03
27	IC 117123 × P. Kranti	44.33	47.33	4.55	5.55	11.15	13.66	14.32	15.24
28	IC 117123 × 15/RES-4	48.00	48.67	4.22	5.00	10.55	13.24	12.05	14.93
29	IC 117245 × Pusa A 4	45.00	48.00	3.33	6.11	10.12	13.79	13.12	14.59
30	IC 117245 × VRO 6	45.67	49.00	3.40	5.34	9.46	13.41	13.03	15.14
31	IC 117245 × P. Kranti	44.67	47.67	4.06	5.55	10.19	13.78	13.06	14.63

32	IC 117245 × 15/RES-4	50.33	48.67	3.62	5.33	8.93	14.17	9.59	14.46
33	IC 117351 × Pusa A 4	45.67	48.00	4.26	5.55	8.77	13.62	14.94	14.79
34	IC 117351 × VRO 6	45.00	48.67	4.53	5.89	9.88	13.16	15.01	14.95
35	IC 117351 × P. Kranti	45.33	48.33	4.53	5.34	8.38	12.06	13.79	14.38
36	IC 117351 × 15/RES-4	50.00	48.00	4.73	4.89	8.12	13.02	10.66	14.43
37	IC 117355 × Pusa A 4	47.00	48.33	3.47	5.66	9.53	14.09	14.39	14.70
38	IC 117355 × VRO 6	45.00	49.00	4.40	5.67	9.98	13.54	13.18	15.71
39	IC 117355 × P. Kranti	45.00	48.33	3.62	5.56	8.19	11.73	12.23	13.49
40	IC 117355 × 15/RES-4	50.00	48.00	3.49	4.78	8.24	13.15	9.93	14.87
41	IC 117328 × Pusa A 4	45.00	48.00	3.40	5.78	8.67	13.46	13.58	14.27
42	IC 117328 × VRO 6	44.67	48.33	3.47	5.78	10.57	13.45	14.67	14.90
43	IC 117328 × P. Kranti	45.00	48.00	4.26	5.78	9.57	12.09	13.60	12.41
44	IC 117328 × 15/RES-4	49.33	48.33	3.60	4.89	9.62	12.54	9.67	14.59
45	IC 093655	45.33	47.67	3.78	6.33	9.48	12.73	14.49	13.91
46	EC 169430	45.00	47.67	4.20	6.00	8.62	15.57	13.70	16.50
47	EC 169435	45.33	48.00	4.66	5.56	9.50	12.69	13.24	13.11
48	EC 169506	45.00	47.67	4.44	5.89	8.79	14.28	13.33	15.22
49	EC 169400	45.33	47.67	4.03	6.22	8.08	12.48	12.59	13.74
50	EC 169408	46.00	48.33	3.86	6.00	8.53	12.30	14.08	13.60
51	IC 117123	45.00	47.67	4.30	6.67	8.49	13.48	13.73	15.28
52	IC 117245	44.67	47.33	3.67	6.44	9.55	13.91	13.87	14.66
53	IC 117351	45.00	47.33	3.81	6.23	8.82	15.91	13.44	16.16
54	IC 117355	44.67	46.67	3.77	6.00	8.63	14.74	13.25	14.67
55	IC 117328	45.33	47.33	3.78	7.44	9.42	11.97	14.35	14.50
56	Pusa A 4	45.67	48.00	3.86	6.67	9.69	13.57	14.22	16.15
57	VRO 6	45.67	48.00	4.04	6.22	10.00	13.22	13.36	13.84
58	P. Kranti	44.67	47.33	3.92	6.00	8.61	13.42	13.21	14.21
59	15/RES-4	51.67	52.67	4.08	7.11	8.94	13.28	13.12	13.36
60	A. Anamika (Check)	44.33	47.33	4.14	6.33	9.29	12.59	12.63	14.38
	Mean	46.11	48.08	4.20	5.90	9.42	13.38	13.23	14.79
	C.V. (%)	2.17	2.24	10.92	11.28	10.08	7.67	9.31	6.56
	S.E.	0.58	0.62	0.27	0.38	0.55	0.59	0.71	0.56
	C.D. 5%	1.62	1.74	0.74	1.08	1.53	1.66	1.99	1.57
	C.D. 1%	2.14	2.30	0.98	1.42	2.03	2.19	2.63	2.07
	Lowest Range	44	46.67	3.3167	4.67	7.8333	11.73	9.52	12.41
	Highest Range	52.3333	52.67	6.0933	7.44	11.6067	15.91	15.0867	16.81

Table 4.6: Contd...

S. No.	Characters	Average Fruit weight (g)		Number of fruits per plant		Number of primary branches per plant	
	Treatments (F ₁ + Parents)	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	13.95	13.06	8.77	17.56	2.50	2.11
2	IC 093655 × VRO 6	9.71	14.23	9.60	18.89	1.83	1.78
3	IC 093655 × P. Kranti	11.71	12.39	11.42	17.89	2.20	2.00
4	IC 093655 × 15/RES-4	10.66	12.18	8.04	15.67	2.22	2.00
5	EC 169430 × Pusa A 4	11.65	14.08	14.47	19.78	2.67	2.11
6	EC 169430 × VRO 6	13.66	13.37	20.87	19.89	2.97	2.11
7	EC 169430 × P. Kranti	13.82	12.64	17.80	20.22	2.56	1.89
8	EC 169430 × 15/RES-4	12.41	12.92	14.72	16.89	2.33	2.56
9	EC 169435 × Pusa A 4	12.40	12.84	16.40	17.33	3.00	2.11
10	EC 169435 × VRO 6	15.10	13.41	22.07	19.56	3.17	2.22
11	EC 169435 × P. Kranti	12.95	13.48	17.53	18.89	3.19	2.33
12	EC 169435 × 15/RES-4	11.19	12.61	12.78	17.11	2.65	2.33
13	EC 169506 × Pusa A 4	9.99	12.55	11.40	17.55	2.11	2.22
14	EC 169506 × VRO 6	11.33	12.96	13.17	17.78	2.72	2.00
15	EC 169506 × P. Kranti	10.50	13.54	12.22	17.67	1.83	2.11
16	EC 169506 × 15/RES-4	10.05	12.10	11.35	16.67	2.00	2.11
17	EC 169400 × Pusa A 4	11.33	12.53	9.60	16.89	2.33	2.01
18	EC 169400 × VRO 6	12.49	12.35	10.90	17.56	2.75	1.89
19	EC 169400 × P. Kranti	11.11	11.46	14.28	16.11	2.58	2.11
20	EC 169400 × 15/RES-4	8.82	10.64	10.74	16.78	1.89	2.00
21	EC 169408 × Pusa A 4	12.81	12.47	19.40	20.67	2.78	2.22
22	EC 169408 × VRO 6	12.34	12.80	25.67	19.78	3.33	2.11
23	EC 169408 × P. Kranti	13.41	13.22	17.48	19.00	3.08	2.11
24	EC 169408 × 15/RES-4	12.75	12.92	14.40	18.89	3.19	2.56
25	IC 117123 × Pusa A 4	11.61	12.52	12.54	16.67	2.31	2.11
26	IC 117123 × VRO 6	11.43	10.82	10.73	16.56	2.67	2.00
27	IC 117123 × P. Kranti	14.83	12.02	12.33	14.55	2.31	2.00
28	IC 117123 × 15/RES-4	11.69	11.36	12.48	16.00	2.00	2.00
29	IC 117245 × Pusa A 4	11.89	11.61	10.32	17.22	2.11	2.11
30	IC 117245 × VRO 6	13.34	10.64	11.27	13.67	1.64	2.11
31	IC 117245 × P. Kranti	9.85	10.31	11.80	14.89	2.33	2.00

32	IC 117245 × 15/RES-4	10.57	9.29	11.97	16.11	2.00	2.00
33	IC 117351 × Pusa A 4	12.69	10.63	11.27	15.11	2.22	1.78
34	IC 117351 × VRO 6	11.57	10.09	12.73	13.56	2.20	1.89
35	IC 117351 × P. Kranti	13.24	10.85	12.73	15.45	2.45	2.00
36	IC 117351 × 15/RES-4	10.29	9.71	8.82	15.67	2.22	2.00
37	IC 117355 × Pusa A 4	11.93	11.81	11.98	15.78	1.67	2.11
38	IC 117355 × VRO 6	13.11	10.18	24.07	14.11	1.56	2.11
39	IC 117355 × P. Kranti	9.38	10.70	14.57	15.66	2.23	2.00
40	IC 117355 × 15/RES-4	10.69	10.26	11.20	15.00	1.89	2.00
41	IC 117328 × Pusa A 4	9.95	11.79	8.48	15.78	2.00	2.00
42	IC 117328 × VRO 6	14.23	9.83	10.86	13.11	1.58	2.00
43	IC 117328 × P. Kranti	10.05	11.59	10.87	15.44	1.89	2.22
44	IC 117328 × 15/RES-4	11.20	10.88	7.89	14.22	1.86	2.00
45	IC 093655	13.34	12.57	8.33	15.11	2.22	2.11
46	EC 169430	11.41	12.59	14.49	18.33	2.67	2.00
47	EC 169435	11.85	13.50	14.53	15.45	2.71	2.00
48	EC 169506	10.57	11.97	10.00	14.22	2.53	2.14
49	EC 169400	12.07	13.64	11.67	16.56	2.11	2.11
50	EC 169408	11.93	13.78	11.81	16.78	2.61	2.11
51	IC 117123	11.37	12.49	9.82	18.89	2.81	2.11
52	IC 117245	9.55	10.95	9.73	19.22	2.36	1.89
53	IC 117351	9.49	11.08	12.08	19.22	2.50	2.00
54	IC 117355	12.67	12.15	13.31	17.44	2.67	2.00
55	IC 117328	11.73	11.30	10.69	17.78	2.49	2.00
56	Pusa A 4	12.73	11.60	10.26	16.78	2.81	1.78
57	VRO 6	11.62	11.28	10.60	18.44	2.72	2.00
58	P. Kranti	10.77	12.44	9.84	19.33	2.69	1.89
59	15/RES-4	9.88	10.83	7.07	17.67	2.33	2.00
60	A. Anamika (Check)	10.84	11.10	10.19	18.89	2.67	1.89
	Mean	11.69	11.95	12.64	16.99	2.40	2.06
	C.V. (%)	7.81	6.20	12.98	6.36	15.23	15.44
	S.E.	0.53	0.43	0.95	0.62	0.21	0.18
	C.D. 5%	1.48	1.20	2.65	1.75	0.59	0.51
	C.D. 1%	1.95	1.58	3.51	2.31	0.78	0.68
	Lowest Range	8.8167	9.29	7.0667	13.11	1.5567	1.78
	Highest Range	15.0967	14.23	25.6667	20.67	3.3333	2.56

Table 4.6: Contd...

S. No.	Characters	Stem diameter (mm)		Internodal length (cm)		Plant height (cm)	
	Treatments (F_1 + Parents)	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 $\times$ Pusa A 4	17.79	16.98	5.64	6.96	60.23	90.23
2	IC 093655 $\times$ VRO 6	16.92	18.75	5.38	6.58	56.10	89.66
3	IC 093655 $\times$ P. Kranti	17.17	17.32	5.27	6.91	64.13	88.36
4	IC 093655 $\times$ 15/RES-4	12.78	16.69	5.49	5.59	46.07	84.70
5	EC 169430 $\times$ Pusa A 4	19.80	18.48	6.98	6.08	83.77	107.18
6	EC 169430 $\times$ VRO 6	17.20	19.19	6.22	6.82	77.30	96.53
7	EC 169430 $\times$ P. Kranti	16.89	18.58	7.01	6.52	87.03	98.10
8	EC 169430 $\times$ 15/RES-4	14.58	20.29	5.60	6.23	76.60	95.90
9	EC 169435 $\times$ Pusa A 4	19.80	18.35	7.83	6.13	81.50	103.36
10	EC 169435 $\times$ VRO 6	16.49	19.51	6.13	6.30	86.30	98.02
11	EC 169435 $\times$ P. Kranti	20.17	19.21	6.94	6.63	84.83	90.59
12	EC 169435 $\times$ 15/RES-4	15.32	19.84	6.05	5.99	73.55	94.08
13	EC 169506 $\times$ Pusa A 4	14.99	18.98	5.75	6.10	65.17	101.83
14	EC 169506 $\times$ VRO 6	15.80	19.19	5.35	5.87	60.27	91.66
15	EC 169506 $\times$ P. Kranti	16.83	18.13	5.54	6.45	57.50	88.78
16	EC 169506 $\times$ 15/RES-4	13.33	17.93	5.42	6.42	51.37	85.78
17	EC 169400 $\times$ Pusa A 4	15.41	18.02	4.88	6.57	79.63	99.71
18	EC 169400 $\times$ VRO 6	14.95	18.37	5.30	6.12	72.43	89.33
19	EC 169400 $\times$ P. Kranti	17.94	18.07	5.12	6.20	62.83	88.09
20	EC 169400 $\times$ 15/RES-4	13.06	17.53	4.57	6.10	50.93	91.08
21	EC 169408 $\times$ Pusa A 4	19.52	17.32	6.45	6.95	87.03	96.16
22	EC 169408 $\times$ VRO 6	20.89	18.86	6.57	6.05	87.57	89.76
23	EC 169408 $\times$ P. Kranti	19.33	17.62	6.10	7.11	78.43	90.37
24	EC 169408 $\times$ 15/RES-4	16.43	19.70	6.0	6.59	70.94	94.24
25	IC 117123 $\times$ Pusa A 4	15.79	16.99	5.32	6.65	69.03	88.37
26	IC 117123 $\times$ VRO 6	18.18	16.53	6.27	6.62	65.43	85.52
27	IC 117123 $\times$ P. Kranti	13.80	15.19	5.92	5.68	83.07	79.57
28	IC 117123 $\times$ 15/RES-4	15.33	16.98	5.51	5.89	65.33	81.13
29	IC 117245 $\times$ Pusa A 4	16.49	18.28	4.77	6.72	48.97	88.89
30	IC 117245 $\times$ VRO 6	16.41	16.20	5.13	5.16	56.0	75.60
31	IC 117245 $\times$ P. Kranti	14.31	16.27	4.87	6.21	66.20	83.57
32	IC 117245 $\times$ 15/RES-4	11.31	18.07	4.67	5.84	47.72	85.53
33	IC 117351 $\times$ Pusa A 4	18.68	18.70	5.38	6.77	62.87	91.48

34	IC 117351 × VRO 6	16.69	16.34	5.15	5.86	75.30	82.78
35	IC 117351 × P. Kranti	15.34	16.38	5.53	6.53	80.49	81.15
36	IC 117351 × 15/RES-4	12.23	18.32	5.71	5.51	53.79	86.98
37	IC 117355 × Pusa A 4	14.14	18.77	4.15	6.52	60.30	93.60
38	IC 117355 × VRO 6	18.56	16.08	4.23	5.66	63.73	78.15
39	IC 117355 × P. Kranti	15.99	17.83	4.35	6.51	56.5	83.95
40	IC 117355 × 15/RES-4	11.06	17.56	4.47	5.98	45.67	80.33
41	IC 117328 × Pusa A 4	15.41	17.41	4.27	6.44	71.97	86.37
42	IC 117328 × VRO 6	15.79	15.67	4.59	5.86	44.47	77.58
43	IC 117328 × P. Kranti	11.73	17.55	4.25	6.53	54.0	84.10
44	IC 117328 × 15/RES-4	10.67	17.20	4.43	5.84	44.17	79.61
45	IC 093655	15.31	17.74	4.93	6.85	66.56	108.18
46	EC 169430	18.78	17.78	6.73	6.36	80.22	117.08
47	EC 169435	17.63	17.66	6.77	6.73	82.43	107.58
48	EC 169506	16.87	17.43	5.13	6.29	63.58	93.67
49	EC 169400	15.03	15.96	5.48	6.61	86.74	97.32
50	EC 169408	18.42	16.40	6.24	6.38	71.65	92.01
51	IC 117123	16.78	19.60	5.35	6.75	72.33	112.20
52	IC 117245	15.69	18.22	5.07	6.62	57.63	101.26
53	IC 117351	17.26	17.26	5.69	6.63	77.37	99.53
54	IC 117355	17.07	18.43	4.85	6.77	67.84	95.82
55	IC 117328	15.06	19.34	4.77	6.55	66.96	99.62
56	Pusa A 4	15.35	18.28	5.42	6.49	53.86	100.49
57	VRO 6	15.59	17.91	5.23	6.28	52.55	93.75
58	P. Kranti	15.13	18.80	5.03	6.49	55.22	97.72
59	15/RES-4	14.35	18.60	4.27	6.21	48.49	91.52
60	A. Anamika (Check)	15.66	19.72	4.96	6.62	61.22	113.62
	Mean	16.02	17.91	5.44	6.34	66.35	92.32
	C.V. (%)	8.67	6.18	6.94	7.89	12.39	12.25
	S.E.	0.80	0.64	0.22	0.29	4.75	6.53
	C.D. 5%	2.25	1.79	0.61	0.81	13.29	18.28
	C.D. 1%	2.97	2.37	0.81	1.07	17.58	24.17
	Lowest Range	10.6667	15.19	4.1533	5.16	44.1667	75.60
	Highest Range	20.89	20.29	7.8267	7.11	87.5667	113.62

Table 4.6: Contd...

S. No.	Characters	Fruit yield per plant (g)		Total yield q/ha.		Number of seeds per fruit	
	Treatments (F ₁ + Parents)	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	121.65	230.90	81.10	128.27	52.46	56.13
2	IC 093655 × VRO 6	93.93	269.14	62.62	149.52	56.29	60.42
3	IC 093655 × P. Kranti	132.86	222.36	88.57	123.53	53.56	59.35
4	IC 093655 × 15/RES-4	85.63	190.89	57.09	106.05	46.73	41.72
5	EC 169430 × Pusa A 4	167.93	278.18	111.95	154.54	63.11	67.34
6	EC 169430 × VRO 6	283.89	265.98	189.26	147.77	67.34	74.59
7	EC 169430 × P. Kranti	246.70	256.05	164.47	142.25	61.36	67.38
8	EC 169430 × 15/RES-4	182.35	218.41	121.56	121.34	50.16	53.43
9	EC 169435 × Pusa A 4	203.52	222.60	135.68	123.66	62.43	60.36
10	EC 169435 × VRO 6	333.14	262.02	222.09	145.57	61.52	59.52
11	EC 169435 × P. Kranti	226.66	254.37	151.10	141.32	62.43	65.34
12	EC 169435 × 15/RES-4	143.20	215.90	95.47	119.95	62.26	59.62
13	EC 169506 × Pusa A 4	113.96	220.77	75.97	122.65	57.41	53.34
14	EC 169506 × VRO 6	148.16	230.92	98.78	128.29	53.38	54.41
15	EC 169506 × P. Kranti	127.04	239.54	84.69	133.08	64.26	56.56
16	EC 169506 × 15/RES-4	114.03	202.04	76.02	112.24	49.66	47.32
17	EC 169400 × Pusa A 4	108.75	210.78	72.50	117.10	64.07	56.25
18	EC 169400 × VRO 6	136.16	217.28	90.78	120.71	59.32	59.32
19	EC 169400 × P. Kranti	157.86	185.15	105.24	102.86	59.12	55.71
20	EC 169400 × 15/RES-4	94.53	179.03	63.01	99.46	44.41	42.67
21	EC 169408 × Pusa A 4	248.21	257.51	165.47	143.06	56.55	62.35
22	EC 169408 × VRO 6	316.23	253.43	210.82	140.79	54.19	58.42
23	EC 169408 × P. Kranti	234.21	251.43	156.14	139.68	54.51	54.37
24	EC 169408 × 15/RES-4	184.07	244.31	122.71	135.73	51.58	49.66
25	IC 117123 × Pusa A 4	144.90	209.39	96.60	116.33	59.48	49.41
26	IC 117123 × VRO 6	123.25	179.09	82.16	99.49	48.53	47.16
27	IC 117123 × P. Kranti	182.28	175.65	121.52	97.58	50.31	47.34
28	IC 117123 × 15/RES-4	145.63	181.84	97.09	101.02	46.36	52.98
29	IC 117245 × Pusa A 4	122.96	200.21	81.97	111.23	48.40	60.42
30	IC 117245 × VRO 6	150.77	146.15	100.51	81.20	61.42	61.43
31	IC 117245 × P. Kranti	117.60	154.15	78.40	85.64	65.38	54.20
32	IC 117245 × 15/RES-4	126.41	149.66	84.28	83.14	43.28	39.40

33	IC 117351 × Pusa A 4	143.35	161.12	95.57	89.51	63.61	49.46
34	IC 117351 × VRO 6	145.03	136.95	96.68	76.08	58.19	56.51
35	IC 117351 × P. Kranti	168.37	167.95	112.25	93.30	58.19	56.60
36	IC 117351 × 15/RES-4	92.51	152.09	61.68	84.50	50.78	53.27
37	IC 117355 × Pusa A 4	142.98	186.61	95.32	103.67	47.66	57.46
38	IC 117355 × VRO 6	316.22	143.97	210.81	79.99	59.51	58.57
39	IC 117355 × P. Kranti	136.63	168.41	91.09	93.56	56.55	55.65
40	IC 117355 × 15/RES-4	119.83	153.72	79.89	85.40	47.53	45.34
41	IC 117328 × Pusa A 4	84.52	186.52	56.34	103.62	54.15	56.65
42	IC 117328 × VRO 6	154.32	128.76	102.88	71.53	54.18	52.51
43	IC 117328 × P. Kranti	109.05	179.73	72.70	99.85	58.36	50.65
44	IC 117328 × 15/RES-4	88.50	154.67	59.00	85.93	43.60	40.87
45	IC 093655	111.01	190.01	74.01	105.56	47.97	44.29
46	EC 169430	164.75	230.99	109.83	128.32	58.51	56.18
47	EC 169435	172.62	208.66	115.08	115.92	56.51	66.28
48	EC 169506	105.92	170.68	70.61	94.82	57.11	54.27
49	EC 169400	140.40	225.68	93.60	125.38	53.40	51.51
50	EC 169408	142.02	231.45	94.68	128.58	51.37	67.16
51	IC 117123	110.88	235.62	73.92	130.90	51.41	52.25
52	IC 117245	92.63	211.29	61.75	117.38	50.65	46.56
53	IC 117351	114.70	213.63	76.47	118.68	54.31	47.65
54	IC 117355	169.00	212.33	112.66	117.96	50.17	53.13
55	IC 117328	125.66	201.10	83.77	111.72	55.44	51.57
56	Pusa A 4	130.39	195.29	86.93	108.49	62.13	58.53
57	VRO 6	123.24	208.40	82.16	115.78	61.03	59.81
58	P. Kranti	105.89	240.64	70.60	133.69	58.75	61.43
59	15/RES-4	69.63	191.84	46.42	106.57	45.03	42.42
60	A. Anamika (Check)	109.48	210.05	72.99	116.69	60.09	59.42
	Mean	150.13	204.55	100.09	113.64	55.29	54.90
	C.V. (%)	13.74	10.76	13.74	10.76	5.65	5.36
	S.E.	11.91	12.71	7.94	7.06	1.81	1.70
	C.D. 5%	33.36	35.58	22.24	19.77	5.05	4.76
	C.D. 1%	44.10	47.04	29.40	26.13	6.68	6.29
	Lowest Range	69.6267	128.76	46.42	71.53	43.28	39.40
	Highest Range	333.1367	278.18	222.09	154.54	67.3367	74.59

rainy season respectively. Among the F_1 s, maximum fruit diameter was recorded in EC 169506 $\times$ Pusa A 4 (15.09 mm) and EC 169408 $\times$ 15/RES-4 (16.81 mm), while minimum values were found in IC 093655 $\times$ 15/RES-4 (9.52mm) and IC 117328 $\times$ Parbhani Kranti (12.41 mm) during summer and rainy season, respectively.

4.3.4 Fruit diameter (mm)

Mean values for fruit diameter ranged from 9.52 to 15.09 and 12.41 to 16.81 mm, during summer and rainy seasons, respectively. IC 093655 (14.49 mm) and EC 169430 (16.50 mm) recorded maximum fruit diameter among the parents, whereas minimum value was found in IC 169400 (12.59 mm) and EC 169435 (13.11 mm) during summer and rainy season respectively. Among the F_1 s, maximum fruit diameter was recorded in EC 169506 $\times$ Pusa A 4 (15.09 mm) and EC 169408 $\times$ 15/RES-4 (16.81 mm), while minimum values were found in IC 093655 $\times$ 15/RES-4 (9.52 mm) and IC 117328 $\times$ Parbhani Kranti (12.41 mm) during summer and rainy season, respectively.

4.3.5 Average fruit weight (g)

Average fruit weight exhibited variation among fifty nine treatments which ranged from 8.82 g to 15.10 g and 9.29 to 14.23 g during summer and rainy season, respectively. Among the parents, IC 093655 (13.34 g) and EC169408 (13.78 g) was recorded maximum average fruit weight, while minimum average fruit weight was recorded in IC 117351 (9.49 g) and 15/RES-4 (10.83 g) during summer and rainy season, respectively. Among the F_1 hybrids generated, maximum average fruit weight was recorded in EC169435 $\times$ VRO 6 (15.10 g) and IC093655 $\times$ VRO 6 (14.23 g) during summer and rainy season, respectively. The minimum value for the same characters was recorded in EC169400 $\times$ 15/RES-4 (8.82 g) in summer season, whereas cross combination EC117245 $\times$ 15/RES-4 (9.29 g) exhibited minimum value for the same trait during rainy season.

4.3.6 Number of fruits per plant

Mean values for number of fruits per plant ranged from 7.07 to 25.67 and 13.11 to 20.67 during summer and rainy season, respectively. Among the parents, EC 169435 (14.53) and Parbhani Kranti (19.33) recorded maximum number of fruits per plant, while, parents namely 15/RES-4 (7.07) and EC169506 (14.22) recorded minimum number of fruits per plant during summer and rainy season, respectively. Among the 44 cross

combinations, EC169408 × VRO 6 (25.67) and EC169408 × Pusa A 4 (20.67) recorded maximum mean values during summer and rainy season, respectively, whereas minimum number of fruits per plant were recorded in IC117328 × 15/RES-4 (7.89) and IC117328 × VRO 6 (13.11) during summer and rainy season, respectively.

4.3.7 Number of primary branches per plant

Perusal of data revealed that mean values for number of primary branches per plant ranged from 1.56 to 3.33 and 1.78 to 2.56 during summer and rainy season, respectively. Among the parents, maximum value for this trait was recorded in IC 117123 and Pusa A 4 (2.81) during summer season and IC 169506 (2.14) during rainy season. Whereas, EC 169400 (2.11) and Pusa A 4 (1.78) recorded minimum values for this trait during summer and rainy season, respectively. among the crosses EC 169408 × VRO 6 (3.33) recorded maximum value during summer season and EC 169430 × 15/RES-4 and EC 169408 × 15/RES-4 (2.56) during rainy season. While, Minimum value for same trait was recorded in IC 117355 × VRO 6 (1.56) and IC 117355 × Pusa A 4 (1.78) during summer and rainy season, respectively.

4.3.8 Stem diameter (mm)

During summer and rainy season, mean values for stem diameter ranged from 10.67 to 20.89 and 15.19 to 20.29 mm, respectively. EC 169430 (18.78 mm) and IC 117123 (19.60 mm) recorded maximum value among the parents, whereas minimum value was found in 15/RES-4 (14.35 mm) and EC169400 (15.96 mm) during summer and rainy season, respectively. Among the F₁s, maximum values for stem diameter were recorded in EC 169408 × VRO 6 (20.89 mm) and EC 169430 × 15/RES-4 (20.29 mm) during summer and rainy season, respectively. While, IC 117328 × 15/RES-4 (10.67 mm) and IC 117123 × Parbhani Kranti (15.19 mm) recorded minimum values for the same trait during summer and rainy season, respectively.

4.3.9 Inter-nodal length (cm)

Inter-nodal length ranged from 4.15 to 7.83 and 5.16 to 7.11 cm during summer and rainy season, respectively. Among the parents, maximum inter-nodal length was observed in EC 169435 (6.77 cm) and IC093655 (6.85 cm) during summer and rainy season, respectively. Whereas minimum values were recorded in 15/RES-4 (4.27 cm

and 6.21 cm) in both the respective season. Among the F_1 s, cross combination EC 169435 $\times$ Pusa A 4 (7.83 cm) and EC 169408 $\times$ Parbhani Kranti (7.11 cm) recorded maximum values during summer and rainy season respectively. Although, minimum inter-nodal length recorded in IC117355 $\times$ Pusa A 4 (4.15 cm) and IC117245 $\times$ VRO 6 (5.16 cm) during summer and rainy season, respectively.

4.3.10 Plant height (cm)

Perusal of data revealed that mean values for plant height ranged from 44.17 to 87.57 and 75.60 to 113.62 cm during summer and rainy season, respectively. Among the parents, during summer and rainy season, maximum mean values for plant height were recorded in EC 169400 (86.74 cm) and EC 169430 (117.08 cm), whereas, minimum values in 15/RES-4 (48.49 and 91.52 cm) during both season, respectively. Among the 44 F_1 s, EC 169408 $\times$ VRO 6 (87.57 cm) and EC 169430 $\times$ Pusa A 4 (107.18 cm) recorded maximum value for plant height. While, the cross combination IC117328 $\times$ 15/RES-4 (44.17 cm) and IC 117245 $\times$ VRO 6 (75.60 cm) recorded minimum mean values for plant height during summer and rainy season, respectively.

4.3.11 Fruit yield per plant (g)

Mean values for fruit yield per plant ranged from 69.63 to 333.14 g and 128.76 to 278.18 g during summer and rainy season, respectively. Among the parents, EC 169435 (172.62 g) and Parbhani Kranti (240.64 g) recorded the highest fruit yield per plant during summer and rainy season, respectively. While, lowest fruit yield per plant was recorded in 15/RES-4 (69.63 g) and EC 169506 (170.68 g) during summer and rainy season, respectively. Among the 44 F_1 s, EC169435 $\times$ VRO 6 (333.14 g) and EC169430 $\times$ Pusa A 4 (278.18 g) exhibited highest fruit yield per plant, while IC117328 $\times$ Pusa A 4 (84.52 g) and IC117328 $\times$ VRO 6 (128.76 g) recorded lowest fruit yield per plant during summer and rainy season, respectively.

4.3.12 Total yield (q/ha)

Total yield q/ha ranged from 46.42 to 222.09 and 71.53 to 154.54 q. during summer and rainy season, respectively. Among the parents, EC 169435 (115.08 q.) and Parbhani Kranti (133.69 q.) recorded the highest total yield q/ha during summer and rainy season, respectively. While, lowest total yield q/ha was recorded in 15/RES-4 (46.42 q.) and EC

169506 (94.82 q.) during summer and rainy season, respectively. Among the 44 F_1 s, EC169435 $\times$ VRO 6 (222.09 q.) and EC169430 $\times$ Pusa A 4 (154.54 q.) exhibited highest fruit yield per plant, while IC117328 $\times$ Pusa A 4 (56.34 q.) and IC117328 $\times$ VRO 6 (71.53 q.) recorded lowest total yield q/ha during summer and rainy season, respectively.

4.3.13 Number of seeds per fruit

Perusal of data revealed that mean values for number of seeds per fruit ranged from 43.28 to 67.34 and 39.40 to 74.59 during summer and rainy season, respectively. Among the parents, maximum value for number of seeds per fruit was noticed in Pusa A 4 (62.13) and EC169408 (67.16) during summer and rainy season, respectively. Whereas, minimum value was recorded in 15/RES-4 (45.03 and 42.42) during both season, respectively. Among the 44 F_1 s, EC169430 $\times$ VRO 6 (67.34 and 74.59) recorded maximum number of seeds per fruit during both seasons, respectively. However, cross combination IC117245 $\times$ 15/RES-4 (43.28 and 39.40) recorded minimum number of seeds per fruit during both seasons, respectively.

4.4 Estimation of Heterosis

Okra is a powerhouse of valuable nutrients grown throughout India. Its fast growth, short duration and photo-insensitive nature enable the geneticist and plant breeders to grow two crops in a year, facilitating quicker genetic crop improvement. Plant breeding can be divided into three stages; assembly or creation of a gene pool of variable germplasm, selection of superior individuals from the gene pool and utilization of the selected individuals directly for commercial cultivation or in hybridization to create a superior variety (Dudley and Moll, 1969). The improvement in yield, which is considered as a final product in almost all the crop plants, is usually obtained by screening, spotting and selecting out the suitable genes available from a huge collection of germplasm, synthesizing and accumulating them in a productive genotype for commercial cultivation.

For improving genetic yield potential of varieties and hybrids, the decision should be made about the choice of right type of parents for hybridization. The *per se* performance in respect of yield and other desirable economic characters could be considered as an important criteria in selection of the parents. Further, success in genetic improvement depends on the understanding of the nature of inheritance of yield and its component traits. This emphasizes on the importance of testing the parents for their

combining ability because most of the times high yielding parents may not combine well to give good segregation. Line $\times$ tester mating system has been found to be of considerable value to the plant breeders for screening and better understanding of the genetic makeup of the parents.

Thus, heterosis, combining ability and gene action are the basic requirements for thorough knowledge of genetic architecture of yield and its components. The genetic studies so far made in okra are limited to heterosis and combining ability. The literature on gene action involved in the control of yield contributing traits is very scanty. Keeping these views in mind the present study was undertaken.

Production of hybrids, as opposed to inbreds or open pollinated varieties, depends largely on the level of dominance or epistasis (especially dominance $\times$ dominance) or both. Again, level of dominance and forms of epistasis will influence the selection of parents to develop open pollinated varieties. For cheap production of hybrid seeds, availability of suitable male sterility system (maintenance and restoration) is essential for crops having economic importance. Cotton is a unique example in which successful exploitation of hybrid vigor, in the absence of male sterility system is feasible by hand emasculation and pollination. Okra also belongs to family 'Malvaceae' having similar floral structure like cotton hence there are enough chances to exploit heterosis on commercial scale.

Keeping these facts in view heterosis over mid parent, better parent and standard parent (Arka Anamika) was studied in okra. But the measure of heterosis over mid parental value has relatively limited importance and more academic interest than practical use. Hence, heterobeltiosis and standard heterosis measured in terms of superiority over better parent and standard parent is more viable. The estimates of heterosis measured as per cent increase or decrease over mid-parent (relative heterosis), better parent (heterobeltiosis) and standard parent (Standard heterosis) estimated for 13 different characters during summer and rainy season of 2018 presented in table 4.7 to 4.19.

For the earliness characters like days to 50 per cent flowering, first fruit producing node and inter-nodal length, the low scoring parent was considered as better parent. The magnitude of heterosis in various crosses for 13 different quantitative characters is presented as below:

4.4.1 Days to 50% flowering

Days to 50 per cent flowering are one of the important earliness character. So, parents and hybrids with negative heterosis are preferred and data are presented in table 4.7. During summer season, relative heterosis ranged from -7.85 (IC117351 $\times$ VRO 6) to 17.16% (IC093655 $\times$ 15/RES-4) and heterobeltiosis ranged from -12.90 (EC169435 $\times$ Parbhani Kranti, EC169400 $\times$ Pusa A4, IC117245 $\times$ Pusa A4, IC117351 $\times$ VRO 6, IC117355 $\times$ Parbhani Kranti) to 17.16% (IC093655 $\times$ 15/RES-4) while, standard heterosis ranged from -0.75 EC169400 $\times$ Parbhani Kranti to 18.05% (IC093655 $\times$ 15/RES-4). Among 44 F₁s, 8 hybrids and 11 hybrids had significant and negative relative heterosis and heterobeltiosis, respectively, indicating earliness in flowering of these hybrids which are presented in table 4. Out of all crosses, significant negative heterosis over mid parent for days to 50 per cent flowering in desirable direction was noticed in eight cross combinations with maximum in IC117351 $\times$ VRO 6 (-7.85%) followed by EC169435 $\times$ Parbhani Kranti (-7.22%), IC117245 $\times$ Pusa A4 (-7.22%), EC169400 $\times$ Pusa A4 (-6.90%), IC117355 $\times$ Parbhani Kranti (-6.57%), EC169430 $\times$ VRO 6 (-6.21%), EC169408 $\times$ VRO 6 (-5.15%) and IC093655 $\times$ Parbhani Kranti (-4.83%). Whereas, nine cross combinations recorded significant positive undesirable relative heterosis for the same trait. Among forty four crosses, significant negative heterobeltiosis was observed in eleven cross combinations viz., EC169435 $\times$ Parbhani Kranti, EC169400 $\times$ Pusa A4, IC117245 $\times$ Pusa A4, IC117351 $\times$ VRO 6, IC117355 $\times$ Parbhani Kranti (-12.90%), EC169430 $\times$ VRO 6 (-12.24), IC093655 $\times$ Parbhani Kranti (-10.97), EC169408 $\times$ VRO 6 (-10.97), IC117123 $\times$ 15/RES-4 (-7.10%), EC169506 $\times$ 15/RES-4 (-5.81%), IC117328 $\times$ 15/RES-4 (-4.52%) while, seven cross combinations were exhibited significant positive better parent heterosis for the same trait.

Among cross combinations, none of the cross was recorded significant negative standard heterosis in desirable direction.

During rainy season evaluation, relative heterosis, heterobeltiosis and standard heterosis for days to 50 per cent flowering ranged from -4.98 (EC169400 $\times$ Pusa A4) to 2.84% (IC093655 $\times$ 15/RES-4), -9.49 (EC169400 $\times$ Pusa A4) to 2.11% (IC093655 $\times$ 15/RES-4, IC117351 $\times$ Parbhani Kranti) and -0.70 (EC169435 $\times$ 15/RES-4, EC169400 $\times$ Parbhani Kranti) to 4.23% (IC093655 $\times$ Parbhani Kranti, EC169506 $\times$ 15/RES-4), respectively.

Table 4.7: Heterosis for days to 50% flowering

Characters		Days to 50% Flowering							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	45.33	48.67	-0.37	1.39	-0.73	1.39	2.26	2.82
2	IC 093655 × VRO 6	46.00	48.67	0.36	1.04	0.00	0.69	3.76 *	2.82
3	IC 093655 × P. Kranti	46.00	49.33	-4.83 **	-1.66	-10.97 **	-6.33 **	3.76 *	4.23 *
4	IC 093655 × 15/RES-4	52.33	48.33	17.16 **	2.84	17.16 **	2.11	18.05 **	2.11
5	EC 169430 × Pusa A 4	45.67	48.33	0.74	1.05	0.00	0.69	3.01	2.11
6	EC 169430 × VRO 6	45.33	48.00	-6.21 **	-4.32	-12.26 **	-8.86 **	2.26	1.41
7	EC 169430 × P. Kranti	44.67	47.67	-0.74	0.35	-1.47	0.00	0.75	0.70
8	EC 169430 × 15/RES-4	48.67	47.33	7.35 **	-0.70	6.57 **	-1.39	9.77 **	0.00
9	EC 169435 × Pusa A 4	45.67	48.33	0.74	1.05	0.00	0.69	3.01	2.11
10	EC 169435 × VRO 6	45.00	47.67	-1.10	-0.35	-1.46	-0.69	1.50	0.70
11	EC 169435 × P. Kranti	45.00	48.00	-7.22 **	-4.32	-12.90 **	-8.86 **	1.50	1.41
12	EC 169435 × 15/RES-4	50.00	47.00	11.52 **	-0.70	11.11 **	-0.70	12.78 **	-0.70
13	EC 169506 × Pusa A 4	45.67	48.33	1.86	1.75	1.48	1.40	3.01	2.11
14	EC 169506 × VRO 6	44.67	47.33	-1.83	-1.05	-2.19	-1.39	0.75	0.00
15	EC 169506 × P. Kranti	44.67	47.67	-1.47	-0.35	-2.19	-0.69	0.75	0.70
16	EC 169506 × 15/RES-4	48.67	49.33	0.69	-1.33	-5.81 **	-6.33 **	9.77 **	4.23 *
17	EC 169400 × Pusa A 4	45.00	47.67	-6.90 **	-4.98 **	-12.90 **	-9.49 **	1.50	0.70
18	EC 169400 × VRO 6	45.00	47.67	0.00	0.35	-0.74	0.00	1.50	0.70
19	EC 169400 × P. Kranti	44.00	47.00	-2.94	-1.74	-3.65 *	-2.08	-0.75	-0.70
20	EC 169400 × 15/RES-4	51.33	48.33	13.65 **	2.11	12.41 **	0.69	15.79 **	2.11
21	EC 169408 × Pusa A 4	45.67	48.67	0.37	1.39	0.00	1.39	3.01	2.82
22	EC 169408 × VRO 6	46.00	48.67	-5.15 **	-2.99	-10.97 **	-7.59 **	3.76 *	2.82
23	EC 169408 × P. Kranti	45.33	48.33	1.12	1.75	0.74	1.40	2.26	2.11

24	EC 169408 × 15/RES-4	47.67	47.33	5.54 **	0.00	4.38 *	-1.39	7.52 **	0.00
25	IC 117123 × Pusa A 4	44.33	47.67	-1.48	0.00	-2.21	-0.69	0.00	0.70
26	IC 117123 × VRO 6	45.33	48.33	-1.09	0.35	-1.45	0.00	2.26	2.11
27	IC 117123 × P. Kranti	44.33	47.33	-1.85	-0.70	-2.92	-1.39	0.00	0.00
28	IC 117123 × 15/RES-4	48.00	48.67	-0.35	-2.01	-7.10 **	-7.59 **	8.27 **	2.82
29	IC 117245 × Pusa A 4	45.00	48.00	-7.22 **	-4.64 **	-12.90 **	-8.86 **	1.50	1.41
30	IC 117245 × VRO 6	45.67	49.00	0.74	2.44	-0.72	1.38	3.01	3.52
31	IC 117245 × P. Kranti	44.67	47.67	-1.11	0.00	-2.19	-0.69	0.75	0.70
32	IC 117245 × 15/RES-4	50.33	48.67	10.62 **	2.10	10.22 **	1.39	13.53 **	2.82
33	IC 117351 × Pusa A 4	45.67	48.00	0.74	0.35	0.00	0.00	3.01	1.41
34	IC 117351 × VRO 6	45.00	48.67	-7.85 **	-3.63 *	-12.90 **	-7.59 **	1.50	2.82
35	IC 117351 × P. Kranti	45.33	48.33	1.49	2.11	1.49	2.11	2.26	2.11
36	IC 117351 × 15/RES-4	50.00	48.00	9.89 **	0.70	9.49 **	0.00	12.78 **	1.41
37	IC 117355 × Pusa A 4	47.00	48.33	3.68 *	1.05	2.92	0.69	6.02 **	2.11
38	IC 117355 × VRO 6	45.00	49.00	-1.10	2.44	-1.46	2.08	1.50	3.52
39	IC 117355 × P. Kranti	45.00	48.33	-6.57 **	-3.33 *	-12.90 **	-8.23 **	1.50	2.11
40	IC 117355 × 15/RES-4	50.00	48.00	11.11 **	1.41	10.29 **	1.41	12.78 **	1.41
41	IC 117328 × Pusa A 4	45.00	48.00	0.37	1.05	0.00	0.70	1.50	1.41
42	IC 117328 × VRO 6	44.67	48.33	-1.83	1.05	-2.19	0.69	0.75	2.11
43	IC 117328 × P. Kranti	45.00	48.00	-0.74	0.70	-1.46	0.00	1.50	1.41
44	IC 117328 × 15/RES-4	49.33	48.33	1.72	-3.33 *	-4.52 **	-8.23 **	11.28 **	2.11
	Maximum	52.33	49.33	17.16	2.84	17.16	2.11	18.05	4.23
	Minimum	44.00	47.00	-7.85	-4.98	-12.90	-9.49	-0.75	-0.70

Cross combinations, EC169400 $\times$ Pusa A4 (-4.98%) and IC117245 $\times$ Pusa A4 (-4.64%) were exhibited significant negative heterosis over mid parents. However, none of the cross was showed significant positive relative heterosis for the same trait. Eleven cross combinations same like summer exhibited significant and negative heterobeltiosis in desirable direction. Significant positive heterobeltiosis for the same trait was not observed in any crosses.

Among cross combination, none of the cross was showed significant negative standard heterosis in desirable direction.

Out of forty four cross combinations, six of them viz., EC169430 $\times$ VRO 6, EC169435 $\times$ Parbhani Kranti, EC169400 $\times$ Pusa A4, IC117245 $\times$ Pusa A4, IC117351 $\times$ VRO 6 and IC117355 $\times$ Parbhani Kranti showed significant negative desired heterosis over better parent as well as mid parent for days to 50 per cent flowering consistently during both season. Significant negative heterosis was also reported by Dhankhar *et al.* (1996); Kumar and Shreeparvathi (2010); Medagam *et al.* (2012); Obiadalla-ali *et al.* (2013); Jindal *et al.* (2010); Singh *et al.* (2016); and Paul *et al.* (2017).

4.4.2 First fruit producing node

First fruit producing node is also an earliness character, so their negative heterosis over mid parent and better parent is desirable. During first season evaluation, data presented in table 4.8 revealed that relative heterosis and heterobeltiosis ranged from -23.78 (IC117245 $\times$ Pusa A4) to 51.32% (EC169430 $\times$ Pusa A4) and -28.88 (IC093655 $\times$ Pusa A4) to 45.31% (EC169408 $\times$ VRO 6), respectively. Significant negative relative heterosis and heterobeltiosis was recorded in four crosses viz., IC117245 $\times$ Pusa A4 (-23.78, -28.52%), IC093655 $\times$ Pusa A4 (-23.75, -28.88%), IC117328 $\times$ Pusa A4 (-18.66, -23.48%) and IC117355 $\times$ Pusa A4 (-18.08, -21.83%). Whereas, 13 cross combinations were exhibited significant positive relative heterosis and none of the cross combination showed significant positive heterobeltiosis for the same trait.

Among forty four crosses, two cross combinations was showed significant negative standard heterosis with maximum in IC093655 $\times$ Pusa A4 (-19.89%) and IC117245 $\times$ Pusa A4 (-19.48%). During second season evaluation, out of forty four cross combinations,

relative heterosis and heterobeltiosis ranged from -32.80 (IC117328 $\times$ 15/RES-4) to 9.28% (EC169506 $\times$ Pusa A4) and -35.83 (IC117355 $\times$ 15/RES-4) to 9.22% (EC169506 $\times$ Pusa A4). Significant negative heterosis in desirable direction were found in nine crosses with maximum in IC117328 $\times$ 15/RES-4 (-32.80%) for relative heterosis and fourteen cross for heterobeltiosis maximum in IC117355 $\times$ 15/RES-4 (-35.83%), indicating earliness for first fruit producing node. Among forty four crosses, significant negative standard heterosis in desirable direction was observed in eight cross combinations viz., EC169506 $\times$ 15/RES-4 (-26.32%), IC117351 $\times$ 15/RES-4 (-24.58%), EC169400 $\times$ 15/RES-4 (-22.79%), IC117351 $\times$ 15/RES-4 (-22.79%), IC117328 $\times$ 15/RES-4 (-22.79%), IC117351 $\times$ 15/RES-4 (-21.11%), IC093655 $\times$ 15/RES-4 (-19.32%) and EC169408 $\times$ 15/RES-4 (-17.58%) while, none of them showed significant positive standard heterosis.

Among forty four cross combinations, none of them exhibited consistent significant negative desired heterosis over mid parent as well as better parent for first fruit producing node over both the seasons. Significant negative heterosis was also reported by Poshia and Shukla (1986); Jindal *et al.* (2010); and Ram *et al.* (2015).

4.4.3 Fruit length (cm)

Fruit length is a vital character influencing the fruit quality. Fruits with more desirable length and diameter are preferable both for consumption and processing purpose. The perusal of data presented in the table 4.9 revealed that during first season, relative heterosis, heterobeltiosis and standard heterosis for fruit length ranged from 28.30 (EC169430 $\times$ Parbhani Kranti) to -18.33% (EC169408 $\times$ Pusa A4), 22.43 (EC169430 $\times$ Parbhani Kranti) to -19.13% (EC169408 $\times$ Pusa A4) and 24.94% (EC169430 $\times$ Parbhani Kranti) to -15.68% (EC169408 $\times$ Pusa A4) respectively.

Among forty four cross combinations, significant positive heterosis over mid parent was showed by eight crosses with highest in EC169430 $\times$ Parbhani Kranti (28.30%) followed by EC169400 $\times$ Parbhani Kranti (23.17%) and EC169506 $\times$ Pusa A4 (20.44%). Whereas, two cross combinations exhibited significant negative heterosis over mid parent in undesirable direction.

Table 4.8: Heterosis for first fruit producing node

Characters		First fruit producing node							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	3.32	6.11	-23.75 **	3.79	-28.88 **	-1.77	-19.89 *	-3.47
2	IC 093655 × VRO 6	4.33	5.89	12.31	-7	12.26	-11.65	4.67	-7
3	IC 093655 × P. Kranti	3.88	5.89	-7.39	-14.54 *	-9.76	-17.21 *	-6.2	-7.05
4	IC 093655 × 15/RES-4	3.61	5.11	-6.2	-14.83	-7.91	-14.88	-12.88	-19.32 *
5	EC 169430 × Pusa A 4	6.09	5.89	51.32 **	-7.08	45.19 **	-11.7	47.18 **	-7.05
6	EC 169430 × VRO 6	4.83	6.44	13.37	-0.87	8.78	-9.38	16.75	1.74
7	EC 169430 × P. Kranti	5.19	6.44	34.78 **	4.51	32.43 **	1.74	25.28 **	1.74
8	EC 169430 × 15/RES-4	4.72	5.45	20.27 *	-12.53	16.85	-12.57	13.93	-14
9	EC 169435 × Pusa A 4	5.14	5.78	24.86 **	-5.51	22.48 *	-7.18	24.15 **	-8.79
10	EC 169435 × VRO 6	4.87	6.56	23.42 **	1.73	20.76 *	-1.65	17.55	3.53
11	EC 169435 × P. Kranti	5.67	6.11	44.21 **	-9.1	38.86 **	-14.06	36.96 **	-3.53
12	EC 169435 × 15/RES-4	4.61	5.44	19.38 *	-10.96	17.7	-12.63	11.35	-14.05
13	EC 169506 × Pusa A 4	3.98	6.56	-1.97	9.28	-5.24	9.22	-3.95	3.53
14	EC 169506 × VRO 6	3.6	6.45	-10.74	3.59	-10.82	3.59	-13.04	1.79
15	EC 169506 × P. Kranti	4.05	6.44	-0.74	-3.35	-5.89	-3.35	-2.17	1.74
16	EC 169506 × 15/RES-4	3.58	4.67	-9.17	-30.03 **	-12.24	-34.36 **	-13.45	-26.32 **
17	EC 169400 × Pusa A 4	3.76	6.22	-9.18	-5.13	-10.41	-12.52	-9.18	-1.79
18	EC 169400 × VRO 6	4.07	6.45	2.35	5.51	0.91	3.59	-1.77	1.79
19	EC 169400 × P. Kranti	3.75	6.22	-10.07	-3.44	-12.86	-6.65	-9.42	-1.74
20	EC 169400 × 15/RES-4	3.86	4.89	1.18	-22.81 **	0.09	-26.65 **	-6.76	-22.79 **
21	EC 169408 × Pusa A 4	4.97	6.67	16.67 *	9.08	6.58	0	20.05 *	5.26
22	EC 169408 × VRO 6	5.93	6.44	46.26 **	-3.35	45.31 **	-9.38	43.32 **	1.74

23	EC 169408 × P. Kranti	4.97	5.55	21.01 **	-12.29	15.57	-16.70 *	20.13 *	-12.32
24	EC 169408 × 15/RES-4	4.73	5.22	21.21 *	-14.61	17.26	-16.12	14.33	-17.58 *
25	IC 117123 × Pusa A 4	4.36	5.78	1.63	0	-6.5	-3.67	5.31	-8.79
26	IC 117123 × VRO 6	5.13	5.56	30.01 **	-9.08	27.17 **	-10.71	23.99 **	-12.26
27	IC 117123 × P. Kranti	4.55	5.55	20.96 *	-15.28 *	17.98	-16.70 *	9.9	-12.32
28	IC 117123 × 15/RES-4	4.22	5	7.34	-23.79 **	3.27	-29.72 **	1.85	-21.11 *
29	IC 117245 × Pusa A 4	3.33	6.11	-23.78 **	-3.53	-28.52 **	-14.06	-19.48 *	-3.53
30	IC 117245 × VRO 6	3.4	5.34	-12.56	-11.03	-13.19	-11.06	-17.87	-15.74
31	IC 117245 × P. Kranti	4.06	5.55	5.32	-12.32	0.5	-13.81	-2.01	-12.32
32	IC 117245 × 15/RES-4	3.62	5.33	-5.07	-24.40 **	-6.05	-28.35 **	-12.48	-15.79
33	IC 117351 × Pusa A 4	4.26	5.55	2.65	-11.55	-4.13	-16.70 *	2.9	-12.32
34	IC 117351 × VRO 6	4.53	5.89	14.14	-10.2	11.02	-17.21 *	9.5	-7.05
35	IC 117351 × P. Kranti	4.53	5.34	19.56 *	-14.2	15.74	-17.18 *	9.5	-15.74
36	IC 117351 × 15/RES-4	4.73	4.89	20.99 *	-28.44 **	17.09	-34.30 **	14.17	-22.79 **
37	IC 117355 × Pusa A 4	3.47	5.66	-18.08 *	-6.49	-21.83 *		-16.1	-10.58
38	IC 117355 × VRO 6	4.4	5.67	15.23	-12.77	14.09	-14.95	6.28	-10.47
39	IC 117355 × P. Kranti	3.62	5.56	-6.49	-18.00 *	-11.27	-21.85 **	-12.48	-12.26
40	IC 117355 × 15/RES-4	3.49	4.78	-9.27	-28.92 **	-10.89	-35.83 **	-15.7	-24.58 **
41	IC 117328 × Pusa A 4	3.4	5.78	-18.66 *	-2.8	-23.48 **	-3.67	-17.87	-8.79
42	IC 117328 × VRO 6	3.47	5.78	-11.3	-7.99	-14.12	-8.79	-16.26	-8.79
43	IC 117328 × P. Kranti	4.26	5.78	11.18	-10.36	10.46	-13.3	2.9	-8.74
44	IC 117328 × 15/RES-4	3.6	4.89	-8.4	-32.80 **	-11.84	-34.30 **	-13.04	-22.79 **
	Maximum	6.09	6.67	51.32	9.28	45.31	9.22	47.18	5.26
	Minimum	3.32	4.67	-23.78	-32.80	-28.88	-35.83	-19.89	-26.32

Significant positive heterosis over better parent was recorded in four crosses viz., EC169430 × Parbhani Kranti (22.43%), EC169506 × Pusa A4 (20.37%), EC169408 × Parbhani Kranti (18.89%), IC117123 × 15/RES-4 (18.09%). While, two cross combinations recorded significant negative heterosis over better parent in undesired direction.

Among cross combination, three crosses were recorded significant positive standard heterosis in desirable direction viz., EC169430 × Parbhani Kranti (24.94%), EC169400 × Parbhani Kranti (22.57%) and IC117123 × Parbhani Kranti (19.99%).

During second season, relative heterosis, heterobeltiosis and standard heterosis ranged from 14.65 to -18.50%, 12.30 to -24.50% and 24.36 to -6.80%, respectively. Out of forty four crosses, two cross combinations recorded significant positive heterosis over mid parent in desirable direction viz., EC169430 × Parbhani Kranti (14.65%) and EC169408 × 15/RES-4 (11.25%), whereas, two cross combinations exhibited significant negative relative heterosis in undesirable direction. Among forty four crosses, none of them were showed significant positive heterobeltiosis in desirable direction.

Among cross combination, four crosses were exhibited significant positive standard heterosis in desirable direction viz., EC169430 × 15/RES-4 (24.36%), EC169408 × 15/RES-4 (23.56%), EC169435 × Parbhani Kranti (18.43%) and EC169435 × 15/RES-4 (15.59%). Among all the crosses, the cross EC169430 × Parbhani Kranti showed significant positive heterosis over mid parent, better parent and standard check, respectively in first season while, the cross EC169435 × Parbhani Kranti exhibited positive heterosis over mid parent, better parent and standard check, respectively in second season. Significant heterosis for fruit length was also reported by Singh *et al.* (2002); Kumar *et al.* (2006); Mehta *et al.* (2007); Hosamani *et al.* (2008); Khanpara *et al.* (2009); Kumar and Sreeparvathy (2010); Parmar *et al.* (2011); Kumar and Singh (2012); and Singh *et al.* (2016).

Table 4.9: Heterosis for fruit length (cm)

Characters		Fruit length (cm)							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	9.33	13.15	-4.24	1.53	-6.64	-0.53	0.47	4.47
2	IC 093655 × VRO 6	9.48	12.46	4.06	-3.70	-2.13	-8.18	2.05	-1.06
3	IC 093655 × P. Kranti	10.41	13.65	19.41 *	2.07	16.45	1.31	12.02	8.45
4	IC 093655 × 15/RES-4	8.58	13.20	-0.46	-6.27	-0.54	-10.47	-7.64	4.85
5	EC 169430 × Pusa A 4	10.44	13.69	14.04	-6.02	7.78	-12.06 *	12.38	8.74
6	EC 169430 × VRO 6	9.17	13.61	3.46	-1.20	2.61	-4.67	-1.29	8.13
7	EC 169430 × P. Kranti	11.61	13.35	28.30 **	2.10	22.43 **	-0.52	24.94 **	6.06
8	EC 169430 × 15/RES-4	9.79	15.66	4.02	7.48	-2.10	-1.59	5.35	24.36 **
9	EC 169435 × Pusa A 4	9.00	13.03	-3.29	-9.46	-9.94	-16.27 **	-3.09	3.52
10	EC 169435 × VRO 6	9.73	13.20	9.55	1.37	0.45	-2.70	4.74	4.85
11	EC 169435 × P. Kranti	10.38	14.91	12.72	14.65 **	9.49	12.30	11.73	18.43 **
12	EC 169435 × 15/RES-4	9.72	14.55	11.47	-0.77	10.17	-8.53	4.59	15.59 *
13	EC 169506 × Pusa A 4	10.38	11.97	20.44 *	-17.44 **	20.37 *	-23.13 **	11.73	-4.95
14	EC 169506 × VRO 6	10.38	12.62	14.87 *	-1.76	3.83	-4.54	11.73	0.26
15	EC 169506 × P. Kranti	10.09	13.92	10.96	2.95	4.13	2.60	8.58	10.56
16	EC 169506 × 15/RES-4	8.70	13.01	-2.01	-10.85 *	-2.65	-18.23 **	-6.35	3.34
17	EC 169400 × Pusa A 4	8.85	11.75	0.76	-18.50 **	-1.01	-24.50 **	-4.77	-6.65
18	EC 169400 × VRO 6	8.88	13.36	6.41	3.19	3.10	-0.45	-4.41	6.14
19	EC 169400 × P. Kranti	11.39	13.29	23.17 **	-0.47	13.90	-1.41	22.57 **	5.53
20	EC 169400 × 15/RES-4	9.81	13.55	7.14	-4.30	1.27	-8.12	5.60	7.60
21	EC 169408 × Pusa A 4	7.83	13.40	-18.33 *	2.08	-19.13 *	-1.23	-15.68	6.43
22	EC 169408 × VRO 6	8.64	13.31	1.61	3.39	-3.28	0.28	-6.96	5.75

23	EC 169408 × P. Kranti	10.24	12.72	19.72 *	-5.43	18.89 *	-5.61	10.23	1.03
24	EC 169408 × 15/RES-4	9.75	15.56	4.74	11.25 *	-2.43	5.52	4.99	23.56 **
25	IC 117123 × Pusa A 4	9.08	13.32	0.28	2.06	-4.39	-0.74	-2.26	5.82
26	IC 117123 × VRO 6	8.95	12.45	-3.40	-2.43	-10.47	-5.82	-3.66	-1.09
27	IC 117123 × P. Kranti	11.15	13.66	15.91 *	-0.59	15.07	-1.82	19.99 *	8.47
28	IC 117123 × 15/RES-4	10.55	13.24	20.17 *	-5.47	18.09 *	-10.17	13.60	5.19
29	IC 117245 × Pusa A 4	10.12	13.79	9.84	6.20	6.60	3.84	8.97	9.50
30	IC 117245 × VRO 6	9.46	13.41	10.34	4.28	9.83	-0.07	1.83	6.54
31	IC 117245 × P. Kranti	10.19	13.78	4.28	1.55	1.93	-0.96	9.69	9.43
32	IC 117245 × 15/RES-4	8.93	14.17	-6.58	10.97	-7.85	4.42	-3.91	12.52
33	IC 117351 × Pusa A 4	8.77	13.62	-5.03	-2.18	-9.43	-4.62	-5.56	8.18
34	IC 117351 × VRO 6	9.88	13.16	13.11	2.87	10.56	-0.90	6.35	4.50
35	IC 117351 × P. Kranti	8.38	12.06	-7.67	-11.73 *	-12.19	-13.28 *	-9.76	-4.18
36	IC 117351 × 15/RES-4	8.12	13.02	-16.37 *	3.37	-18.77 *	-1.54	-12.59	3.42
37	IC 117355 × Pusa A 4	9.53	14.09	1.49	2.46	-4.63	-1.33	2.62	11.91
38	IC 117355 × VRO 6	9.98	13.54	4.14	2.99	3.03	-0.17	7.43	7.57
39	IC 117355 × P. Kranti	8.19	11.73	-11.34	-13.68 *	-14.18	-15.65 *	-11.80	-6.80
40	IC 117355 × 15/RES-4	8.24	13.15	-8.67	3.61	-12.59	-2.01	-11.34	4.47
41	IC 117328 × Pusa A 4	8.67	13.46	-0.33	-2.85	-1.33	-5.77	-6.64	6.88
42	IC 117328 × VRO 6	10.57	13.45	8.51	3.61	5.70	1.69	13.74	6.80
43	IC 117328 × P. Kranti	9.57	12.09	3.39	-17.99 **	-1.24	-24.03 **	2.98	-4.00
44	IC 117328 × 15/RES-4	9.62	12.54	4.83	-0.67	2.12	-5.57	3.59	-0.42
	Maximum	11.61	15.66	28.30	14.65	22.43	12.30	24.94	24.36
	Minimum	7.83	11.73	-18.33	-18.50	-19.13	-24.50	-15.68	-6.80

4.4.4 Fruit Diameter (mm)

The perusal of data presented in the table 4.10 revealed that relative heterosis, heterobeltiosis and standard heterosis ranged from 12.13 to -32.84%, 10.12 to -33.13% and 19.42 to -24.64%, respectively during first season evaluation. Among the crosses, none of them were exhibited positive significant relative heterosis and heterobeltiosis, while seven cross combination showed significant positive standard heterosis for this traits. Significant positive heterosis over standard check for fruit diameter was recorded in EC169506 $\times$ Pusa A4 (19.42%), EC169408 $\times$ Parbhani Kranti (18.94%), IC117351 $\times$ VRO 6 (18.79%), EC169506 $\times$ Pusa A4 (18.39%), IC117351 $\times$ Pusa A4 (18.28%), EC169506 $\times$ Parbhani Kranti (16.36%) and IC117351 $\times$ VRO 6 (16.09%).

During second season evaluation, out of forty four F₁ hybrids, significant and positive relative heterosis, heterobeltiosis and standard heterosis was expressed by nine crosses, two crosses and two cross, respectively. The maximum positive and negative significant value for relative heterosis was observed in EC169408 $\times$ 15/RES-4 (17.92%) and IC117328 $\times$ Parbhani Kranti (-23.16%), respectively. The maximum positive and negative significant value for heterobeltiosis was observed in EC169408 $\times$ 15/RES-4 (14.61%) and IC117328 $\times$ Parbhani Kranti (-23.17%), respectively. However, maximum positive and negative significant value for standard heterosis was observed in EC169408 $\times$ 15/RES-4 (16.90%) and IC117328 $\times$ Parbhani Kranti (-13.68%).

Fruit diameter is an important fruit quality parameter. Among the cross combinations, the most promising hybrid was EC169408 $\times$ 15/RES-4, which exhibited high *per se* performance with consistent significant positive heterosis over mid parent better parent as well as standard check for fruit diameter during summer season, while none of the cross combinations exhibited consistent significant heterosis over both season consistently. The results are in close agreement with the findings of Hosamani *et al.* (2008); Khanpara *et al.* (2009); Kumar and Sreeparvathy (2010); Parmar *et al.* (2011); Rani (2015); and Singh *et al.* (2016).

Table 4.10: Heterosis for fruit diameter (mm)

Characters		Fruit diameter (mm)							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	13.44	15.51	1.01	15.07 **	0.55	12.04 *	6.36	7.86
2	IC 093655 × VRO 6	14.48	14.47	2.32	-2.73	1.80	-10.42 *	14.59	0.63
3	IC 093655 × P. Kranti	13.67	15.82	1.86	10.49 *	-0.41	3.53	8.23	10.01
4	IC 093655 × 15/RES-4	9.52	14.61	-28.04 **	1.19	-28.15 **	-0.39	-24.64 **	1.60
5	EC 169430 × Pusa A 4	13.55	14.71	-2.91	-9.90 *	-4.69	-10.85 *	7.28	2.29
6	EC 169430 × VRO 6	12.92	15.71	-2.28	9.95 *	-3.07	3.22	2.30	9.25
7	EC 169430 × P. Kranti	14.36	15.64	3.67	11.25 *	-0.92	10.09	13.67	8.79
8	EC 169430 × 15/RES-4	12.90	16.22	-3.78	8.16	-4.07	0.41	2.08	12.82 *
9	EC 169435 × Pusa A 4	13.04	14.09	-3.61	-7.13	-4.79	-14.61 **	3.25	-2.02
10	EC 169435 × VRO 6	13.51	15.40	0.80	3.02	-4.99	-4.66	6.94	7.09
11	EC 169435 × P. Kranti	13.79	14.93	-0.13	9.52	-4.88	7.33	9.13	3.85
12	EC 169435 × 15/RES-4	12.63	15.83	-5.23	4.28	-6.05	-2.00	-0.03	10.11
13	EC 169506 × Pusa A 4	15.09	13.32	12.13	-13.23 **	10.12	-19.25 **	19.42 *	-7.35
14	EC 169506 × VRO 6	14.28	14.78	10.08	7.15	6.88	6.77	13.06	2.78
15	EC 169506 × P. Kranti	14.70	15.88	5.19	1.02	3.38	-1.71	16.36 *	10.41
16	EC 169506 × 15/RES-4	12.05	13.52	-9.26	-8.36	-10.36	-16.30 **	-4.62	-5.96
17	EC 169400 × Pusa A 4	14.96	14.12	11.55	-5.41	9.17	-14.42 **	18.39 *	-1.81
18	EC 169400 × VRO 6	12.88	14.75	-0.14	5.56	-2.50	3.82	1.95	2.60
19	EC 169400 × P. Kranti	14.59	14.82	7.68	1.80	6.24	-2.99	15.46	3.08
20	EC 169400 × 15/RES-4	10.87	15.08	-20.86 **	-2.16	-23.56 **	-6.67	-13.96	4.84
21	EC 169408 × Pusa A 4	14.38	15.37	4.71	5.01	1.10	-4.87	13.80	6.86

22	EC 169408 × VRO 6	12.05	15.26	-6.26	12.60 *	-8.16	11.01	-4.64	6.10
23	EC 169408 × P. Kranti	15.03	14.77	11.56	0.15	9.44	-3.36	18.94 *	2.69
24	EC 169408 × 15/RES-4	11.18	16.81	-15.98 *	17.92 **	-16.34 *	14.61 **	-11.50	16.90 **
25	IC 117123 × Pusa A 4	12.96	15.08	-2.03	10.36 *	-2.14	6.10	2.56	4.84
26	IC 117123 × VRO 6	13.34	15.03	-2.79	9.56	-5.26	8.60	5.57	4.54
27	IC 117123 × P. Kranti	14.32	15.24	1.98	-1.05	0.73	-5.63	13.38	6.00
28	IC 117123 × 15/RES-4	12.05	14.93	-8.62	6.58	-9.08	1.82	-4.64	3.85
29	IC 117245 × Pusa A 4	13.12	14.59	-0.44	10.24 *	-0.91	9.23	3.85	1.46
30	IC 117245 × VRO 6	13.03	15.14	-4.52	8.86	-7.46	6.52	3.11	5.26
31	IC 117245 × P. Kranti	13.06	14.63	-4.11	2.67	-5.86	-0.18	3.35	1.74
32	IC 117245 × 15/RES-4	9.59	14.46	-32.84 **	-5.68	-33.13 **	-10.50 *	-24.06 **	0.53
33	IC 117351 × Pusa A 4	14.94	14.79	8.47	-5.72	5.09	-8.44	18.28 *	2.85
34	IC 117351 × VRO 6	15.01	14.95	10.37	10.89 *	6.61	9.90	18.79 *	3.94
35	IC 117351 × P. Kranti	13.79	14.38	1.85	-0.39	-0.58	-1.91	9.16	-0.02
36	IC 117351 × 15/RES-4	10.66	14.43	-23.04 **	1.85	-25.67 **	-0.46	-15.59	0.37
37	IC 117355 × Pusa A 4	14.39	14.70	7.80	1.16	7.68	-3.42	13.91	2.23
38	IC 117355 × VRO 6	13.18	15.71	-8.17	4.50	-9.04	-2.74	4.35	9.25
39	IC 117355 × P. Kranti	12.23	13.49	-9.39	-3.69	-11.85	-7.96	-3.22	-6.19
40	IC 117355 × 15/RES-4	9.93	14.87	-27.91 **	3.59	-30.76 **	2.55	-21.37 **	3.41
41	IC 117328 × Pusa A 4	13.58	14.27	2.30	-3.05	1.83	-6.26	7.47	-0.79
42	IC 117328 × VRO 6	14.67	14.90	5.30	7.36	1.20	7.09	16.09 *	3.62
43	IC 117328 × P. Kranti	13.60	12.41	-1.70	-23.16 **	-4.38	-23.17 **	7.63	-13.68 *
44	IC 117328 × 15/RES-4	9.67	14.59	-29.55 **	4.75	-32.57 **	0.62	-23.43 **	1.46
	Maximum	15.09	16.81	12.13	17.92	10.12	14.61	19.42	16.90
	Minimum	9.52	12.41	-32.84	-23.16	-33.13	-23.17	-24.64	-13.68

4.4.5 Average fruit weight (g)

The read-through of data presented in the table 4.11 revealed that out of 44 cross combinations, 12, 6 and 17 during first season, while 8, 3 and 21 crosses during second season exhibited significant and positive heterosis over mid parent better parent and standard parent, respectively.

During first season, relative heterosis for average fruit weight ranged from -30.59 (EC169400 × 15/RES-4) to 33.59% (EC169430 × VRO 6). Twelve cross combinations showed significant positive heterosis over mid parent for average fruit weight in desirable direction. EC169430 × VRO 6 (33.59%) recorded maximum heterotic value followed by IC117123 × P. Kranti (30.08%) and IC117351 × P. Kranti (30.35%), whereas, five crosses showed significant negative undesirable relative heterosis for the same trait with minimum in EC169400 × 15/RES-4 (-30.59%). With looking up to heterobeltiosis, out of forty four crosses, thirteen cross combinations exhibited significant heterosis over better parent which ranged from -30.76 (EC169400 × 15/RES-4) to 29.19% (EC169430 × VRO 6). Among thirteen significant cross combinations, six crosses recorded significant positive heterosis over better parent for average fruit weight in desirable direction with maximum heterotic value in EC169430 × VRO 6 (29.19%) followed by IC117351 × P.Kranti (23.00%), and EC169435 × VRO 6 (18.56%).

While, significant undesired negative heterosis over better parent was noticed in other seven cross combinations with minimum in EC169400 × 15/RES-4 (-30.76%). Standard heterosis ranged from -18.69% to 39.23% for average fruit weight. Among cross combination, twenty one crosses were showed significant positive standard heterosis in desirable direction with maximum in EC169435 × VRO 6 (39.23%).

During second season, out of forty four F_1 hybrids, seventeen crosses were recorded significant relative heterosis which ranged from -18.91 (IC117245 × 15/RES-4) to 17.23% (EC169430 × VRO 6). Among seventeen significant F_1 hybrids, only eight F_1 hybrids showed significant positive relative heterosis with maximum in EC169430 × VRO 6 (17.23%) followed by EC169430 × Pusa A 4 (16.41%) and EC169435 × P. Kranti (15.24%). Significant heterosis over better parent for this trait ranged between IC117351 × VRO 6 (-26.78%) to EC169430 × 15/RES-4 (14.57%). Three cross combinations namely EC169430 × 15/RES-4 (14.57%) followed by EC169430 × Pusa A 4 (11.86%) and

Table 4.11: Heterosis for average fruit weight (g)

Characters		Average Fruit weight (g)							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	13.95	13.06	18.86 **	5.43	17.69 **	-3.23	28.65 **	17.65 **
2	IC 093655 × VRO 6	9.71	14.23	-21.26 **	12.14 **	-23.74 **	3.29	-10.45	28.16 **
3	IC 093655 × P. Kranti	11.71	12.39	10.28	6.26	3.05	-0.80	8.02	11.62 *
4	IC 093655 × 15/RES-4	10.66	12.18	-9.03	-0.98	-15.86 **	-2.12	-1.69	9.67
5	EC 169430 × Pusa A 4	11.65	14.08	-3.48	16.41 **	-8.51	11.86 *	7.44	26.81 **
6	EC 169430 × VRO 6	13.66	13.37	33.59 **	17.23 **	29.19 **	11.67 *	25.98 **	20.38 **
7	EC 169430 × P. Kranti	13.82	12.64	14.64 **	1.09	3.57	0.58	27.45 **	13.84 *
8	EC 169430 × 15/RES-4	12.41	12.92	17.62 **	15.59 **	6.83	14.57 **	14.48 *	16.39 **
9	EC 169435 × Pusa A 4	12.40	12.84	7.70	7.60	6.71	2.01	14.36 *	15.64 **
10	EC 169435 × VRO 6	15.10	13.41	21.71 **	6.29	18.56 **	-1.64	39.23 **	20.80 **
11	EC 169435 × P. Kranti	12.95	13.48	11.57 *	15.24 **	-2.92	7.29	19.46 **	21.44 **
12	EC 169435 × 15/RES-4	11.19	12.61	10.53	7.20	3.96	1.34	3.23	13.54 *
13	EC 169506 × Pusa A 4	9.99	12.55	-9.86	0.29	-12.39	-0.29	-7.84	13.03 *
14	EC 169506 × VRO 6	11.33	12.96	-4.33	4.05	-6.13	-4.94	4.52	16.75 **
15	EC 169506 × P. Kranti	10.50	13.54	-12.86 *	12.38 **	-17.54 **	8.38	-3.17	21.95 **
16	EC 169506 × 15/RES-4	10.05	12.10	3.84	10.40 *	1.79	9.18	-7.29	8.95
17	EC 169400 × Pusa A 4	11.33	12.53	6.47	7.03	-0.67	-0.42	4.49	12.88 *
18	EC 169400 × VRO 6	12.49	12.35	9.34	-5.25	3.42	-9.41 *	15.16 *	11.26 *
19	EC 169400 × P. Kranti	11.11	11.46	-3.36	-3.59	-4.42	-8.27	2.43	3.21
20	EC 169400 × 15/RES-4	8.82	10.64	-30.59 **	-10.43 *	-30.76 **	-12.45 *	-18.69 **	-4.17
21	EC 169408 × Pusa A 4	12.81	12.47	4.23	-0.65	0.63	-7.63	18.17 **	12.31 *
22	EC 169408 × VRO 6	12.34	12.80	12.44 *	4.62	2.21	-6.14	13.80 *	15.28 **

23	EC 169408 × P. Kranti	13.41	13.22	21.17 **	6.07	17.98 **	5.84	23.67 **	19.09 **
24	EC 169408 × 15/RES-4	12.75	12.92	4.95	10.30 *	0.61	6.34	17.55 *	16.39 **
25	IC 117123 × Pusa A 4	11.61	12.52	2.68	-3.47	-2.02	-7.26	7.10	12.76 *
26	IC 117123 × VRO 6	11.43	10.82	-2.90	-13.61 **	-4.16	-21.44 **	5.44	-2.52
27	IC 117123 × P. Kranti	14.83	12.02	33.08 **	6.64	16.47 **	3.62	36.77 **	8.29
28	IC 117123 × 15/RES-4	11.69	11.36	3.73	-1.13	-7.71	-6.50	7.84	2.34
29	IC 117245 × Pusa A 4	11.89	11.61	9.46	-4.55	0.34	-13.98 **	9.68	4.59
30	IC 117245 × VRO 6	13.34	10.64	17.55 **	-18.80 **	11.82	-22.74 **	23.02 **	-4.14
31	IC 117245 × P. Kranti	9.85	10.31	-6.99	-7.20	-15.26 *	-8.57	-9.19	-7.11
32	IC 117245 × 15/RES-4	10.57	9.29	-13.57 *	-18.91 **	-16.96 **	-19.97 **	-2.49	-16.36 **
33	IC 117351 × Pusa A 4	12.69	10.63	8.92	-9.84 *	-0.31	-11.22 *	17.06 *	-4.29
34	IC 117351 × VRO 6	11.57	10.09	6.14	-18.03 **	-2.99	-26.78 **	6.73	-9.16
35	IC 117351 × P. Kranti	13.24	10.85	30.35 **	-7.18	23.00 **	-12.75 *	22.13 **	-2.25
36	IC 117351 × 15/RES-4	10.29	9.71	-11.90 *	-13.97 **	-12.33	-14.04 *	-5.13	-12.52 *
37	IC 117355 × Pusa A 4	11.93	11.81	7.54	1.62	2.70	-1.31	10.05	6.39
38	IC 117355 × VRO 6	13.11	10.18	0.58	-15.79 **	-1.72	-19.02 **	20.93 **	-8.35
39	IC 117355 × P. Kranti	9.38	10.70	-3.48	-1.71	-5.06	-2.22	-13.53	-3.60
40	IC 117355 × 15/RES-4	10.69	10.26	-4.95	-13.59 **	-8.86	-17.55 **	-1.38	-7.63
41	IC 117328 × Pusa A 4	9.95	11.79	-6.78	-3.40	-7.62	-5.23	-8.27	6.18
42	IC 117328 × VRO 6	14.23	9.83	13.98 **	-17.56 **	6.62	-21.78 **	31.20 **	-11.47 *
43	IC 117328 × P. Kranti	10.05	11.59	-9.51	2.16	-21.05 **	-0.14	-7.29	4.35
44	IC 117328 × 15/RES-4	11.20	10.88	3.69	-1.72	-4.52	-3.75	3.32	-2.04
	Maximum	15.10	14.23	33.59	17.23	29.19	14.57	39.23	28.16
	Minimum	8.82	9.29	-30.59	-18.91	-30.76	-26.78	-18.69	-16.36

EC169430 × VRO 6 (17.23%) showed significant positive desired heterobeltiosis for average fruit weight while, other ten cross combinations recorded significant negative heterobeltiosis for the same trait. Standard heterosis ranged from -16.36% to 28.16% for this particular trait. Among cross combination, four crosses were showed significant positive standard heterosis in desirable direction with maximum in IC093655 × VRO 6 (28.16%).

Average fruit weight directly affects the total fruit yield per plant, so this character is very important for improvement. Among the hybrids evaluated, during both the seasons consistently, three promising cross combinations viz., EC169430 × VRO 6, EC169430 × 15/RES-4 and EC169435 × Parbhani Kranti recorded significant positive desired heterosis over mid parent as well as standard check for average fruit weight. Whereas, only one cross combinations EC169430 × VRO 6 were exhibited significant positive desired heterosis over better parent for the same trait during both the seasons consistently. Among cross combination, twelve crosses were exhibited significant positive standard heterosis in desirable direction during both the seasons consistently. Similar results were also reported by Mehta *et al.* (2007); Hosamani *et al.* (2008); Khanpara *et al.* (2009); Kumar and Sreeparvathy (2010); Kumar and Singh (2012); Obiadalla-ali *et al.* (2013); Rani (2015); More *et al.* (2017); and Chowdhury and Kumar (2019).

4.4.6 Number of fruits per plant

The read-through of data presented in the table 4.12 revealed that out of 44 crosses, 17 crosses, 11 crosses and 15 cross during first season, while 8 cross, 5 crosses and 1 cross during second season showed significant and positive heterosis over mid parent, better parent and standard parent, respectively.

During first season, relative heterosis ranged from -30.55 (IC093655 × 15/RES-4) to 174.02% (EC169408 × VRO 6). Among 44 crosses, seventeen cross combinations recorded significant positive heterosis over mid parent in desirable direction with maximum in EC169408 × VRO 6 (174.02%) followed by IC117355 × VRO 6 (158.83%) and EC169430 × VRO 6 (144.53%). While two cross combinations were showed undesirable significant negative relative heterosis with minimum in IC093655 × 15/RES-4 (-30.55%). With looking up to heterobeltiosis, out of all crosses, seventeen crosses exhibited significant heterosis which ranged from -39.68 (IC093655 × Pusa A 4) to

(134.49% (IC117355 × VRO 6). Among seventeen crosses, only eleven crosses showed significant positive desired heterosis over better parent for number of fruits per plant with maximum in IC117355 × VRO 6 (134.49%) followed by EC169408 × VRO 6 (120.00%) and EC169435 × P. Kranti (110.40%). Whereas, six cross combinations recorded significant negative heterobeltiosis for the same trait with minimum in IC093655 × Pusa A 4 (-39.68%). Among all cross combination, fifteen crosses showed desirable significant positive standard heterosis with maximum in EC169408 × VRO 6 (151.88%) followed by IC117355 × VRO 6 (136.18%) and EC169435 VRO 6 (116.55%).

During second season, twenty seven cross combinations showed significant relative heterosis which ranged from -24.31 (IC117245 × VRO 6) to 28.26% (EC169408 × Pusa A 4). Among twenty seven crosses only eight crosses recorded desirable significant positive heterosis over mid parent with maximum in EC169408 × Pusa A 4 (28.26%) followed by EC169435 × VRO 6 (17.33%) and EC169408 × VRO 6 (15.57%), while other nineteen crosses exhibited undesirable significant negative relative heterosis for same trait with minimum in IC117245 × VRO 6 (-24.31%). With looking up to heterobeltiosis, twenty eight crosses had noticed significant heterosis with ranged from -29.31 (IC117245 × VRO 6) to 23.16% (EC169408 × Pusa A 4). Among twenty eight crosses, only five of them showed significant positive heterosis over better parent in desirable direction with maximum in EC169408 × Pusa A 4 (23.16%) followed by EC169435 × VRO 6 (16.55%) and EC169430 × VRO 6 (12.58%). Standard heterosis for number of fruits per plant ranged from 9.41 to -30.60%. Among all cross combination, only EC169408 × Pusa A 4 (9.41%) was showed significant positive standard heterosis in desirable direction.

Number of fruits per plant is directly affecting the fruit yield per plant, so this character is very important for fruit yield. Over both the season, out of all crosses, six cross combinations viz., EC169430 × VRO 6, EC169435 × VRO 6, EC169408 × Pusa A4 and EC169408 × VRO 6 showed significant positive desired heterosis over both mid parent as well as better parent for number of fruits per plant. EC169408 × Pusa A4 also exhibited significant standard heterosis during both the season consistently. Heterosis for number of fruits per plant was also reported by Padma and Singh (1999); Mamta *et al.* (2002); Tripathy *et al.* (2004); Desai *et al.* (2007); Hosamani *et al.* (2008); Khanpara *et al.* (2009); Parmar *et al.* (2011); Obiadalla-ali *et al.* (2013); Solankey *et al.* (2013); Verma and Sood (2015); Singh *et al.* (2016); and More *et al.* (2017).

Table 4.12: Heterosis for number of fruit per plant

Characters		Number of fruits per plant							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	8.77	17.56	-30.23 **	3.61	-39.68 **	-4.81	-13.97	-7.06
2	IC 093655 × VRO 6	9.60	18.89	-13.02	12.57 **	-18.71	12.57 *	-5.79	0.00
3	IC 093655 × P. Kranti	11.42	17.89	35.23 *	-2.12	16.25	-5.29	12.07	-5.29
4	IC 093655 × 15/RES-4	8.04	15.67	-30.55 **	-14.80 **	-39.59 **	-18.97 **	-21.10	-17.06 **
5	EC 169430 × Pusa A 4	14.47	19.78	16.90	12.66 **	-0.14	7.89	41.97 **	4.71
6	EC 169430 × VRO 6	20.87	19.89	144.53 **	24.75 **	108.67 **	12.58 *	104.78 **	5.29
7	EC 169430 × P. Kranti	17.80	20.22	95.86 **	17.42 **	80.83 **	4.60	74.68 **	7.06
8	EC 169430 × 15/RES-4	14.72	16.89	29.78 **	-10.31 *	21.79	-12.12 *	44.42 **	-10.59 *
9	EC 169435 × Pusa A 4	16.40	17.33	30.76 **	-5.74	13.21	-6.02	60.94 **	-8.24
10	EC 169435 × VRO 6	22.07	19.56	101.25 **	17.33 **	89.14 **	16.55 **	116.55 **	3.53
11	EC 169435 × P. Kranti	17.53	18.89	127.71 **	15.25 **	110.40 **	6.92	72.06 **	0.00
12	EC 169435 × 15/RES-4	12.78	17.11	16.60	-11.24 **	5.79	-11.50 *	25.45	-9.42 *
13	EC 169506 × Pusa A 4	11.40	17.55	-6.29	-6.80	-21.31 *	-9.21 *	11.87	-7.08
14	EC 169506 × VRO 6	13.17	17.78	18.28	1.60	12.86	-3.60	29.21 *	-5.88
15	EC 169506 × P. Kranti	12.22	17.67	21.71	-0.94	19.10	-6.48	19.95	-6.48
16	EC 169506 × 15/RES-4	11.35	16.67	18.54	-9.63 *	-6.07	-13.28 **	11.38	-11.77 *
17	EC 169400 × Pusa A 4	9.60	16.89	-10.92	-6.19	-33.73 **	-7.89	-5.79	-10.61 *
18	EC 169400 × VRO 6	10.90	17.56	1.35	-2.16	-6.57	-9.19 *	6.97	-7.06
19	EC 169400 × P. Kranti	14.28	16.11	39.90 **	-13.70 **	34.79 **	-14.72 **	40.17 **	-14.72 **
20	EC 169400 × 15/RES-4	10.74	16.78	-8.88	-1.96	-19.31	-3.82	5.40	-11.19 *
21	EC 169408 × Pusa A 4	19.40	20.67	56.47 **	28.26 **	33.49 **	23.16 **	90.38 **	9.41 *
22	EC 169408 × VRO 6	25.67	19.78	174.02 **	15.57 **	120.00 **	11.94 *	151.88 **	4.69
23	EC 169408 × P. Kranti	17.48	19.00	77.80 **	-0.58	77.62 **	-1.72	71.57 **	0.58

24	EC 169408 × 15/RES-4	14.40	18.89	20.47 *	5.26	8.19	2.40	41.32 **	-0.02
25	IC 117123 × Pusa A 4	12.54	16.67	2.91	-4.16	-13.69	-13.79 **	23.09	-11.77 *
26	IC 117123 × VRO 6	10.73	16.56	-4.20	-5.99	-9.12	-10.23 *	5.33	-12.35 *
27	IC 117123 × P. Kranti	12.33	14.55	23.40 *	-19.16 **	20.17	-24.29 **	21.03	-22.96 **
28	IC 117123 × 15/RES-4	12.48	16.00	22.46	-8.86 *	-6.26	-9.43	22.44	-15.30 **
29	IC 117245 × Pusa A 4	10.32	17.22	-4.41	4.01	-28.97 **	-2.53	1.31	-8.84
30	IC 117245 × VRO 6	11.27	13.67	4.06	-24.31 **	-4.60	-29.31 **	10.57	-27.65 **
31	IC 117245 × P. Kranti	11.80	14.89	16.12	-20.94 **	11.36	-22.54 **	15.80	-21.18 **
32	IC 117245 × 15/RES-4	11.97	16.11	14.24	-6.76	11.98	-9.38	17.44	-14.72 **
33	IC 117351 × Pusa A 4	11.27	15.11	11.20	-2.49	9.78	-9.93	10.57	-19.99 **
34	IC 117351 × VRO 6	12.73	13.56	34.91 **	-21.29 **	7.82	-23.26 **	24.96	-28.23 **
35	IC 117351 × P. Kranti	12.73	15.45	30.13 *	-19.88 **	29.36 *	-20.10 **	24.96	-18.23 **
36	IC 117351 × 15/RES-4	8.82	15.67	-17.12	-13.49 **	-17.47	-15.06 **	-13.44	-17.06 **
37	IC 117355 × Pusa A 4	11.98	15.78	16.36	-3.40	13.09	-14.46 **	17.60	-16.48 **
38	IC 117355 × VRO 6	24.07	14.11	158.83 **	-11.50 *	134.49 **	-15.89 **	136.18 **	-25.29 **
39	IC 117355 × P. Kranti	14.57	15.66	73.56 **	-15.08 **	49.83 **	-18.52 **	43.02 **	-17.08 **
40	IC 117355 × 15/RES-4	11.20	15.00	9.11	-19.14 **	4.80	-22.40 **	9.91	-20.58 **
41	IC 117328 × Pusa A 4	8.48	15.78	-14.50	-5.96	-15.17	-18.40 **	-16.75	-16.48 **
42	IC 117328 × VRO 6	10.86	13.11	14.70	-21.86 **	2.45	-28.92 **	6.54	-30.60 **
43	IC 117328 × P. Kranti	10.87	15.44	-2.74	-14.20 **	-10.07	-19.65 **	6.64	-18.25 **
44	IC 117328 × 15/RES-4	7.89	14.22	-11.15	-19.74 **	-26.20 *	-19.99 **	-22.60	-24.70 **
	Maximum	25.67	20.67	174.02	28.26	134.49	23.16	151.88	9.41
	Minimum	7.89	13.11	-30.55	-24.31	-39.68	-29.31	-22.60	-30.60

4.4.7 Number of primary branches per plant

The perusal of data presented in the table 4.13 revealed that, among the 44 F_1 hybrids, 4 hybrid, 2 hybrid during summer season while, 2 and 2 hybrid during rainy season exhibited significant and positive heterosis over mid parent and better parent, respectively.

During summer season, relative heterosis, heterobeltiosis and standard heterosis for number of primary branches per plant ranged from 50.04 to -38.15%, 42.86 to -44.54% and 24.69 to -41.77%, respectively. A total of four crosses showed significant positive relative heterosis with maximum in EC169408 $\times$ VRO 6 (50.04%). Whereas, thirteen crosses revealed significant negative relative heterosis this exhibited undesirable for this trait. Highly significant heterobeltiosis in desired positive direction was observed in only two cross combinations viz., EC169408 $\times$ VRO 6 (42.86%) followed by EC169435 $\times$ Parbhani Kranti (36.86%). Whereas, fifteen crosses showed significant negative heterobeltiosis in undesired direction. Highly significant standard heterosis in desired positive direction was observed in cross EC169408 $\times$ VRO 6 (24.69%).

During rainy season, two crosses showed highly significant positive relative heterosis viz., EC169430 $\times$ 15/RES-4 (27.94%) and EC169408 $\times$ 15/RES-4 (27.83%). With looking up to heterobeltiosis, out of all cross combinations, two crosses recorded significant heterobeltiosis for number of primary branches per plant with maximum in EC169430 $\times$ 15/RES-4 (27.83%) and EC 169408 $\times$ 15/RES-4 (27.83%).

With looking up to standard heterosis, among cross combinations, two cross combination namely EC169430 $\times$ 15/RES-4 (35.27%) and EC169408 $\times$ 15/RES-4 (35.27%) exhibited significant positive heterosis over standard parent for this particular trait. Heterosis for number of primary branches per plant in desirable direction was also reported by Rewale *et al.* (2003a); Tripathi *et al.* (2004); Khanpara *et al.* (2009); Obiadalla-ali *et al.* (2013); and Singh *et al.* (2016).

Table 4.13: Heterosis for primary branches per plant

Characters		Number of primary branches per plant							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeliosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	2.50	2.11	-8.03	5.59	-8.20	5.50	-6.48	11.64
2	IC 093655 × VRO 6	1.83	1.78	-32.31 **	-8.48	-34.68 **	-15.64	-31.42 **	-5.82
3	IC 093655 × P. Kranti	2.20	2.00	-14.53	-2.92	-21.73 *	-5.37	-17.83	5.64
4	IC 093655 × 15/RES-4	2.22	2.00	-17.04	2.83	-17.45	0.00	-16.83	5.82
5	EC 169430 × Pusa A 4	2.67	2.11	-2.68	11.64	-4.99	5.50	-0.25	11.64
6	EC 169430 × VRO 6	2.97	2.11	22.36 *	1.77	17.68	-1.56	11.22	11.64
7	EC 169430 × P. Kranti	2.56	1.89	4.00	-5.50	-5.07	-10.43	-4.36	0.00
8	EC 169430 × 15/RES-4	2.33	2.56	-10.66	27.94 *	-14.32	27.83 *	-12.72	35.27 *
9	EC 169435 × Pusa A 4	3.00	2.11	11.18	5.50	10.16	5.50	12.22	11.64
10	EC 169435 × VRO 6	3.17	2.22	28.81 **	14.31	12.83	5.37	18.45	17.64
11	EC 169435 × P. Kranti	3.19	2.33	40.16 **	13.45	36.86 **	10.58	19.45	23.46
12	EC 169435 × 15/RES-4	2.65	2.33	1.93	20.07	-1.73	16.86	-1.00	23.46
13	EC 169506 × Pusa A 4	2.11	2.22	-21.37 *	14.31	-21.66	11.17	-21.07	17.64
14	EC 169506 × VRO 6	2.72	2.00	12.41	-2.68	-0.24	-5.21	1.62	5.82
15	EC 169506 × P. Kranti	1.83	2.11	-34.68 **	8.48	-34.68 **	0.00	-31.42 **	11.64
16	EC 169506 × 15/RES-4	2.00	2.11	-17.24	5.50	-20.00	5.32	-25.19 *	11.64
17	EC 169400 × Pusa A 4	2.33	2.01	-6.79	0.42	-12.72	0.33	-12.72	6.35
18	EC 169400 × VRO 6	2.75	1.89	14.50	-5.50	2.10	-10.43	2.87	0.00
19	EC 169400 × P. Kranti	2.58	2.11	-6.57	2.68	-7.96	0.00	-3.37	11.64
20	EC 169400 × 15/RES-4	1.89	2.00	-30.94 **	5.82	-32.66 **	0.00	-29.30 *	5.82
21	EC 169408 × Pusa A 4	2.78	2.22	0.72	17.74	-0.95	11.35	3.99	17.64
22	EC 169408 × VRO 6	3.33	2.11	50.04 **	2.59	42.86 **	0.00	24.69 *	11.64

23	EC 169408 × P. Kranti	3.08	2.11	12.12	5.50	9.86	0.00	15.34	11.64
24	EC 169408 × 15/RES-4	3.19	2.56	18.49	27.83 *	17.26	27.83 *	19.45	35.27 *
25	IC 117123 × Pusa A 4	2.31	2.11	-14.55	8.58	-14.86	5.68	-13.59	11.64
26	IC 117123 × VRO 6	2.67	2.00	0.00	-2.68	-2.08	-5.21	-0.25	5.82
27	IC 117123 × P. Kranti	2.31	2.00	-10.71	8.99	-17.81	5.82	-13.72	5.82
28	IC 117123 × 15/RES-4	2.00	2.00	-20.00	-0.08	-25.00 *	-0.17	-25.19 *	5.82
29	IC 117245 × Pusa A 4	2.11	2.11	-16.25	5.50	-22.11 *	5.32	-20.95	11.64
30	IC 117245 × VRO 6	1.64	2.11	-38.15 **	5.50	-39.11 **	0.00	-38.65 **	11.64
31	IC 117245 × P. Kranti	2.33	2.00	-8.20	2.83	-14.32	0.00	-12.72	5.82
32	IC 117245 × 15/RES-4	2.00	2.00	-24.48 *	5.82	-28.74 **	0.00	-25.19 *	5.82
33	IC 117351 × Pusa A 4	2.22	1.78	-16.63	-9.26	-20.78	-16.95	-16.83	-5.82
34	IC 117351 × VRO 6	2.20	1.89	-10.99	-8.27	-15.71	-10.58	-17.71	-0.18
35	IC 117351 × P. Kranti	2.45	2.00	-3.17	5.82	-9.16	5.82	-8.48	5.82
36	IC 117351 × 15/RES-4	2.22	2.00	-14.83	0.00	-18.48	0.00	-16.96	5.82
37	IC 117355 × Pusa A 4	1.67	2.11	-36.38 **	1.85	-38.68 **	-1.56	-37.53 **	11.64
38	IC 117355 × VRO 6	1.56	2.11	-38.10 **	8.48	-44.54 **	0.00	-41.77 **	11.64
39	IC 117355 × P. Kranti	2.23	2.00	-5.11	2.74	-5.65	-0.17	-16.71	5.82
40	IC 117355 × 15/RES-4	1.89	2.00	-27.07 **	2.83	-29.83 **	0.00	-29.30 *	5.82
41	IC 117328 × Pusa A 4	2.00	2.00	-23.50 *	-0.83	-25.87 *	-6.69	-25.31 *	5.82
42	IC 117328 × VRO 6	1.58	2.00	-35.98 **	-2.68	-41.86 **	-5.21	-40.77 **	5.82
43	IC 117328 × P. Kranti	1.89	2.22	-28.77 **	17.74	-32.66 **	11.35	-29.30 *	17.64
44	IC 117328 × 15/RES-4	1.86	2.00	-22.87 *	-0.08	-25.30 *	-0.17	-30.42 **	5.82
	maximum	3.33	2.56	50.04	27.94	42.84	27.83	24.69	35.27
	minimum	1.56	1.78	-38.15	-9.26	-44.54	-16.95	-41.77	-5.82

4.4.8 Stem diameter (mm)

Data presented in the table 4.14 revealed that during summer season, out of all crosses, only eight crosses showed significant relative heterosis for stem diameter. It ranged from -28.09 (IC117328 × Parbhani Kranti) to 42.24% (EC169408 × VRO 6). Among all cross heterotic combinations nine crosses showed negative significant heterotic value for stem diameter are in undesirable direction. Heterobeltiosis ranged from -32.06 (IC117328 × Parbhani Kranti) to 39.02% (EC169408 × VRO 6).

Among all crosses, four crosses recorded significant positive heterosis over better parent for stem diameter in desirable direction. However, twelve crosses were recorded significant negative heterobeltiosis for the same trait. Standard heterosis ranged from -31.87 (IC117328 × 15/RES 4) to 33.43% (EC169408 × VRO 6). Among all crosses, ten crosses recorded significant positive heterosis over standard parent for this trait however, eight crosses were recorded significant negative standard heterosis for the same trait.

During rainy season, fourteen crosses showed significant relative heterosis for stem diameter, which ranged from -16.76 (IC117123 × Prabhani Kranti) to (15.39%) (EC169430 × 15/RES-4). Out of 14 crosses, only 4 crosses showed significant positive heterosis for this trait while, ten cross combinations exhibited significant negative heterosis in undesirable direction. With looking up to heterobeltiosis, out of 44 cross combinations, it ranged from -16.89 (IC117123 × Prabhani Kranti) to 13.29% (EC169430 × 15/RES-4). Thirteen cross combinations were showed significant heterosis over better parent, among them only one cross EC169430 × 15/RES-4 (13.29%) showed significant positive heterosis over better parent for stem diameter in desirable direction while, other twelve crosses recorded significant negative heterobeltiosis for the same trait. Standard heterosis ranged from -22.97 (IC117123 × Prabhani Kranti) to 2.89% (EC169430 × 15/RES-4). Among all crosses, none of them recorded significant positive heterosis over standard parent for this trait however, twenty one crosses were recorded significant negative standard heterosis for the same trait. Out of all crosses, none of the cross combinations had exhibited consistent significant positive heterosis over better parent during both seasons.

Table 4.14: Heterosis for stem diameter (mm)

Characters		Stem diameter (mm)							
Sr. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	17.79	16.98	7.10	-4.54	0.91	-5.21	13.65	-13.91 **
2	IC 093655 × VRO 6	16.92	18.75	0.19	8.11	-8.14	2.57	8.05	-4.94
3	IC 093655 × P. Kranti	17.17	17.32	10.34	-9.30 *	2.34	-11.62 *	9.69	-12.15 **
4	IC 093655 × 15/RES-4	12.78	16.69	-20.60 **	-10.34 *	-25.12 **	-11.22 *	-18.37 *	-15.37 **
5	EC 169430 × Pusa A 4	19.80	18.48	16.02 **	2.51	5.43	1.11	26.46 **	-6.29
6	EC 169430 × VRO 6	17.20	19.19	10.19	6.51	1.94	3.17	9.86	-2.69
7	EC 169430 × P. Kranti	16.89	18.58	10.97	1.67	10.30	-1.19	7.88	-5.80
8	EC 169430 × 15/RES-4	14.58	20.29	-11.24	15.39 **	-15.53 *	13.29 *	-6.88	2.89
9	EC 169435 × Pusa A 4	19.80	18.35	15.21 **	2.82	5.43	2.44	26.46 **	-6.96
10	EC 169435 × VRO 6	16.49	19.51	8.56	13.98 **	7.40	6.75	5.32	-1.06
11	EC 169435 × P. Kranti	20.17	19.21	36.03 **	5.71	31.74 **	3.28	28.85 **	-2.59
12	EC 169435 × 15/RES-4	15.32	19.84	-5.39	10.07 *	-11.24	5.55	-2.15	0.63
13	EC 169506 × Pusa A 4	14.99	18.98	-11.58	3.76	-20.18 **	0.94	-4.26	-3.77
14	EC 169506 × VRO 6	15.80	19.19	3.22	13.33 **	1.35	7.15	0.94	-2.69
15	EC 169506 × P. Kranti	16.83	18.13	4.73	-4.25	0.28	-7.48	7.47	-8.05
16	EC 169506 × 15/RES-4	13.33	17.93	-15.67 *	0.03	-22.79 **	-3.58	-14.88 *	-9.06
17	EC 169400 × Pusa A 4	15.41	18.02	-6.98	-0.91	-17.96 **	-3.10	-1.60	-8.60
18	EC 169400 × VRO 6	14.95	18.37	-0.82	5.71	-1.15	-2.29	-4.49	-6.85
19	EC 169400 × P. Kranti	17.94	18.07	10.85	-3.67	6.93	-7.82	14.61 *	-8.38
20	EC 169400 × 15/RES-4	13.06	17.53	-19.43 **	-4.47	-23.48 **	-4.87	-16.59 *	-11.09 *
21	EC 169408 × Pusa A 4	19.52	17.32	18.37 **	-3.58	10.72	-5.22	24.70 **	-12.15 **
22	EC 169408 × VRO 6	20.89	18.86	42.24 **	9.13 *	39.02 **	1.38	33.43 **	-4.38
23	EC 169408 × P. Kranti	19.33	17.62	21.19 **	-8.21 *	15.22 *	-10.09 *	23.48 **	-10.63 *

24	EC 169408 × 15/RES-4	16.43	19.70	0.59	8.42	-3.75	6.89	4.92	-0.10
25	IC 117123 × Pusa A 4	15.79	16.99	-3.60	-6.81	-10.45	-9.65 *	0.85	-13.86 **
26	IC 117123 × VRO 6	18.18	16.53	6.89	-3.63	-1.30	-7.69	16.10 *	-16.16 **
27	IC 117123 × P. Kranti	13.80	15.19	-11.12	-16.76 **	-12.09	-16.89 **	-11.88	-22.97 **
28	IC 117123 × 15/RES-4	15.33	16.98	-2.38	-8.29	-10.16	-8.71	-2.07	-13.89 **
29	IC 117245 × Pusa A 4	16.49	18.28	3.13	0.82	-6.48	-1.74	5.32	-7.32
30	IC 117245 × VRO 6	16.41	16.20	-2.18	-7.94	-10.91	-13.81 **	4.79	-17.83 **
31	IC 117245 × P. Kranti	14.31	16.27	-8.50	-9.95 *	-8.79	-10.72 *	-8.58	-17.51 **
32	IC 117245 × 15/RES-4	11.31	18.07	-25.65 **	-3.93	-26.36 **	-6.58	-27.78 **	-8.37
33	IC 117351 × Pusa A 4	18.68	18.70	15.93 *	4.73	10.71	2.32	19.31 **	-5.17
34	IC 117351 × VRO 6	16.69	16.34	1.90	-6.62	-9.36	-12.13 *	6.62	-17.12 **
35	IC 117351 × P. Kranti	15.34	16.38	-0.43	-11.53 **	-2.23	-12.89 **	-2.00	-16.95 **
36	IC 117351 × 15/RES-4	12.23	18.32	-20.21 **	-1.63	-21.57 **	-5.27	-21.89 **	-7.08
37	IC 117355 × Pusa A 4	14.14	18.77	-12.87 *	6.20	-16.18 *	4.78	-9.67	-4.83
38	IC 117355 × VRO 6	18.56	16.08	21.04 **	-10.72 *	20.89 **	-12.02 *	18.54 *	-18.46 **
39	IC 117355 × P. Kranti	15.99	17.83	6.48	-3.13	1.91	-4.12	2.15	-9.57 *
40	IC 117355 × 15/RES-4	11.06	17.56	-26.73 **	-7.91	-26.88 **	-9.20	-29.36 **	-10.94 *
41	IC 117328 × Pusa A 4	15.41	17.41	-3.71	-3.88	-8.69	-7.38	-1.60	-11.70 *
42	IC 117328 × VRO 6	15.79	15.67	2.20	-12.12 **	1.28	-12.53 *	0.87	-20.55 **
43	IC 117328 × P. Kranti	11.73	17.55	-28.09 **	-1.20	-32.06 **	-3.96	-25.10 **	-10.99 *
44	IC 117328 × 15/RES-4	10.67	17.20	-27.46 **	-9.36 *	-29.19 **	-11.10 *	-31.87 **	-12.80 **
	Maximum	20.89	20.29	42.24	15.39	39.02	13.92	33.43	2.89
	Minimum	10.67	15.19	-28.09	-16.76	-32.06	-16.89	-31.87	-22.97

4.4.9 Inter-nodal length (cm)

Heterosis in negative direction is desirable for this trait as plant with shorter inter-nodal length accommodates more number of flowers and ultimately more number of fruits even in smaller stature. The read-through of data presented in the table 4.15 revealed that out of 44 F_1 hybrids, 8 hybrids, 16 hybrids and 5 hybrids during summer season, while 6 hybrids, 7 hybrids and 5 hybrids during rainy season showed significant negative heterosis over mid parent, better parent and standard parent, respectively.

During summer season, heterosis over mid parent, better parent and standard parent ranged from -23.41 (IC117328 $\times$ Parbhani Kranti) to 51.00% (EC169435 $\times$ Parbhani Kranti), -29.63 (IC117245 $\times$ Pusa A4) to 40.93% (EC169435 $\times$ Parbhani Kranti) and -16.32 (IC117355 $\times$ Pusa A4) to 57.69% (EC169435 $\times$ Pusa A4), respectively. Out of all crosses, eight cross combinations had recorded significant negative desired relative heterosis for inter-nodal length with maximum in IC117328 $\times$ Parbhani Kranti (-23.41%) followed by IC117355 $\times$ Pusa A4 (-19.77%) and IC117355 $\times$ VRO 6 (-18.30%). Whereas, fourteen cross combinations was exhibited significant positive heterosis over mid parent for the same trait with highest in EC169435 $\times$ Parbhani Kranti (51.00%). With looking heterosis over better parent, sixteen cross combinations were recorded significant negative desired heterobeltiosis with maximum in IC117245 $\times$ Pusa A4 (-29.63%) followed by EC169400 $\times$ Pusa A4 (-27.52%) and IC117328 $\times$ Parbhani Kranti (-25.21%). While, nine cross combinations showed significant positive undesirable heterosis over better parent for the same trait. However, among cross combinations, five combinations were recorded significant negative standard heterosis in desirable direction with maximum in IC117355 $\times$ Pusa A4 (-16.32%). During rainy season, heterosis over mid parent, better parent and standard parent ranged from IC117245 $\times$ VRO 6 (-19.81%) to EC169430 $\times$ VRO 6 (9.1%), IC117245 $\times$ VRO 6 (-20.53%) to EC169430 $\times$ VRO 6 (8.43%) and IC117245 $\times$ VRO 6 (-22.09%) to IC093655 $\times$ Pusa A4 (5.03%), respectively. Out of forty four crosses, six cross combinations exhibited significant relative heterosis in negative direction which is desirable. With looking up to heterosis over better parent, seven cross combinations was exhibited significant heterosis over better parent in negative direction for inter-nodal length with highest in IC117245 $\times$ VRO 6 (-20.53%). With looking up to standard heterosis, five cross combinations exhibited significant negative standard heterosis in desirable direction with maximum in IC117245 $\times$ VRO 6 (-22.09%).

Table 4.15: Heterosis for inter-nodal length (cm)

Characters		Internodal length (cm)							
Sr. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	5.64	6.96	-6.0	6.92	-16.73 **	3.32	13.63 *	5.03
2	IC 093655 × VRO 6	5.38	6.58	-7.80	2.20	-13.88 **	1.28	8.33	-0.70
3	IC 093655 × P. Kranti	5.27	6.91	9.49	6.64	-1.56	2.37	6.11	4.33
4	IC 093655 × 15/RES-4	5.49	5.59	11.03 *	-15.74 **	9.08	-17.44 **	10.54	-15.65 *
5	EC 169430 × Pusa A 4	6.98	6.08	14.92 **	-5.37	3.71	-6.37	40.70 **	-8.20
6	EC 169430 × VRO 6	6.22	6.82	32.39 **	9.1	21.33 **	8.43	25.32 **	2.92
7	EC 169430 × P. Kranti	7.01	6.52	40.88 **	-2.3	39.43 **	-4.86	41.30 **	-1.56
8	EC 169430 × 15/RES-4	5.6	6.23	2.57	-3.41	-1.58	-5.94	12.76 *	-5.89
9	EC 169435 × Pusa A 4	7.83	6.13	30.88 **	-3.03	16.24 **	-3.62	57.69 **	-7.50
10	EC 169435 × VRO 6	6.13	6.3	12.50 *	-3.87	11.85 *	-4.74	23.57 **	-4.88
11	EC 169435 × P. Kranti	6.94	6.63	51.00 **	1.45	40.93 **	-3.31	39.89 **	0.05
12	EC 169435 × 15/RES-4	6.05	5.99	12.85 *	-6.62	6.33	-9.56	21.83 **	-9.51
13	EC 169506 × Pusa A 4	5.75	6.1	-2.3	-5.06	-14.65 **	-6.06	15.78 *	-7.90
14	EC 169506 × VRO 6	5.35	5.87	-0.09	-8.95	-2.43	-11.24	7.79	-11.37
15	EC 169506 × P. Kranti	5.54	6.45	2.88	-2.54	2.21	-4.4	11.62	-2.57
16	EC 169506 × 15/RES-4	5.42	6.42	8.8	-2.13	-4.75	-3.12	9.13	-3.07
17	EC 169400 × Pusa A 4	4.88	6.57	-11.30 *	4.51	-27.52 **	3.3	-1.68	-0.86
18	EC 169400 × VRO 6	5.3	6.12	0.76	-6.56	-3.4	-7.41	6.72	-7.55
19	EC 169400 × P. Kranti	5.12	6.2	-3.25	-4.89	-4.36	-8.2	3.09	-6.44
20	EC 169400 × 15/RES-4	4.57	6.1	-10.97 *	-8.04	-15.62 **	-9.9	-7.86	-7.95
21	EC 169408 × Pusa A 4	6.45	6.95	5.85	5.14	-4.72	3.27	30.02 **	4.98
22	EC 169408 × VRO 6	6.57	6.05	34.79 **	-5.59	19.88 **	-8.47	32.44 **	-8.61

23	EC 169408 × P. Kranti	6.1	7.11	17.47 **	7.37	13.96 *	5.33	22.83 **	7.35
24	EC 169408 × 15/RES-4	6	6.59	18.98 **	1.02	14.73 *	-2.61	20.82 **	-0.50
25	IC 117123 × Pusa A 4	5.32	6.65	-9.80 *	0.5	-21.41 **	-1.29	7.25	0.35
26	IC 117123 × VRO 6	6.27	6.62	9.27	4.66	0.37	3.87	26.26 **	0
27	IC 117123 × P. Kranti	5.92	5.68	12.97 *	-13.32 *	9.29	-14.15 *	19.34 **	-14.19 *
28	IC 117123 × 15/RES-4	5.51	5.89	20.86 **	-9.17	13.60 *	-12.91 *	11.08	-11.02
29	IC 117245 × Pusa A 4	4.77	6.72	-13.67 **	3.79	-29.63 **	-0.25	-3.96	1.41
30	IC 117245 × VRO 6	5.13	5.16	-8.93	-19.81 **	-17.78 **	-20.53 **	3.43	-22.09 **
31	IC 117245 × P. Kranti	4.87	6.21	-5.31	-3.67	-6.76	-6.14	-1.81	-6.19
32	IC 117245 × 15/RES-4	4.67	5.84	-8.38	-10.48	-13.90 *	-10.85	-5.98	-11.88
33	IC 117351 × Pusa A 4	5.38	6.77	1.96	5.95	-0.8	4.26	8.33	2.21
34	IC 117351 × VRO 6	5.15	5.86	-2.09	-6.94	-17.57 **	-8.15	3.69	-11.58
35	IC 117351 × P. Kranti	5.53	6.53	9.48	-0.41	9.08	-1.36	11.35	-1.41
36	IC 117351 × 15/RES-4	5.71	5.51	14.34 **	-14.03 *	9.31	-15.78 *	15.11 *	-16.76 **
37	IC 117355 × Pusa A 4	4.15	6.52	-19.77 **	3.82	-20.54 **	3.76	-16.32 *	-1.51
38	IC 117355 × VRO 6	4.23	5.66	-18.30 **	-15.13 **	-22.02 **	-17.36 **	-14.84 *	-14.49 *
39	IC 117355 × P. Kranti	4.35	6.51	-6.89	1.48	-14.21 *	-1.66	-12.42 *	-1.71
40	IC 117355 × 15/RES-4	4.47	5.98	-8.68	-8.33	-11.07	-8.71	-9.87	-9.76
41	IC 117328 × Pusa A 4	4.27	6.44	-15.92 **	0.78	-16.71 **	-0.82	-13.97 *	-2.77
42	IC 117328 × VRO 6	4.59	5.86	-9.65	-10.81 *	-12.24 *	-14.54 *	-7.59	-11.58
43	IC 117328 × P. Kranti	4.25	6.53	-23.41 **	-0.51	-25.21 **	-1.51	-14.30 *	-1.46
44	IC 117328 × 15/RES-4	4.43	5.84	-2.03	-8.39	-7.13	-10.74	-10.81	-11.78
	Maximum	7.83	7.11	51.00	9.10	40.93	8.43	57.69	5.03
	Minimum	4.15	5.16	-23.41	-19.81	-23.63	-20.53	-16.32	-22.09

Tall plant with shorter internode plays an important role in increasing the yield as fruiting takes place at each node. Among the crosses, two, three and two most promising cross combinations were identified which exhibited consistent significant negative desired heterosis over mid parent, better parent and standard parent, respectively during both the seasons. This is in conformity with the findings of Mehta *et al.* (2007); Dabhi *et al.* (2009); Khanpara *et al.* (2009); Jethava *et al.* (2014); and Patel *et al.* (2015).

4.4.10 Plant height (cm)

Tall plant stature is desired over short one as it increases the number of nodes and in turn, increases number of flowers and fruits per plant. Data presented in the table 4.16 revealed that during summer season, heterosis over mid parent ranged from -25.34 (IC117328 × VRO 6) to 49.01% (IC117123 × Parbhani Kranti) Out of forty four cross combinations, fifteen crosses were recorded significant positive relative heterosis in desirable direction with maximum in IC117123 × Parbhani Kranti (49.01%) followed by EC169435 × Parbhani Kranti (47.47%) and EC169430 × Parbhani Kranti (42.93%). Whereas, six cross combinations showed significant negative relative heterosis in undesirable direction. With looking up to heterosis over better parent for plant.

Out of all crosses, only five hybrids recorded significant positive heterosis over better parent in desired direction for the same trait. Whereas, sixteen cross combinations showed significant negative heterobeltiosis in undesirable direction with minimum in IC117245 × Pusa A4 (-40.60%). Standard heterosis ranged from -27.86 to 43.04% for this particular trait. Among cross combination, fourteen crosses were showed significant positive standard heterosis in desirable direction with maximum in EC169408 × VRO 6 (43.04%), EC169430 × Parbhani Kranti (42.16%) and EC169408 × Pusa A4 (42.16%).

During rainy season evaluation, heterosis over mid parent ranged from -25.09 (IC117355 × VRO 6) to 4.25% (EC169430 × VRO 6). Out of all cross combinations, none of the F₁ hybrid was recorded significant positive relative heterosis. Whereas, nine cross combinations showed significant negative relative heterosis in undesirable direction with minimum in IC117355 × VRO 6 (-25.09%). However, heterosis over better parent for plant height ranged from -28.29 (IC117328 × VRO 6) to 3.06% (EC169430 × VRO 6). Among forty four cross combination, none of the cross combination had showed significant positive desired heterosis over better parent, while thirteen cross combinations

Table 4.16: Heterosis for plant height (cm)

Characters		Plant height (cm)							
S. No.	F ₁ hybrids	<i>Per se</i> performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	60.23	90.23	-10.75	-10.36	-26.93 **	-16.12	-1.61	-20.59 *
2	IC 093655 × VRO 6	56.1	89.66	-10.61	-6.85	-21.71 *	-10.78	-8.36	-21.09 *
3	IC 093655 × P. Kranti	64.13	88.36	6.16	-13.26	-11.34	-21.25 *	4.76	-22.24 **
4	IC 093655 × 15/RES-4	46.07	84.7	-25.13 **	-12.47	-32.10 **	-13.32	-24.75 *	-25.46 **
5	EC 169430 × Pusa A 4	83.77	107.18	24.95 **	-1.48	4.42	-8.46	36.83 **	-5.67
6	EC 169430 × VRO 6	77.3	96.53	37.95 **	4.25	21.58 *	3.06	26.27 *	-15.04
7	EC 169430 × P. Kranti	87.03	98.1	42.93 **	-4.71	30.75 **	-9.32	42.16 **	-13.66
8	EC 169430 × 15/RES-4	76.6	95.9	17.92 *	-0.77	-1	-3.65	25.12 *	-15.6
9	EC 169435 × Pusa A 4	81.5	103.36	22.77 *	-1.95	1.59	-11.72	33.13 **	-9.04
10	EC 169435 × VRO 6	86.3	98.02	22.76 **	-0.89	-0.51	-2.45	40.97 **	-13.73
11	EC 169435 × P. Kranti	84.83	90.59	47.47 **	-9.28	27.45 **	-16.26	38.57 **	-20.27 *
12	EC 169435 × 15/RES-4	73.55	94.08	10.95	-4.61	-4.93	-5.48	20.15	-17.20 *
13	EC 169506 × Pusa A 4	65.17	101.83	-3.77	-5.18	-18.77 *	-13.02	6.45	-10.38
14	EC 169506 × VRO 6	60.27	91.66	-13.47	-4.06	-30.52 **	-5.82	-1.56	-19.33 *
15	EC 169506 × P. Kranti	57.5	88.78	-8.87	-16.52 *	-20.51 *	-20.87 *	-6.08	-21.87 **
16	EC 169506 × 15/RES-4	51.37	85.78	-18.37	-10.21	-33.61 **	-13.82	-16.09	-24.51 **
17	EC 169400 × Pusa A 4	79.63	99.71	23.74 *	-4.4	-0.74	-14.84	30.08 **	-12.25
18	EC 169400 × VRO 6	72.43	89.33	2.05	-8.4	-16.50 *	-8.58	18.32	-21.38 **
19	EC 169400 × P. Kranti	62.83	88.09	0.63	-14.45	-13.13	-21.49 **	2.64	-22.47 **
20	EC 169400 × 15/RES-4	50.93	91.08	-16.3	-7.21	-24.93 *	-9.37	-16.8	-19.84 *
21	EC 169408 × Pusa A 4	87.03	96.16	27.71 **	-7.57	5.58	-10.62	42.16 **	-15.37
22	EC 169408 × VRO 6	87.57	89.76	29.51 **	-4.94	0.95	-7.77	43.04 **	-21.01 *
23	EC 169408 × P. Kranti	78.43	90.37	22.98 *	-13.9	8.43	-19.46 *	28.12 *	-20.47 *
24	EC 169408 × 15/RES-4	70.94	94.24	17.85	-0.58	4.56	-1.65	15.88	-17.06 *

25	IC 117123 × Pusa A 4	69.03	88.37	0.3	-13.91	-16.26	-17.86 *	12.76	-22.23 **
26	IC 117123 × VRO 6	65.43	85.52	5.37	-7.92	-8.68	-8.77	6.88	-24.73 **
27	IC 117123 × P. Kranti	83.07	79.57	49.01 **	-21.12 **	44.13 **	-21.42 *	35.69 **	-29.97 **
28	IC 117123 × 15/RES-4	65.33	81.13	12.32	-13.39	-3.7	-15.33	6.72	-28.59 **
29	IC 117245 × Pusa A 4	48.97	88.89	-25.20 **	-10.71	-40.60 **	-17.37 *	-20.02	-21.77 **
30	IC 117245 × VRO 6	56	75.6	-11.72	-20.31 *	-21.85 *	-22.64 *	-8.53	-33.46 **
31	IC 117245 × P. Kranti	66.2	83.57	20.17	-14.29	14.86	-17.47	8.13	-26.45 **
32	IC 117245 × 15/RES-4	47.72	85.53	-21.01 *	-14.51	-28.74 **	-14.88	-22.05 *	-24.72 **
33	IC 117351 × Pusa A 4	62.87	91.48	7.06	-5.77	-1.12	-8.97	2.69	-19.49 *
34	IC 117351 × VRO 6	75.3	82.78	25.35 *	-9.79	5.09	-10.03	23.00 *	-27.15 **
35	IC 117351 × P. Kranti	80.49	81.15	42.65 **	-18.43 *	39.66 **	-19.85 *	31.48 **	-28.58 **
36	IC 117351 × 15/RES-4	53.79	86.98	-9.99	-10.04	-19.68	-12.69	-12.14	-23.45 **
37	IC 117355 × Pusa A 4	60.3	93.6	3.85	-0.11	-5.16	-0.16	-1.5	-17.62 *
38	IC 117355 × VRO 6	63.73	78.15	5.84	-25.09 **	-4.26	-27.75 **	4.1	-31.22 **
39	IC 117355 × P. Kranti	56.5	83.95	6.48	-12.9	-1.97	-17.09	-7.71	-26.11 **
40	IC 117355 × 15/RES-4	45.67	80.33	-25.25 **	-18.58 *	-31.80 **	-19.36 *	-25.41 *	-29.30 **
41	IC 117328 × Pusa A 4	71.97	86.37	21.16 *	-9.75	13.19	-11.62	17.55	-23.99 **
42	IC 117328 × VRO 6	44.47	77.58	-25.34 *	-23.16 **	-33.20 **	-28.29 **	-27.37 *	-31.72 **
43	IC 117328 × P. Kranti	54	84.1	-17.7	-15.91 *	-30.21 **	-16.31	-11.79	-25.98 **
44	IC 117328 × 15/RES-4	44.17	79.61	-23.49 *	-16.70 *	-34.04 **	-20.08 *	-27.86 *	-29.93 **
	Maximum	87.57	107.18	49.01	4.25	44.13	3.06	43.03	-5.67
	Minimum	44.17	75.60	-25.34	-25.09	-40.60	-28.29	-27.86	-33.46

recorded undesirable significant negative heterobeltiosis for plant height with minimum in IC117328 × VRO 6 (-28.29%). Standard heterosis ranged from -33.43 to -5.67% for this particular trait. Among cross combination, none of the crosses were showed significant positive standard heterosis in desirable direction. Heterosis for plant height in okra was also reported by Desai *et al.* (2007); Khanpara *et al.* (2009); Kumar and Sreeparvathy (2010); Parmar *et al.* (2011); Obiadalla-ali *et al.* (2013); Bhatt *et al.* (2016); and Chowdhury and Kumar (2019).

4.4.11 Fruit yield per plant (g)

Perusal of data presented in the table 4.17 revealed that out of 44 F₁ hybrids, 19 hybrids, 14 hybrids and 22 hybrids during summer season, while 9 hybrid, 5 hybrids and 9 hybrids during rainy season showed significant and positive heterosis over mid parent, better parent and standard parent, respectively.

During summer season evaluation, out of all crosses, 23 cross combinations exhibited significant heterotic value over mid parent which ranged from -37.70 (IC093655 × 15/RES-4) to 223.44% (EC169430 × VRO 6) Among 23 significant cross combinations, 19 F₁ hybrids showed significant positive heterosis over mid parent in desirable direction for fruit yield per plant. Whereas, four cross recorded significant negative heterosis over mid parent. With look up to heterobeltiosis, out of all crosses, 22 cross combinations showed significant heterosis over better parent with ranged from -49.33 (IC093655 × 15/RES-4) to 168.03% (EC169430 × VRO 6). Among 22 significant cross combinations, fourteen crosses showed significant positive desired heterobeltiosis for fruit yield per plant. Whereas, other eight cross combinations exhibited significant negative heterobeltiosis with minimum heterotic value in IC093655 × 15/RES-4 (-49.33%).

Standard heterosis ranged from 204.29 to -22.80%. Among all cross combination, 22 crosses were exhibited significant positive standard heterosis in desirable direction with maximum heterotic value in EC169435 × VRO 6 (204.29%) and EC169408 × VRO 6 (188.85%).

During rainy season, heterosis over mid parent was found significant in 22 cross combinations with a range of -38.08 (IC117245 × VRO 6) to 46.74% (EC169430 × VRO 6).

Table 4.17: Heterosis for fruit yield per plant (g)

Characters		Fruit yield per plant (g)							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	121.65	230.90	-17.76	10.73	-29.53 **	10.66	11.12	9.93
2	IC 093655 × VRO 6	93.93	269.14	-31.04 **	26.14 **	-33.86 **	16.28 *	-14.21	28.13 **
3	IC 093655 × P. Kranti	132.86	222.36	47.21 **	4.04	19.82	-5.63	21.36	5.86
4	IC 093655 × 15/RES-4	85.63	190.89	-37.70 **	-15.72 *	-49.33 **	-20.68 **	-21.78	-9.12
5	EC 169430 × Pusa A 4	167.93	278.18	13.80	30.52 **	1.93	20.43 *	53.39 **	32.44 **
6	EC 169430 × VRO 6	283.89	265.98	223.44 **	46.74 **	168.03 **	38.65 **	159.31 **	26.63 **
7	EC 169430 × P. Kranti	246.70	256.05	127.47 **	18.91 *	122.23 **	6.41	125.34 **	21.90 *
8	EC 169430 × 15/RES-4	182.35	218.41	53.27 **	3.50	47.96 **	2.24	66.56 **	3.98
9	EC 169435 × Pusa A 4	203.52	222.60	41.34 **	1.32	23.54 *	-3.63	85.90 **	5.97
10	EC 169435 × VRO 6	333.14	262.02	146.04 **	24.48 **	137.28 **	16.10 *	204.29 **	24.74 **
11	EC 169435 × P. Kranti	226.66	254.37	150.96 **	33.23 **	104.18 **	32.60 **	107.03 **	21.10 *
12	EC 169435 × 15/RES-4	143.20	215.90	29.83 *	-4.94	24.84	-10.28	30.80	2.79
13	EC 169506 × Pusa A 4	113.96	220.77	-15.78	-6.38	-30.83 **	-8.26	4.09	5.11
14	EC 169506 × VRO 6	148.16	230.92	12.40	6.39	5.53	2.32	35.33 *	9.94
15	EC 169506 × P. Kranti	127.04	239.54	5.31	11.18	-2.57	1.66	16.04	14.04
16	EC 169506 × 15/RES-4	114.03	202.04	23.72	-0.34	-0.59	-5.42	4.16	-3.81
17	EC 169400 × Pusa A 4	108.75	210.78	-7.20	-0.30	-33.99 **	-8.75	-0.66	0.35
18	EC 169400 × VRO 6	136.16	217.28	10.57	-6.81	-3.02	-9.71	24.37	3.45
19	EC 169400 × P. Kranti	157.86	185.15	34.85 **	-16.60 *	28.09 *	-21.42 **	44.19 **	-11.85
20	EC 169400 × 15/RES-4	94.53	179.03	-36.85 **	-12.16	-44.07 **	-15.68	-13.66	-14.77
21	EC 169408 × Pusa A 4	248.21	257.51	63.82 **	27.50 **	43.79 **	23.41 **	126.71 **	22.60 *
22	EC 169408 × VRO 6	316.23	253.43	201.13 **	21.40 **	125.24 **	12.29	188.85 **	20.65 *
23	EC 169408 × P. Kranti	234.21	251.43	116.08 **	5.58	111.22 **	4.48	113.93 **	19.70 *
24	EC 169408 × 15/RES-4	184.07	244.31	25.97 *	16.14 *	8.92	15.06	68.13 **	16.31

25	IC 117123 × Pusa A 4	144.90	209.39	4.05	-6.79	-16.06	-12.99	32.35 *	-0.31
26	IC 117123 × VRO 6	123.25	179.09	-7.07	-18.57 *	-13.22	-22.62 **	12.57	-14.74
27	IC 117123 × P. Kranti	182.28	175.65	63.47 **	-13.60	39.79 **	-16.87	66.50 **	-16.38
28	IC 117123 × 15/RES-4	145.63	181.84	22.06	-10.02	-13.83	-14.36	33.02 *	-13.43
29	IC 117245 × Pusa A 4	122.96	200.21	1.51	-0.02	-28.77 **	-4.05	12.31	-4.68
30	IC 117245 × VRO 6	150.77	146.15	21.63	-38.08 **	6.16	-39.26 **	37.71 *	-30.42 **
31	IC 117245 × P. Kranti	117.60	154.15	8.96	-26.54 **	-4.58	-27.04 **	7.42	-26.61 **
32	IC 117245 × 15/RES-4	126.41	149.66	-1.26	-24.49 **	-3.05	-25.58 **	15.47	-28.75 **
33	IC 117351 × Pusa A 4	143.35	161.12	21.32	-11.95	9.94	-17.50	30.94 *	-23.29 **
34	IC 117351 × VRO 6	145.03	136.95	37.05 **	-35.29 **	2.12	-40.83 **	32.47 *	-34.80 **
35	IC 117351 × P. Kranti	168.37	167.95	69.63 **	-25.68 **	59.00 **	-30.21 **	53.79 **	-20.04 *
36	IC 117351 × 15/RES-4	92.51	152.09	-25.66 *	-25.72 **	-26.38	-27.02 **	-15.50	-27.59 **
37	IC 117355 × Pusa A 4	142.98	186.61	24.79	-1.55	16.02	-10.46	30.60	-11.16
38	IC 117355 × VRO 6	316.22	143.97	161.98 **	-25.27 **	142.51 **	-26.28 **	188.84 **	-31.46 **
39	IC 117355 × P. Kranti	136.63	168.41	68.42 **	-16.45 *	47.51 *	-20.29 *	24.80	-19.82 *
40	IC 117355 × 15/RES-4	119.83	153.72	3.50	-30.40 **	-4.64	-36.12 **	9.46	-26.82 **
41	IC 117328 × Pusa A 4	84.52	186.52	-20.20	-9.31	-20.21	-22.49 **	-22.80	-11.20
42	IC 117328 × VRO 6	154.32	128.76	31.76 *	-35.36 **	25.22	-38.22 **	40.96 **	-38.70 **
43	IC 117328 × P. Kranti	109.05	179.73	-11.02	-12.09	-16.37	-15.87	-0.40	-14.43
44	IC 117328 × 15/RES-4	88.50	154.67	-9.36	-21.27 **	-29.57 *	-23.09 *	-19.16	-26.36 **
	Maximum	333.14	278.18	223.44	46.74	168.03	38.65	204.29	32.44
	Minimum	84.52	128.76	-37.70	-38.08	-49.33	-40.83	-22.80	-38.70

Among twenty two significant cross combinations, nine crosses exhibited significant positive desirable with maximum heterotic value in EC169430 × VRO 6 (46.74%) followed by EC169435 × Parbhani Kranti (33.23%). However, other thirteen crosses had significant negative heterosis for same character. With looking up to heterobeltiosis among cross combinations, twenty one cross combinations showed significant heterosis over better parent which ranged from -40.83 (IC117351 × VRO 6) to 38.65 (EC169430 × VRO 6). Among twenty significant crosses, significant positive heterobeltiosis was observed in six cross combinations. Whereas, other fifteen crosses had recorded significant negative heterobeltiosis for the same trait. Standard heterosis ranged from 32.44 to -38.70%. Among cross combination, 9 crosses were exhibited significant positive standard heterosis in desirable direction with maximum in EC169430 × Pusa A4 (32.44%) and IC093655 × VRO 6 (28.13%). Whereas, other twelve crosses had recorded significant negative standard heterosis for the same trait.

Fruit yield per plant is an important trait and should be given prime importance in okra breeding for hybrid development. Among the entire cross combinations, five promising hybrids identified with respect to fruit yield per plant were EC169430 × VRO 6, EC169435 × VRO 6, EC169435 × Parbhani Kranti, EC169408 × Pusa A4 and EC169408 × VRO 6 exhibited significant positive desired relative heterosis, heterobeltiosis and standard heterosis consistently over both the seasons. Significant positive heterosis for fruit yield per plant has been reported by many researchers, some of them are Chauhan and Singh (2002); Bhalekar *et al.* (2004); Desai *et al.* (2007); Jindal *et al.* (2010); Parmar *et al.* (2011); Solankey and Singh (2011); Verma and Sood (2015); Singh *et al.* (2016); Nimbalkar *et al.* (2017); and Chowdhury and Singh (2019).

4.4.12 Total yield (q/ha)

Perusal of data presented in the table 4.18 revealed that out of 44 F₁ hybrids, 17 hybrids, 13 hybrids and 22 hybrids during summer season, while 7 hybrids, 6 hybrids and 9 hybrids during rainy season showed significant and positive heterosis over mid parent, better parent and standard parent, respectively.

During summer season evaluation, out of all crosses, 23 cross combinations exhibited significant heterotic value over mid parent which ranged from -37.70 (IC093655 × 15/RES-4) to 223.44% (EC169430 × VRO 6). Among 23 significant cross

Table 4.18: Heterosis for total yield q/ha

Characters		Total yield q/ha.							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	81.10	128.27	-17.76	10.72	-29.52 **	10.65	11.12	9.92
2	IC 093655 × VRO 6	62.62	149.52	-31.04 **	26.14 **	-33.86 **	16.28 *	-14.20	28.13 **
3	IC 093655 × P. Kranti	88.57	123.53	47.20 **	4.04	19.82	-5.63	21.36	5.86
4	IC 093655 × 15/RES-4	57.09	106.05	-37.70 **	-15.72 *	-49.33 **	-20.68 **	-21.78	-9.12
5	EC 169430 × Pusa A 4	111.95	154.54	13.79	30.52 **	1.93	20.43 *	53.38 **	32.44 **
6	EC 169430 × VRO 6	189.26	147.77	223.44 **	46.74 **	168.04 **	38.65 **	159.31 **	26.63 **
7	EC 169430 × P. Kranti	164.47	142.25	127.47 **	18.91 *	122.23 **	6.41	125.34 **	21.90 *
8	EC 169430 × 15/RES-4	121.56	121.34	53.27 **	3.50	47.97 **	2.24	66.56 **	3.98
9	EC 169435 × Pusa A 4	135.68	123.66	41.34 **	1.32	23.53 *	-3.63	85.89 **	5.97
10	EC 169435 × VRO 6	222.09	145.57	146.04 **	24.49 **	137.28 **	16.10 *	204.29 **	24.74 **
11	EC 169435 × P. Kranti	151.10	141.32	150.95 **	33.23 **	104.18 **	32.60 **	107.03 **	21.10 *
12	EC 169435 × 15/RES-4	95.47	119.95	29.83 *	-4.94	24.84	-10.28	30.80	2.79
13	EC 169506 × Pusa A 4	75.97	122.65	-15.79	-6.38	-30.83 **	-8.25	4.08	5.11
14	EC 169506 × VRO 6	98.78	128.29	12.40	6.39	5.53	2.32	35.34 *	9.93
15	EC 169506 × P. Kranti	84.69	133.08	5.31	11.18	-2.57	1.66	16.04	14.04
16	EC 169506 × 15/RES-4	76.02	112.24	23.72	-0.34	-0.59	-5.42	4.16	-3.81
17	EC 169400 × Pusa A 4	72.50	117.10	-7.20	-0.30	-33.99 **	-8.75	-0.66	0.35
18	EC 169400 × VRO 6	90.78	120.71	10.57	-6.81	-3.02	-9.71	24.37	3.44
19	EC 169400 × P. Kranti	105.24	102.86	34.85 **	-16.61 *	28.10 *	-21.42 **	44.19 **	-11.86
20	EC 169400 × 15/RES-4	63.01	99.46	-36.86 **	-12.16	-44.07 **	-15.69	-13.66	-14.77
21	EC 169408 × Pusa A 4	165.47	143.06	63.82 **	27.50 **	43.79 **	23.41 **	126.71 **	22.60 *
22	EC 169408 × VRO 6	210.82	140.79	201.13 **	21.40 **	125.24 **	12.29	188.85 **	20.65 *
23	EC 169408 × P. Kranti	156.14	139.68	116.08 **	5.58	111.22 **	4.48	113.93 **	19.70 *

24	EC 169408 × 15/RES-4	122.71	135.73	25.97 *	16.14 *	8.92	15.06	68.13 **	16.31
25	IC 117123 × Pusa A 4	96.60	116.33	4.05	-6.79	-16.06	-12.99	32.35 *	-0.31
26	IC 117123 × VRO 6	82.16	99.49	-7.07	-18.57 *	-13.22	-22.62 **	12.57	-14.74
27	IC 117123 × P. Kranti	121.52	97.58	63.47 **	-13.60	39.79 **	-16.87	66.50 **	-16.38
28	IC 117123 × 15/RES-4	97.09	101.02	22.06	-10.02	-13.83	-14.36	33.02 *	-13.43
29	IC 117245 × Pusa A 4	81.97	111.23	1.51	-0.02	-28.77 **	-4.05	12.31	-4.68
30	IC 117245 × VRO 6	100.51	81.20	21.63	-38.08 **	6.16	-39.26 **	37.71 *	-30.42 **
31	IC 117245 × P. Kranti	78.40	85.64	8.95	-26.54 **	-4.58	-27.05 **	7.41	-26.61 **
32	IC 117245 × 15/RES-4	84.28	83.14	-1.26	-24.49 **	-3.05	-25.58 **	15.47	-28.75 **
33	IC 117351 × Pusa A 4	95.57	89.51	21.32	-11.95	9.94	-17.50	30.94 *	-23.30 **
34	IC 117351 × VRO 6	96.68	76.08	37.05 **	-35.29 **	2.12	-40.83 **	32.47 *	-34.80 **
35	IC 117351 × P. Kranti	112.25	93.30	69.63 **	-25.68 **	59.00 **	-30.21 **	53.79 **	-20.04 *
36	IC 117351 × 15/RES-4	61.68	84.50	-25.66 *	-25.72 **	-26.38	-27.02 **	-15.50	-27.59 **
37	IC 117355 × Pusa A 4	95.32	103.67	24.80	-1.54	16.03	-10.45	30.60	-11.16
38	IC 117355 × VRO 6	210.81	79.99	161.98 **	-25.26 **	142.51 **	-26.27 **	188.84 **	-31.46 **
39	IC 117355 × P. Kranti	91.09	93.56	68.41 **	-16.45 *	47.51 *	-20.30 *	24.80	-19.82 *
40	IC 117355 × 15/RES-4	79.89	85.40	3.51	-30.40 **	-4.63	-36.12 **	9.46	-26.82 **
41	IC 117328 × Pusa A 4	56.34	103.62	-20.20	-9.31	-20.20	-22.49 **	-22.80	-11.20
42	IC 117328 × VRO 6	102.88	71.53	31.76 *	-35.37 **	25.22	-38.22 **	40.96 **	-38.70 **
43	IC 117328 × P. Kranti	72.70	99.85	-11.02	-12.09	-16.37	-15.87	-0.40	-14.43
44	IC 117328 × 15/RES-4	59.00	85.93	-9.37	-21.27 **	-29.57 *	-23.09 *	-19.16	-26.37 **
	Maximum	222.09	154.54	223.44	46.74	168.03	38.65	204.29	32.44
	Minimum	56.34	71.53	-37.74	-38.08	-49.33	-40.83	-22.80	-38.70

combinations, 19 F₁ hybrids showed significant positive heterosis over mid parent in desirable direction for total yield. Whereas, four cross recorded significant negative heterosis over mid parent.

With look up to heterobeltiosis, out of all crosses, 22 cross combinations showed significant heterosis over better parent with ranged from -49.33 (IC093655 × 15/RES-4) to 168.03% (EC169430 × VRO 6). Among 22 significant cross combinations, fourteen crosses showed significant positive desired heterobeltiosis for total yield. Whereas, other eight cross combinations exhibited significant negative heterobeltiosis with minimum heterotic value in IC093655 × 15/RES-4 (-49.33%).

Standard heterosis ranged from 204.29 to -22.80%. Among all cross combination, 22 crosses were exhibited significant positive standard heterosis in desirable direction with maximum heterotic value in EC169435 × VRO 6 (204.29%) and EC169408 × VRO 6 (188.85%).

During rainy season, heterosis over mid parent was found significant in 22 cross combinations with a range of -38.08 (IC117245 × VRO 6) to 46.74% (EC169430 × VRO 6). Among twenty two significant cross combinations, nine crosses exhibited significant positive desirable with maximum heterotic value in EC169430 × VRO 6 (46.74%) followed by EC169435 × Parbhani Kranti (33.23%). However, other thirteen crosses had significant negative heterosis for same character.

With looking up to heterobeltiosis among cross combinations, twenty one cross combinations showed significant heterosis over better parent which ranged from -40.83 (IC117351 × VRO 6) to 38.65% (EC169430 × VRO 6). Among twenty one significant crosses, significant positive heterobeltiosis was observed in six cross combinations. Whereas, other fifteen crosses had recorded significant negative heterobeltiosis for the same trait.

Standard heterosis ranged from 32.44 to -38.70%. Among cross combination, 9 crosses were exhibited significant positive standard heterosis in desirable direction with maximum in EC169430 × Pusa A4 (32.44%) and IC093655 × VRO 6 (28.13%). Whereas, other twelve crosses had recorded significant negative standard heterosis for the same

trait. Similar results were reported by Medagam *et al.* (2012); Obiadalla-ali *et al.* (2013); and Nagesh *et al.* (2014)

4.4.13 Number of seeds per fruit

The perusal of data presented in the table 4.19 revealed that 13, 5 and 2 crosses during summer season and 13, 7 and 4 crosses during rainy season had significant and positive heterosis over mid parent, better parent and standard parent, respectively. During summer season evaluation, out of all cross combinations, relative heterosis ranged from -26.37 (IC117245 × 15/RES-4) to 34.25% (EC169435 × Parbhani Kranti). A total of thirteen crosses exhibited significant positive heterosis over mid parent. EC169435 × Parbhani Kranti showed maximum heterosis over mid parent with the heterotic value of 34.25% followed by EC169430 × VRO 6 (31.85%) and EC169400 × Pusa A4 (23.75%). Minimum relative heterosis was recorded in IC117245 × 15/RES-4 (-26.37%). Twenty two crosses recorded significant heterobeltiosis for number of seeds per fruit, which ranged from IC117245 × 15/RES-4 (-30.34%) to EC169435 × Parbhani Kranti (30.13%).

Among twenty two crosses, five crosses exhibited significant heterobeltiosis in positive direction for number of seeds per fruit out of which EC169435 (30.13%) revealed maximum heterosis, while other seventeen crosses displayed significant negative and undesired heterobeltiosis for the same trait. Among cross combination, only two crosses namely EC169430 × VRO 6 (12.06%) and IC117245 × Parbhani Kranti (8.80%) were recorded significant positive standard heterosis in desirable direction, while twenty one cross combinations exhibited significant negative standard heterosis in undesirable direction with minimum in IC117245 × 15/RES-4 (-27.97%).

During rainy season, heterosis over mid-parent value, better parent value ranged from 54.30 (EC169430 × VRO 6) to -28.43 (IC117245 × 15/RES-4) and 47.52 (EC169435 × Parbhani Kranti) to -32.69% (IC117245 × 15/RES-4), respectively. Out of all crosses, significant positive relative heterosis in desired direction for number of seeds per fruit were showed from 13 crosses with maximum in EC169430 × VRO 6 (54.30%) followed by EC169435 × Parbhani Kranti (50.71%). Whereas, IC117245 × 15/RES-4 (-28.43%) and IC117123 × VRO 6 (-25.72%) were exhibited significant negative heterosis over mid parent for the same trait. Seven cross combinations exhibited significant positive heterobeltiosis for number of seeds per fruit. Whereas, twenty five cross combinations

Table 4.19: Heterosis for number of seeds per fruit

Characters		Number of seeds per fruit							
S. No.	F ₁ hybrids	Per se performance		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1	IC 093655 × Pusa A 4	52.46	56.13	-10.73 **	-10.96 **	-14.03 **	-15.31 **	-12.69 **	-5.53
2	IC 093655 × VRO 6	56.29	60.42	-0.80	-3.86	-9.39 *	-10.04 **	-6.32	1.69
3	IC 093655 × P. Kranti	53.56	59.35	11.08 *	25.39 **	4.19	13.59 **	-10.87 *	-0.11
4	IC 093655 × 15/RES-4	46.73	41.72	-14.20 **	-27.17 **	-20.46 **	-32.09 **	-22.24 **	-29.78 **
5	EC 169430 × Pusa A 4	63.11	67.34	4.63	17.41 **	1.59	15.05 **	5.03	13.34 **
6	EC 169430 × VRO 6	67.34	74.59	31.85 **	54.30 **	17.90 **	37.45 **	12.06 **	25.54 **
7	EC 169430 × P. Kranti	61.36	67.38	15.00 **	27.46 **	4.45	9.67 *	2.12	13.40 **
8	EC 169430 × 15/RES-4	50.16	53.43	-13.02 **	-0.55	-17.80 **	-10.66 **	-16.52 **	-10.07 *
9	EC 169435 × Pusa A 4	62.43	60.36	4.44	4.07	2.29	0.91	3.89	1.58
10	EC 169435 × VRO 6	61.52	59.52	6.50	8.17 *	-0.98	1.68	2.37	0.17
11	EC 169435 × P. Kranti	62.43	65.34	34.25 **	50.71 **	30.13 **	47.52 **	3.89	9.96 *
12	EC 169435 × 15/RES-4	62.26	59.62	10.14 *	9.32 *	5.98	-2.95	3.61	0.35
13	EC 169506 × Pusa A 4	57.41	53.34	-2.09	-9.30 *	-2.28	-13.18 **	-4.47	-10.23 *
14	EC 169506 × VRO 6	53.38	54.41	-6.69	-2.25	-12.52 **	-9.03 *	-11.16 *	-8.43 *
15	EC 169506 × P. Kranti	64.26	56.56	13.19 **	2.12	3.43	-3.37	6.93	-4.80
16	EC 169506 × 15/RES-4	49.66	47.32	-0.02	5.09	-8.57	-0.69	-17.36 **	-20.35 **
17	EC 169400 × Pusa A 4	64.07	56.25	23.75 **	14.09 **	9.49 *	0.11	6.62	-5.34
18	EC 169400 × VRO 6	59.32	59.32	5.78	5.05	0.97	-3.43	-1.29	-0.16
19	EC 169400 × P. Kranti	59.12	55.71	5.16	-0.57	-3.13	-6.85	-1.62	-6.23
20	EC 169400 × 15/RES-4	44.41	42.67	-20.90 **	-23.58 **	-28.51 **	-27.11 **	-26.09 **	-28.19 **
21	EC 169408 × Pusa A 4	56.55	62.35	-4.68	-0.10	-8.98 *	-5.93	-5.90	4.93
22	EC 169408 × VRO 6	54.19	58.42	10.11 *	24.40 **	1.48	13.42 **	-9.82 *	-1.67
23	EC 169408 × P. Kranti	54.51	54.37	-1.03	-4.35	-7.22	-11.50 **	-9.29 *	-8.50 *
24	EC 169408 × 15/RES-4	51.58	49.66	-7.22	-12.06 **	-15.47 **	-16.97 **	-14.16 **	-16.42 **

25	IC 117123 × Pusa A 4	59.48	49.41	3.20	-22.62 **	1.24	-25.45 **	-1.02	-16.84 **
26	IC 117123 × VRO 6	48.53	47.16	-13.64 **	-25.72 **	-20.47 **	-29.78 **	-19.23 **	-20.63 **
27	IC 117123 × P. Kranti	50.31	47.34	-10.77 **	-9.92 *	-19.01 **	-19.13 **	-16.27 **	-20.33 **
28	IC 117123 × 15/RES-4	46.36	52.98	-2.60	10.89 *	-7.59	-0.29	-22.84 **	-10.83 **
29	IC 117245 × Pusa A 4	48.40	60.42	-4.68	11.17 **	-14.36 **	-8.85 *	-19.46 **	1.68
30	IC 117245 × VRO 6	61.42	61.43	11.56 **	-4.46	4.56	-8.53 *	2.22	3.39
31	IC 117245 × P. Kranti	65.38	54.20	17.09 **	1.91	7.13	-9.38 *	8.80 *	-8.78 *
32	IC 117245 × 15/RES-4	43.28	39.40	-26.37 **	-28.43 **	-30.34 **	-32.69 **	-27.97 **	-33.69 **
33	IC 117351 × Pusa A 4	63.61	49.46	6.69	-12.30 **	2.39	-15.50 **	5.86	-16.76 **
34	IC 117351 × VRO 6	58.19	56.51	20.74 **	3.14	13.29 **	-15.86 **	-3.16	-4.89
35	IC 117351 × P. Kranti	58.19	56.60	6.39	4.81	-0.95	-7.87 *	-3.16	-4.75
36	IC 117351 × 15/RES-4	50.78	53.27	-12.80 **	-4.34	-16.79 **	-10.93 **	-15.49 **	-10.34 *
37	IC 117355 × Pusa A 4	47.66	57.46	-19.31 **	0.73	-21.90 **	-3.93	-20.68 **	-3.30
38	IC 117355 × VRO 6	59.51	58.57	8.10 *	13.92 **	-4.21	0.06	-0.97	-1.43
39	IC 117355 × P. Kranti	56.55	55.65	18.22 **	25.08 **	11.66 *	19.51 **	-5.89	-6.35
40	IC 117355 × 15/RES-4	47.53	45.34	-16.74 **	-19.75 **	-19.09 **	-26.20 **	-20.90 **	-23.69 **
41	IC 117328 × Pusa A 4	54.15	56.65	-6.52	-2.07	-7.82	-7.78 *	-9.88 *	-4.65
42	IC 117328 × VRO 6	54.18	52.51	-0.59	0.88	-11.22 **	-12.21 **	-9.84 *	-11.63 **
43	IC 117328 × P. Kranti	58.36	50.65	0.25	-4.60	-6.06	-13.47 **	-2.87	-14.75 **
44	IC 117328 × 15/RES-4	43.60	40.87	-13.21 **	-13.03 **	-21.35 **	-20.74 **	-27.44 **	-31.21 **
	Maximum	67.34	74.59	34.25	54.30	30.13	47.52	12.06	25.54
	Minimum	43.28	39.40	-26.37	-28.43	-30.34	-32.69	-27.97	-33.69

were showed significant negative heterobeltiosis for the same trait. With looking up to standard heterosis, among cross combination, four crosses were recorded significant positive standard heterosis in desirable direction with maximum in EC169430 $\times$ VRO 6 (25.54%), whereas twenty crosses exhibited significant negative heterosis over standard parent with minimum in IC117245 $\times$ 15/RES-4 (-33.69%).

Three and one most promising cross combinations were identified which showed consistent significant positive heterosis over better parent and standard parent respectively during both years. Similar findings for number of seeds per fruit were reported by Sriram *et al.* (2007); and Jethava *et al.* (2014).

4.5 Estimation of combining ability and gene action

4.5.1 Estimates of combining ability effects

With the advancement in biometrical genetics, several techniques are now available which permit quantitative genetic analysis and selection of promising parents and crosses (line $\times$ tester) for further exploitation. The parents who produce good progenies upon crossing are of immense value to the plant breeder. In a crop improvement programme, success depends upon the isolation of valuable cross combinations as determined in the form of parents with high combining ability. The emphasis is on the importance of testing the combining ability of parents because many times the high yielding parents may not combine well to give good segregates.

Combining ability analysis is a powerful tool to identify the lines having good potential to transmit the desirable traits to their off-springs and also helps in sorting out promising crosses for fruit yield and its attributes. At the same time, it also elucidates the nature of gene action (additive and non-additive) involved in the inheritance of characters. The concept of general and specific combining ability as a measure of gene effects was proposed by Sprague and Tatum, 1942. The resulting total variance is partitioned into the variance due to general combining ability and specific combining ability. This helps the breeders in knowing the relative portion of additive and non-additive genetic variance involved in the inheritance of various characters as well as deciding the appropriate breeding methods for effective utilization of available genetic variation. The general combining ability is attributed to additive genetic effects and is fixable in nature. On the

other hand, specific combining ability is attributable to non-additive gene action and may be due to dominance, additive $\times$ dominance and dominance $\times$ dominance or of higher order interaction and is non fixable.

Based on the combining ability effects the crosses were classified as good, average and poor combiners. Crosses with significant *sca* effects towards desirable direction were considered as good specific combiners and those towards undesirable direction as poor specific combiners, while, non-significant in positive direction were designated as average specific combiners. If crosses showing high *sca* effects involve parents who are also good general combiners, then these crosses could be exploited by simple methods like pedigree selection, provided the additive $\times$ additive component of interaction was significant.

In the present investigation, the general combining ability (*gca*) effects of lines and testers, and specific combining ability (*sca*) effects of hybrids for 13 quantitative traits during two years evaluation are presented in table 4.20 to 4.32. The results obtained are discussed as below:

4.5.1.1 Days to 50 per cent flowering

Estimated *gca* and *sca* effects for days to 50% flowering are presented in table 4.20. Perusal of data revealed that among lines, the highest positive *gca* effect was observed in IC117328 (3.598) and EC169408 (0.523) during summer and rainy season, respectively and the highest negative *gca* effect was observed in EC093655, IC117245 (-1.485) and EC169400 (-0.311) during summer and rainy season, respectively. During summer season evaluation, it was also noticed that among lines, EC093655 (-1.485), IC117245 (-1.485), IC117123 (-1.318), EC169435 (-1.235), EC169400 (-1.152), EC169408 (-0.818) and EC169430 (-0.818) exhibited significant negative *gca* effect in desirable direction. During rainy season evaluation, negative *gca* effect was observed in EC169400 (-0.311), IC117245 (-0.227), EC169506 (-0.061) and IC117351 (-0.227) but there were non-significant for the same trait.

Among different testers, highest positive *gca* effect was recorded in Parbhani Kranti (0.348) and 15/RES-4 (3.598) during summer and rainy season, respectively and the highest negative *gca* effect was recorded in VRO 6 (-0.167 and -0.265) over both the season consistently. Over both the season, VRO 6, EC169400, IC117123, IC117245 and EC169506 exhibited consistent desired negative *gca* effect for days to 50 per cent

Table 4.20: General and specific combining ability estimates for days to 50% flowering

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	0.417	0.682	0.576	-0.068	1.106	0.939	2.152**	0.280	-1.485**	0.106
EC 169430	0.242	0.098	-0.311	-0.394	-0.515	-0.470	0.750	-0.318	-0.818*	0.023
EC 169435	0.333	0.432	-0.091	-0.235	0.273	-0.561	1.568*	-0.803	-1.235**	0.106
EC 169506	-0.182	0.280	-0.333	-0.235	-0.258	-0.485	0.689	1.106	-0.568	-0.061
EC 169400	-0.394	-0.811	-0.515	-0.053	-0.833	-0.818	1.576*	0.098	-1.152**	-0.311
EC 169408	0.659	0.348	0.939	0.523	-0.015	0.364	-2.000**	-0.568	-0.818*	0.523
IC 117123	-1.098	-0.470		-0.068	-0.424	-0.652	-1.727*	0.189	-1.318**	-0.061
IC 117245	0.023	-0.561	-0.182	0.447		0.015	0.492	0.348	-1.485**	-0.227
IC 117351	-0.008	-0.152	-0.394	-0.311	0.152	0.530	0.250	0.015	1.765**	-0.227
IC 117355	1.417	0.515	0.242	0.682	0.273	0.106	-0.265	-0.136	3.515**	0.023
IC 117328	-1.098	0.030		0.348	-3.008**	0.015	-0.477	-0.227	3.598**	0.106
GCA Tester	-0.076	0.068	-0.167	-0.265	0.348	-0.114	-0.106	0.311		

flowering which indicated that these parents are good general combiner and also possessed genes for early flowering. Srivastava *et al.* (2008); Singh and Goswami (2015); and Punea and Garg (2019) have also reported high general combining ability effects for days to 50 per cent flowering in okra.

Among forty four cross combinations, sca effect ranged between 2.125 (IC093655 $\times$ 15/RES-4) to -3.008 (IC117328 $\times$ Parbhani Kranti) and 1.106 (EC169506 $\times$ 15/RES-4) to -0.818 (EC169400 $\times$ Parbhani Kranti) during summer and rainy season, respectively. During summer season, IC117328 $\times$ Parbhani Kranti (-3.008) followed by EC169408 $\times$ 15/RES-4 (-2.00) and IC117123 $\times$ 15/RES-4 (-1.727) recorded desirable significant negative sca effect. During rainy season, none of them crosses were exhibited significant negative sca effect for days to 50 per cent flowering. Over both the years, none of the cross combinations showed consistent significant negative sca effect for this earliness trait. The parents which showed better gca effects indicated predominance of additive gene effects governing early flowering. Similar results have also been reported by Sivakumar *et al.* (1995); Adiger *et al.* (2013); and Nagesh *et al.* (2014).

4.5.1.2 First fruit producing node

Estimated gca and sca effects for first fruit producing node are presented in table 4.21. Among lines, gca effect ranged between 0.471 (EC169430) to -0.412 (IC117328) and 0.731 (EC169400) to -0.770 (IC117328) during summer and rainy season, respectively.

Among eleven lines, significant negative gca effect was exhibited by IC117328 (-0.412, -0.770) over both summer and rainy season consistently. Among different testers, highest positive gca effect was recorded in Pusa A4 (0.207 and 0.096) and the highest negative gca effect was recorded in Parbhani Kranti (-0.126 and -0.055) over both the season consistently. Among parents, over both years, only Parbhani Kranti, VRO 6, IC117328, IC117355 and IC117245 registered negative gca effects but there were non-significant except IC117328 which showed significant. It indicated that these parents possessed genes for early fruiting node. These lines may be used in breeding programme for improving earliness trait.

Among forty four F₁ hybrids, sca effects ranged from -1.135 (IC117328 $\times$ VRO 6) to 1.318 (EC169408 $\times$ VRO 6) and -0.672 (EC169506 $\times$ 15/RES-4) to 0.580 (EC169430 $\times$ VRO 6) during summer and rainy season, respectively. IC117328 $\times$ VRO 6 (-1.135)

Table 4.21: General and specific combining ability estimates for first fruit producing node

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-0.599	-0.008	-0.224	0.126	-0.279	-0.144	-0.372	0.111	0.409*	0.258
EC 169430	1.144**	-0.320	0.843*	0.580	0.632	0.499	0.504	0.158	0.471**	0.368
EC 169435	0.477	-0.288	0.043	-0.013	0.991**	0.106	0.443	0.164	-0.277	0.424
EC 169506	-0.64	0.502	-0.937**	0.019	-0.321	0.320	-0.708*	-0.672	-0.28	0.117
EC 169400	-0.981**	0.106	-0.424	0.029	-0.335	0.242	-0.451	-0.260	0.345	0.731**
EC 169408	0.768*	0.404	1.318**	-0.034	0.935**	-0.418	0.709*	0.211	0.078	-0.075
IC 117123	0.491	-0.335	0.863*	-0.066	0.152	-0.043	0.114	-0.062	-0.108	0.284
IC 117245	-0.66	-0.061	-0.824*	-0.276	-0.055	0.099	-0.444	0.265	-0.081	-0.242
IC 117351	0.061	-0.402	0.185	0.215	0.468	-0.108	0.946**	-0.037	0.021	-0.408
IC 117355	-0.439	-0.151	-0.488	-0.426	-0.566	0.053	-0.244	-0.141	-0.168	-0.688**
IC 117328	-0.466	-0.027	-1.135**	-0.178	-0.240	0.350	-0.258	-0.087	-0.412*	-0.770**
GCA Tester	0.207	0.096	-0.080	-0.045	-0.126	-0.055	-0.002	0.004		

followed by EC169400 $\times$ Pusa A4 (-0.981), EC169506 $\times$ VRO 6 (-0.937), IC117245 $\times$ VRO 6 (-0.824) and EC169506 $\times$ 15/RES-4 (-0.708) exhibited desirable significant negative sca effect during summer season for first fruit producing node. Whereas, during rainy season, none of the hybrid showed significant negative gca effect for this trait. These results are in close agreement with those reported by Shivkumar *et al.* (1995); and Paul *et al.* (2017).

4.5.1.3 Fruit length (cm)

The data pertaining to gca effects of parents and sca effects of their crosses during summer and rainy season is presented in table 4.22.

Among lines, gca effects ranged between 1.076 (IC093655) to -0.831 (IC117328) and 0.553 (IC117355) to -0.722 (EC169430) during both the season respectively. During summer season evaluation, it is evident from the table that significant positive gca effect was observed in IC093655 (1.076) and IC117123 (0.972). During rainy season, positive gca effect were exhibited by IC117355 (0.553) followed by IC117351 (0.493) and IC093655 (0.480) but they were non-significant. Among different testers, over both the season consistent positive gca effect in desirable direction was observed in VRO 6 (0.170 and 0.312) and Pusa A4 (0.058 and 0.057). Whereas Parbhani Kranti (-0.172 and -0.191) and 15/RES-4 (-0.056 and -0.178) exhibited negative gca effect. Over both the years, among parents, VRO 6, Pusa A4, IC093655 and IC117123 were identified as good general combiners for longer fruits because of their highly consistent positive gca effects. Similar results have been reported by Rajni *et al.* (2001); Singh *et al.* (2009); Bhatt *et al.* (2015); Singh *et al.* (2015); and Punea and Garg (2019).

Among 44 F₁ hybrids, sca effect ranged from 1.610 (IC117123 $\times$ Parbhani Kranti) to -1.317 (EC169408 $\times$ Pusa A4) and 1.518 (EC169430 $\times$ 15/RES-4) to -1.797 (IC117328 $\times$ Parbhani Kranti) during both summer and rainy season, respectively. Over both the years, none of the hybrids exhibited consistent significant positive sca effect. Crosses with high significant sca values are indicative of superior combinations for fruit length. These identified crosses could be exploited for improving fruit length. These results are in close agreement with those reported by Singh *et al.* (1996); Srivastava *et al.* (2008); Adiger *et al.* (2013); and More *et al.* (2015).

Table 4.22: General and specific combining ability estimates for fruit length (cm)

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	0.071	-0.574	-0.021	-0.470	-0.068	0.436	-0.922	-0.496	1.076**	0.480
EC 169430	0.714	1.023	0.188	0.096	1.146	-0.269	0.174	1.518	0.110	-0.722
EC 169435	-0.834	0.111	0.263	0.018	-0.198	1.274	0.447	0.917	-0.465	0.083
EC 169506	0.885	-0.453	0.802	-0.814	-0.502	0.468	-0.687	-0.639	-0.520	0.362
EC 169400	-0.765	-0.680	-0.356	0.429	0.687	-0.420	0.078	-0.397	-0.149	-0.208
EC 169408	-1.317	-0.072	-0.709	0.366	-0.118	-0.484	-0.091	1.358	-0.115	-0.463
IC 117123	0.160	0.098	-0.662	-0.729	1.610*	0.793	0.935	-0.466	0.972**	0.062
IC 117245	1.087	0.549	0.190	0.734	0.542	0.657	0.142	0.891	-0.079	-0.526
IC 117351	-0.322	-0.132	0.493	0.464	-0.923	-0.553	-0.777	-0.511	-0.115	0.493
IC 117355	0.326	0.083	-0.712	-0.327	-1.229	-0.896	-0.318	0.125	0.117	0.553
IC 117328	-0.192	-0.048	-0.237	-0.679	0.066	-1.797*	0.952	-0.505	-0.831*	-0.114
GCA Tester	0.058	0.057	0.170	0.312	-0.172	-0.191	-0.056	-0.178		

4.5.1.4 Fruit Diameter (mm)

Estimated gca and sca effects for fruit diameter are presented in table 4.23. Among lines, gca effect ranged from 1.384 (IC117123) to -2.209 (IC117355) and 0.493 (IC117355) to -0.803 (EC169430) during summer and rainy season, respectively. During summer season, it is evident from the table that among the lines, IC117123 (1.384) and EC169430 (1.047) exhibited significant positive gca effect for fruit diameter. Whereas, during rainy season, none of them exhibited significant positive gca effect. Among twelve lines, none of them showed consistent significant gca effect over both the season for the same trait.

Among different testers studied, highest positive gca effect was recorded in Pusa A4 (0.262) and VRO 6 (0.221) during summer and rainy season, respectively. Whereas the highest negative gca effect was recorded in 15/RES-4 (-0.248 and -0.145) during both seasons respectively.

Among forty four F_1 hybrids, sca effect ranged from 1.391 (IC117123 $\times$ 15/RES-4) to -1.252 (IC093655 $\times$ 15/RES-4) and 1.504 (EC169430 $\times$ 15/RES-4) to -2.086 (IC117328 $\times$ Parbhani Kranti) during summer and rainy season, respectively. During summer season, among the cross combinations evaluated, none of them showed significant positive sca effect. Whereas, during rainy season only EC169430 $\times$ 15/RES-4 (1.504) exhibited desirable significant positive sca effect for fruit diameter. These results are in close agreement with those reported by Singh *et al.* (2009); Adiger *et al.* (2013); Bhatt *et al.* (2015); Patel *et al.* (2015); and Joshi *et al.* (2015). None of the cross combinations exhibited consistent significant sca effect over both the years for fruit diameter.

4.5.1.5 Average fruit weight (g)

The general and specific combining ability effects of parents as well as their hybrids for average fruit weight during both the seasons are presented in table 4.24. The gca effect among eleven lines ranged from 1.717 (IC093655) to -1.123 (IC117328) during summer season and 1.099 (EC169430) to -1.868 (IC117328) during rainy season. Significant positive gca effect in desirable direction was observed only in EC169400 during both the seasons indicating that this line was good general combiners for this trait, whereas the line EC117328 exhibited consistent significant undesired negative gca effect which indicated that it is a poor general combiner for average fruit weight. Among different

Table 4.23: General and specific combining ability estimates for fruit diameter (mm)

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-0.154	0.153	0.253	-0.428	-0.575	0.643	-1.252	-0.670	0.886	0.433
EC 169430	-0.869	0.648	-0.787	0.988	0.493	0.424	-0.015	1.504*	1.047*	-0.803*
EC 169435	-1.235	-0.192	0.068	0.352	0.036	-0.219	-0.031	1.412	0.360	0.272
EC 169506	1.059	-0.660	0.985	-0.488	-0.059	0.554	-0.495	-0.830	0.846	0.003
EC 169400	1.045	0.204	-0.168	-0.217	-0.028	-0.719	-0.297	-0.282	0.067	0.183
EC 169408	0.642	0.230	-0.885	0.354	0.662	-0.478	0.158	1.232	0.849	0.033
IC 117123	-0.384	0.018	-0.743	-0.084	0.712	0.808	1.391	-0.280	1.384**	0.458
IC 117245	-0.104	-0.401	-0.803	0.317	-0.411	-0.026	-0.635	-0.132	0.236	-0.429
IC 117351	0.723	-0.077	1.293	0.195	0.573	0.019	0.579	-0.375	-0.319	-0.366
IC 117355	0.314	-0.387	-1.078	0.412	-0.874	-0.800	0.100	0.360	-2.209**	0.493
IC 117328	-0.249	-0.523	0.549	-0.618	0.541	-2.086**	-0.044	0.147	-3.147**	-0.277
GCA Tester	0.262	0.001	0.118	0.221	-0.132	-0.077	-0.248	-0.145		

testers studied, gca effect ranged between 0.159 (VRO 6) to -0.194 (15/RES-4) and 0.105 (Pusa A4) to -0.205 (VRO 6) during summer and rainy seasons, respectively. Positive gca effect in desirable direction was observed in Parbhani Kranti during summer and rainy season, respectively. While, none of the testers showed significant positive gca effect for this traits.

The sca effect among thirty six crosses ranged from 3.013 (IC117123 $\times$ Parbhani Kranti) to -2.253 (IC117355 $\times$ Parbhani Kranti) and 2.679 (IC093655 $\times$ VRO 6) to -1.498 (IC117328 $\times$ VRO 6) during summer and rainy season, respectively. During summer season, six cross combinations, whereas during rainy season four cross combinations exhibited positive significant sca effect in desirable direction. Among the cross combinations, the cross EC169430 $\times$ VRO 6 and EC169408 $\times$ 15/RES-4 showed significant sca effect in both the season consistently for this particular trait. Rajni *et al.* (2001); Singh *et al.* (2009); Adiger *et al.* (2013); Patel *et al.* (2015); and Punea and Garg (2019) also reported similar results for these traits in okra.

4.5.1.6 Number of fruit per plant

The general and specific combining ability effects of parents as well as their hybrids for number of fruits per plant during both the seasons are presented in table 4.25. Number of fruits per plant is a most desirable trait, thus positive gca and sca values are indicative of promising parents and combinations, respectively.

GCA effect of eleven lines ranged from 4.678 (EC169400) to -3.304 (IC117328) and 1.859 (EC169400) to -1.670 (IC117245) during summer and rainy season, respectively. During summer season, significant positive gca effect was observed in EC169400 (4.678) and IC093655 (4.292). Lines IC117328 (-3.304), EC169408 (-2.189) and IC117355 (-1.858) exhibited significant negative gca effect for number of fruits per plant. During rainy season, EC169400 (1.859) followed by EC169435 (1.219), EC169430 (1.080) and IC117123 (0.858) recorded significant positive gca effect. While, significant negative gca effect was noticed in IC117245 (-1.670) and IC117328 (-1.557). EC169400 showed consistent significant positive gca effects during both the years indicating their good general combining ability for this trait. On the other hand, line IC117328 and EC169408 was found to be a poor general combiner as it possessed consistent significant negative gca effects during both the seasons.

Table 4.24: General and specific combining ability estimates for average fruit weight (g)

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	1.224	0.851	-1.797**	2.679**	0.225	-0.297	-0.362	0.338	1.717**	-0.369
EC 169430	0.314	0.974	1.796**	1.431*	0.249	1.044	1.326	0.825	-0.468	1.099**
EC 169435	0.898	0.044	2.290**	0.426	-0.381	1.915**	0.222	0.240	0.756*	0.515
EC 169506	-1.393*	-0.514	-1.640*	0.285	-1.175	0.781	-0.681	-0.243	0.247	-0.002
EC 169400	0.181	-0.504	-0.370	-0.592	-0.735	-0.99	-2.155**	-1.241*	1.002**	0.981**
EC 169408	0.253	-0.052	-0.280	-0.119	1.685*	0.506	1.609*	1.352*	-0.298	-0.456
IC 117123	-0.997	0.040	-0.240	-0.418	3.013**	0.945	0.909	-0.449	-0.129	0.753**
IC 117245	-0.480	-0.840	1.783**	-0.866	-2.136**	-0.455	-0.109	-0.852	0.012	-0.928**
IC 117351	0.642	-1.378*	0.254	-1.395*	1.376	-0.183	-0.561	-0.115	-0.883*	0.402
IC 117355	-0.284	0.119	-0.408	-1.461*	-2.253**	-0.306	-0.039	0.160	-0.833*	-0.126
IC 117328	-2.154**	-0.172	0.539	-1.498**	-0.868	-0.822	0.709	0.807	-1.123**	-1.868**
GCA Tester	-0.007	0.105	0.159	-0.205	0.043	0.063	-0.194	0.036		

Table 4.25: General and specific combining ability estimates for number of fruit per plant

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-3.076*	-0.077	-2.665*	2.879**	-3.199*	0.062	-2.341	-1.055	4.292**	-0.224
EC 169430	0.318	1.548	6.950**	3.090**	1.269	3.750**	3.203*	0.756	-0.306	1.080**
EC 169435	4.349**	-0.161	2.935*	0.546	-0.797	2.145**	1.387	0.693	-0.514	1.219**
EC 169506	-0.534	-0.224	-3.868**	-0.494	-2.811*	-0.344	-1.846	-0.022	-0.122	-0.169
EC 169400	-4.133**	-1.163	-6.017**	-1.000	1.346	-1.163	-1.856	-0.399	4.678**	1.859**
EC 169408	5.460**	2.296**	6.950**	0.948	4.664**	1.444	3.901**	2.448 ***	-2.189**	-1.141**
IC 117123	0.818	-1.25	0.565	1.283	-1.708	-0.929	0.296	-0.994	0.580	0.858*
IC 117245	-3.202*	-0.969	1.216	-1.890*	-0.145	0.146	0.817	0.516	-0.412	-1.670**
IC 117351	-3.065*	-1.869*	0.883	-2.272**	0.906	0.419	-0.233	0.810	-0.843	-0.281
IC 117355	-0.251	-0.469	5.321**	-2.814**	0.947	0.364	2.265	-0.137	-1.858**	0.024
IC 117328	-3.634**	-0.752	-5.792**	-3.080**	-2.744*	-1.428	-2.848*	-1.189	-3.304**	-1.557**
GCA Tester	1.182**	0.344	-0.915*	-0.394	-1.033**	-0.111	0.767*	0.161		

GCA effect of testers ranged from Pusa A4 (1.182 and 0.344) to Parbhani Kranti (-1.033) and VRO 6 (-0.394) during both the seasons, respectively. Over both the years, Pusa A4 and 15/RES-4 showed consistent positive gca effect in desirable direction for this particular trait indicating that it is a good general combiner for this particular trait.

SCA effects ranged from 6.950 (EC169430 $\times$ VRO 6, EC169408 $\times$ VRO 6) to -6.017 (EC169400 $\times$ VRO 6) and 3.750 (EC169430 $\times$ Parbhani Kranti) to -3.080 (IC117328 $\times$ VRO 6) in among forty four crosses during summer and rainy season, respectively. During the summer season, nine cross combinations while, during rainy season six cross combinations exhibited positive significant sca effect in desirable direction. Among the cross combinations, the cross EC169408 $\times$ Pusa A4 (5.460 and 2.296), EC169408 $\times$ VRO 6 (6.950 and 0.948) and EC169408 $\times$ 15/RES-4 (3.901 and 2.448) recorded significant sca effect in both the season consistently for this particular trait. Patil *et al.* (1996b); Singh *et al.* (2001); Srivastava *et al.* (2008); Adiger *et al.* (2013); More *et al.* (2015); Paul *et al.* (2017); and Punea and Garg (2019) reported the combining ability (gca & sca) for number of fruits per plant.

4.5.1.7 Number of primary branches per plant

Estimates of gca effects and sca effects are presented in table 4.26. Among lines, gca effect ranged from 0.650 (EC169400) to -0.349 (IC117328) and 0.228 (IC117351) to -0.134 (EC169408) during summer and rainy season, respectively. It is evident from the table that none of the lines exhibited consistent significant positive gca effect in desirable direction over both the seasons was observed only in EC169400 (1.095 and 1.135) for primary branches per plant, indicating that it possessed genes for increased number of primary branches per plant and can be considered as good general combiners for this trait.

Among different testers studied, gca effect was ranged from 0.095 (VRO 6) to -0.146 (Pusa A4) and 0.063 (VRO 6) to -0.027 (Pusa A4) during summer and rainy season, respectively. Over both the season, among testers, none of them exhibited consistent significant positive gca effect.

Among cross combinations, sca effect ranged from 0.910 (EC169435 $\times$ Parbhani Kranti) to -0.734 (IC117328 $\times$ VRO 6) and 0.355 (EC169408 $\times$ 15/RES-4) to -0.193 (IC117351 $\times$ Pusa A4). During summer season, significant positive sca effect was observed in EC169435 $\times$ Parbhani Kranti (0.910), EC169408 $\times$ 15/RES-4 (0.772), EC169430 $\times$ VRO 6

Table 4.26: General and specific combining ability estimates for number of primary branches per plant

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-0.021	-0.091	-0.105	-0.137	-0.289	-0.067	-0.094	-0.121	-0.119	0.005
EC 169430	0.286	0.024	0.696*	0.128	0.344	-0.176	0.021	0.188	0.186	0.035
EC 169435	0.378	-0.066	0.321	0.195	0.910**	0.268	0.439	0.045	0.084	0.060
EC 169506	-0.408	0.128	-0.370	-0.119	-0.444	0.056	-0.279	-0.178	-0.126	-0.078
EC 169400	-0.255	-0.086	-0.232	-0.148	0.064	-0.035	-0.290	-0.112	0.650**	-0.023
EC 169408	0.501	0.112	0.281	0.072	0.669*	0.046	0.772**	0.355	-0.257	-0.134
IC 117123	-0.106	-0.011	0.487	-0.007	0.125	0.027	-0.388	-0.121	0.083	0.003
IC 117245	-0.374	-0.011	-0.436	0.184	-0.090	-0.063	0.154	0.027	-0.013	-0.078
IC 117351	0.154	-0.193	0.054	-0.040	0.128	0.018	0.133	-0.063	-0.124	0.228
IC 117355	-0.641*	0.047	-0.519	0.054	-0.163	0.018	-0.093	0.018	-0.015	0.061
IC 117328	-0.210	0.018	-0.734**	-0.146	-0.181	-0.055	-0.194	0.018	-0.349*	-0.078
GCA Tester	-0.146	-0.027	0.095	0.063	-0.009	-0.018	0.061	-0.018		

(0.696) and EC169408 × Parbhani Kranti (0.669). Whereas, during rainy season evaluation, among forty four crosses, none of the cross combinations exhibited significant positive sca effect.

Number of primary branches per plant is a desirable trait, thus positive gca and sca values are indicative of promising parents and combinations, respectively for the trait. EC169435 × Parbhani Kranti, EC169408 × 15/RES-4, EC169430 × Pusa A4 and EC169408 × Parbhani Kranti were identified as the best specific cross combinations.

The results with respect to gca effects are similar to the results obtained by Singh *et al.* (2001); Srivastava *et al.* (2008); Singh *et al.* (2015); and Punea and Garg (2019). Whereas, the results with respect to sca effects are similar to the findings of Singh *et al.* (2007); Adiger *et al.* (2013); and Patel *et al.* (2015).

4.5.1.8 Stem diameter (mm)

Estimates of gca effects and sca effects are presented in table 4.27. Among lines, gca effect ranged from 1.915 (IC093655) to -4.623 (IC117328) and 1.135 (EC169400) to -1.430 (IC117245) during summer and rainy season, respectively. It is evident from the table that consistent significant positive gca effect in desirable direction over both the seasons was observed only in EC169400 (1.095 and 1.135) for stem diameter, indicating that it possessed genes for increased stem diameter and can be considered as good general combiners for this trait.

Among different testers studied, gca effect was ranged from 0.365 (15/RES-4) to -0.641 (Parbhani Kranti) and 0.165 (VRO 6) to -0.153 (Parbhani Kranti) during summer and rainy season, respectively. Over both the season, among testers, none of them exhibited consistent significant positive gca effect.

Among forty four crosses, sca effect ranged from 3.490 (EC169408 × VRO 6) to -2.458 (EC169400 × Pusa A4) and 1.88 (IC093655 × VRO 6) to -1.882 (IC117328 × VRO 6) during summer and rainy season, respectively. During summer season, significant positive sca effect was observed in six cross combinations viz., EC169408 × VRO 6 (3.490), EC169435 × 15/RES-4 (2.223), IC117351 × Pusa A4 (2.199), EC169430 × Pusa A4 (2.177), EC169435 × Pusa A4 (2.148) and EC169408 × Parbhani Kranti (2.155). Whereas, during rainy season, significant positive sca effect was observed in three cross

Table 4.27: General and specific combining ability estimates for stem diameter (mm)

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	0.242	-0.579	-0.255	1.880*	-1.011	-0.541	-0.979	-0.883	1.915**	-0.463
EC 169430	2.177*	0.113	0.477	0.595	-0.323	1.347	0.689	1.220	1.560**	0.610
EC 169435	2.148*	-0.275	-0.668	0.618	1.954	1.749*	2.223*	1.092	1.460**	-0.455
EC 169506	-1.868	0.673	-1.383	0.043	-1.116	0.437	-0.777	-1.050	0.419	0.671
EC 169400	-2.458*	-0.511	-1.440	-0.458	-0.028	0.115	-1.464	-0.103	1.095*	1.135**
EC 169408	2.001	0.022	3.490**	-0.203	2.155*	-0.010	1.874	1.809*	1.109*	-0.890*
IC 117123	-0.968	-0.251	0.976	-0.589	-1.189	-1.137	0.568	-0.824	1.880**	-0.060
IC 117245	-1.275	0.808	0.000	-0.600	-0.701	-0.315	-0.133	0.372	-1.077*	-1.430**
IC 117351	2.199*	0.272	-0.720	-0.691	1.123	0.113	0.762	0.370	-2.201**	1.059*
IC 117355	-2.367*	0.084	0.582	-1.213	0.766	1.339	0.385	-0.072	-1.539**	-0.120
IC 117328	-0.310	-0.951	-2.213*	-1.882*	-2.135*	-1.262	-1.015	-0.670	-4.623**	-0.058
GCA Tester	0.124	-0.090	0.152	0.165	-0.641*	-0.153	0.365	0.078		

combinations viz., IC093655 $\times$ VRO 6 (1.880), EC169408 $\times$ 15/RES-4 (1.809) and EC169435 $\times$ Parbhani Kranti (1.749). None of the cross combinations recorded consistent significant sca effect over both the respective seasons.

4.5.1.9 Inter-nodal length (cm)

The data pertaining to gca effects of parents and sca effects of their crosses during both seasons for inter-nodal length is presented in table 4.28.

Among twelve lines, gca effects ranged between 0.892 (EC169430) to -0.647 (IC117328) and 0.545 (EC169435) to -0.481 (IC117328) during summer and rainy season, respectively. It is evident from the table that only one genotype IC117328 exhibited consistent significant negative gca effect in desirable direction for particular trait during both years. This indicates that these lines were good general combiners for inter-nodal length.

Among different testers, gca effect ranged from 0.090 (VRO 6) to -0.058 (15/RES-4) and 0.071 (15/RES-4) to -0.036 (Parbhani Kranti) during summer and rainy season, respectively. Among three testers, only Pusa A4 recorded consistent desirable negative gca effect over both the seasons.

Among 44 F_1 hybrids, sca effect ranged from 1.378 (EC169435 $\times$ Pusa A4) to -1.421 (EC169400 $\times$ Pusa A4) and 0.597 (IC117123 $\times$ VRO 6) to -0.858 (IC117245 $\times$ VRO 6) during summer and rainy season, respectively. During summer season, among the cross combinations evaluated, eleven cross combinations exhibited significant negative sca effect in desirable direction for this trait with maximum in EC169400 $\times$ Pusa A4 (-1.421) followed by IC117355 $\times$ VRO 6 (-1.409) and IC117328 $\times$ Parbhani Kranti (-1.018). During rainy season, only one cross combinations IC117245 $\times$ VRO 6 (-0.858) recorded significant negative sca effect in desirable direction. The findings of Singh *et al.* (2001); Adiger *et al.* (2013); Patel *et al.* (2015); Singh and Goswami (2015); and Paul *et al.* (2017) are in accordance with the results obtained above.

4.5.1.10 Plant height (cm)

The general and specific combining ability effects of parents as well as their hybrids during both the seasons are presented in Table 4.29. Among eleven lines, gca

effect ranged from EC169430 (11.232 and 13.980) to IC117328 (-18.450 and -5.925) during both the season consistently. During summer season, significant positive gca effect in desirable direction was observed in EC169430 (11.232) and EC169400 (10.357), whereas lines IC117328 (-18.450) and IC117355 (-7.966) recorded significant negative gca effect for plant height. During rainy season, only line EC169430 (13.980) exhibited significant desired positive gca effect, Over the both the season consistently, only one line EC169430 exhibited significant positive gca effect indicating their good general combining ability for this trait. Whereas on the other hand, lines EC169408, IC117123, IC117355 and IC117328 were found to be poor general combiners as these possessed consistent negative gca effects.

GCA effect of all testers ranged from Parbhani Kranti (1.519) to VRO 6 (-2.415) and VRO 6 (1.026) to 15/RES-4 (-1.122) during summer and rainy season, respectively. Only Pusa A4 showed positive gca effect in desirable direction for plant height, which indicates that this tester was a good general combiner.

In forty four cross combinations, sca effect ranged from 20.363 (EC169408 $\times$ Pusa A4) to -23.134 (IC117328 $\times$ VRO 6) and 12.833 (EC169430 $\times$ Parbhani Kranti) to -9.553 (IC117328 $\times$ VRO 6) during summer and rainy season, respectively. During summer season, the cross combinations namely EC169408 $\times$ Pusa A4 (20.363), EC169430 $\times$ Parbhani Kranti (15.498), EC169430 $\times$ 15/RES-4 (15.135), EC169408 $\times$ 15/RES-4 (15.037) and EC169435 $\times$ Parbhani Kranti (14.275) exhibited positive significant sca effect in desirable direction, whereas significant negative sca effect was observed in seven cross combinations. During rainy season, none of the cross combinations were showed significant positive sca effect for this trait. In the present study the cross combinations viz., EC 169408 $\times$ Pusa A4, EC169430 $\times$ Parbhani Kranti, EC169435 $\times$ Parbhani Kranti, EC169430 $\times$ 15/RES-4 and EC169408 $\times$ 15/RES-4 over both the season emerged as good crosses for plant height.

These results were also in close confirmation with the observations of Patil *et al.* (1996); Ahmed *et al.* (1997); Singh *et al.* (2009); Adiger *et al.* (2013); Singh and Goswami (2015); and Punea and Garg (2019).

Table 4.28: General and specific combining ability estimates for inter-nodal length (cm)

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	0.005	0.166	-0.047	0.529	-0.181	0.172	0.069	-0.419	0.226	-0.107
EC 169430	0.681*	-0.132	1.273**	0.109	1.296**	0.389	0.179	-0.032	0.892**	-0.055
EC 169435	1.378**	-0.064	0.352	0.220	1.309**	0.389	0.693*	0.163	0.079	0.545**
EC 169506	-0.638*	-0.082	-0.578*	-0.189	0.092	-0.208	0.146	-0.371	-0.462**	0.364
EC 169400	-1.421**	0.278	-0.567	0.073	-0.478	-0.443	-0.762**	0.061	0.372*	-0.187
EC 169408	0.965**	0.141	0.793**	-0.104	0.566	0.479	0.515	0.576	0.014	-0.220
IC 117123	-0.248	-0.136	0.696*	0.597	0.813**	-0.544	0.179	-0.219	0.038	0.394*
IC 117245	-0.721*	-0.172	-0.373	-0.858*	-0.384	0.007	-0.096	0.051	-0.299*	-0.040
IC 117351	0.429	0.139	-0.276	-0.268	0.334	0.332	0.804**	-0.251	-0.138	0.020
IC 117355	-0.941**	-0.086	-1.409**	-0.497	-0.763**	0.205	-0.372	0.220	-0.074	-0.232
IC 117328	-0.760**	-0.161	-1.195**	-0.282	-1.018**	0.240	-0.336	-0.020	-0.647**	-0.481*
GCA Tester	-0.057	-0.006	0.090	-0.028	0.025	-0.036	-0.058	0.071		

Table 4.29: General and specific combining ability estimates for plant height (cm)

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-3.668	-1.704	-7.462	5.333	-2.134	0.581	-13.771*	-2.250	3.731	-2.935
EC 169430	5.897	3.227	8.649	5.661	15.498*	12.833	15.135*	4.909	11.232**	13.980**
EC 169435	6.399	-0.689	9.305	4.897	14.275*	5.605	8.154	4.951	0.032	1.872
EC 169506	-13.869*	-0.350	-13.960*	-1.561	-8.578	-1.054	-13.056*	-3.064	1.824	2.955
EC 169400	1.574	-2.188	-5.728	-2.022	-0.476	-1.833	-7.738	2.357	10.357**	3.153
EC 169408	20.363**	4.312	10.382	-1.314	11.189	2.306	15.037*	5.424	-3.076	-5.650
IC 117123	1.197	-1.708	4.640	1.108	11.149	-3.427	6.472	-5.531	-0.560	-0.142
IC 117245	-17.893**	-0.899	-8.728	-6.953	-2.949	0.481	-0.468	1.485	5.28	-6.98
IC 117351	-5.595	-1.448	11.549	0.512	7.406	-0.070	8.367	2.839	-2.405	0.923
IC 117355	-5.393	0.579	-6.639	-8.884	-15.607*	3.016	-3.688	-1.945	-7.966*	-1.253
IC 117328	2.339	-4.792	-23.134**	-9.553	-10.233	-6.796	-4.211	-2.379	-18.450**	-5.925
GCA Tester	0.353	0.933	-2.415	1.026	1.519	-0.837	0.543	-1.122		

4.5.1.11 Fruit yield per plant (g)

The general and specific combining ability effects of parents as well as their hybrids for fruit yield per plant during both the seasons are presented in table 4.30. Fruit yield per plant is a most desirable trait, thus positive gca and sca values are indicative of promising parents and combinations, respectively.

The gca effect among eleven lines ranged from 76.435 (EC093655) to -52.726 (IC117328) and 38.738 (EC169400) to -49.638 (IC117328) during summer and rainy season, respectively. Line EC169400 showed consistent significant positive gca effect during both the season indicating their good general combining ability for fruit yield per plant suggesting that these parents could be utilized for improving this trait. Whereas, line IC117328 during both the seasons exhibited significant negative gca effect indicating their poor general combining ability for this particular trait.

Among different testers studied, gca effect ranged from 17.012 and 6.513 (Pusa A4) to -11.518 (Parbhani Kranti) and -8.267 (VRO 6) during both the season, respectively. Highest positive gca effect in desirable direction was observed in Pusa A 4 and 15/RES-4 during both the seasons, respectively. Whereas, VRO 6 and Parbhani Kranti showed negative gca effect during both the seasons indicating their poor general combining ability for fruit yield per plant. The results are in parity with those obtained by Ramesh *et al.* (1998), Singh *et al.* (2001), Kushwaha *et al.* (2007), Singh *et al.* (2009), Adiger *et al.* (2013), Singh and Goswami (2015), Patel *et al.* (2015), Paul *et al.* (2017) and Punea and Garg (2019).

The sca effect among forty four crosses ranged from 114.187 (EC169430 × VRO 6) to -85.742 (EC169400 × VRO 6) and 79.794 (IC093655 × VRO 6) to -58.764 (IC117328 × VRO 6) during both seasons, respectively. Out of all combinations, fourteen crosses recorded consistent positive sca effects during both seasons, but only two combination viz., EC169430 × VRO 6 (114.187 and 63.458) and EC169408 × 15/RES-4 (68.121 and 53.564) showed consistent significant positive sca effect in desirable direction over both the seasons. In general, sca is associated with interaction effects, which may be due to dominance and epistatic component of variation that are non-fixable in nature. It helps in the identification of superior cross combination for development of promising

Table 4.30: General and specific combining ability estimates for fruit yield per plant (g)

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-26.261	14.661	-51.327**	79.794**	-36.153*	-4.724	-30.316	-7.416	76.435**	-6.385
EC 169430	2.379	38.584*	114.187**	63.458**	22.242	60.979**	56.706**	22.653	-10.998	30.909**
EC 169435	66.496**	-2.219	82.701**	14.593	-15.336	56.114**	17.562	12.596	-0.112	22.330**
EC 169506	-23.065	-11.596	-73.745**	-1.727	-52.966**	8.410	-29.146	-4.445	4.146	-2.116
EC 169400	-45.809**	-24.770	-85.742**	-22.914	6.385	-31.206	-49.950**	-26.5	73.883**	38.738**
EC 169408	71.765**	26.497	76.787**	10.048	82.734**	27.52	68.121**	53.564**	-31.299**	-19.341*
IC 117123	-3.011	-14.400	6.520	4.521	14.047	2.595	12.146	-19.648	3.453	22.447**
IC 117245	-42.493**	-26.758	34.043*	-35.966*	-22.106	-4.124	2.586	-9.389	-8.320	-35.635**
IC 117351	-37.346*	-45.451**	10.765	-48.350**	28.67	2.122	-2.787	7.825	-22.385**	1.847
IC 117355	-9.189	-5.184	63.232**	-58.328**	-20.611	-0.593	24.536	1.898	-32.077**	-3.157
IC 117328	-67.652**	-12.824	-70.138**	-58.764**	-45.121**	-30.804	-24.335	-0.333	-52.726**	-49.638**
GCA Tester	17.012**	6.513	-11.515*	-8.267	-11.518*	-0.714	6.020	2.468		

hybrids. Similar results have been reported by Singh *et al.* (2001); Singh *et al.* (2009); Patel *et al.* (2015); and Paul *et al.* (2017).

4.5.1.12 Total yield (q/ha)

The general and specific combining ability effects of parents as well as their hybrids for fruit yield per plant during both the seasons are presented in table 4.31. Fruit yield per plant is a most desirable trait, thus positive gca and sca values are indicative of promising parents and combinations, respectively.

The gca effect among eleven lines ranged from 50.956 (EC093655) to -35.148 (IC117328) and 21.521 (EC169400) to -27.576 (IC117328) during summer and rainy season, respectively. Line EC169400 showed consistent significant positive gca effect during both the season indicating their good general combining ability for total yield, suggesting that these parents could be utilized for improving this trait. Whereas, line IC117328 during both the seasons exhibited significant negative gca effect indicating their poor general combining ability for this particular trait.

Among different testers studied, gca effect ranged from 11.341 and 3.618 (Pusa A4) to -7.678 (Parbhani Kranti) and -4.592 (VRO 6) during both the season, respectively. Highest positive gca effect in desirable direction was observed in Pusa A 4 and 15/RES-4 during both the seasons, respectively. Whereas, VRO 6 and Parbhani Kranti showed negative gca effect during both the seasons indicating their poor general combining ability for this trait. The results are in parity with those obtained by Singh *et al.* (2001); Patel *et al.* (2015); and Paul *et al.* (2017).

The sca effect among forty four crosses ranged from 76.123 (EC169430 $\times$ VRO 6) to -57.161 (EC169400 $\times$ VRO 6) and 44.329 (IC093655 $\times$ VRO 6) to -32.648 (IC117328 $\times$ VRO 6) during both seasons, respectively. Out of all combinations, fourteen crosses recorded consistent positive sca effects during both seasons, but only two combination viz., EC169430 $\times$ VRO 6 (76.123 and 35.254) and EC169408 $\times$ 15/RES-4 (45.413 and 29.758) showed consistent significant positive sca effect in desirable direction over both the seasons. In general, sca is associated with interaction effects, which may be due to dominance and epistatic component of variation that are non-fixable in nature. It helps in the identification of superior cross combination for development of promising hybrids.

Table 4.31: General and specific combining ability estimates for total yield q/ha

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-17.506	8.142	-34.215**	44.329**	-24.102*	-2.623	-20.209	-4.121	50.956**	-3.547
EC 169430	1.585	21.436*	76.123**	35.254**	14.829	33.875**	37.804**	12.585	-7.335	17.172**
EC 169435	44.329**	-1.233	55.133**	8.110	-10.226	31.176**	11.708	6.999	-0.074	12.406**
EC 169506	-15.379	-6.440	-49.162**	-0.959	-35.310**	4.672	-19.43	-2.471	2.764	-1.175
EC 169400	-30.535**	-13.763	-57.161**	-12.732	4.255	-17.338	-33.302**	-14.723	49.256**	21.521**
EC 169408	47.843**	14.722	51.190**	5.582	55.156**	15.289	45.413**	29.758**	-20.865**	-10.745*
IC 117123	-2.008	-8.001	4.346	2.513	9.366	1.442	8.099	-10.914	2.302	12.469**
IC 117245	-28.330**	-14.863	22.694*	-19.980*	-14.739	-2.291	1.724	-5.217	-5.547	-19.798**
IC 117351	-24.898*	-25.254**	7.175	-26.863**	19.112*	1.179	-1.858	4.347	-14.923**	1.027
IC 117355	-6.123	-2.877	42.156**	-32.403**	-13.740	-0.330	16.36	1.054	-21.385**	-1.753
IC 117328	-45.102**	-7.123	-46.759**	-32.648**	-30.081**	-17.113	-16.225	-0.185	-35.148**	-27.576**
GCA Tester	11.341**	3.618	-7.677*	-4.592	-7.678*	-0.396	4.014	1.370		

Similar results have been reported by Singh *et al.* (2001); Singh *et al.* (2009); Patel *et al.* (2015); and Paul *et al.* (2017).

4.5.1.13 Number of seeds per fruit

Estimates of gca effect and sca effect for number of seeds per fruit are presented in table 4.32. Out of eleven lines, gca effect ranged from 6.217 (EC169430) to -9.238 (IC117328) and 5.914 (IC093655) to -10.313 (IC117328) during summer and rainy season, respectively.

Among lines, three lines namely IC093655 (3.833 and 5.194), EC169430 (6.217 and 4.288) and EC169506 (2.655 and 4.507) exhibited consistent significant positive gca effect over both the respective seasons. Whereas, in all three different testers studied, gca effect ranged from Parbhani Kranti (1.042) to VRO 6 (-1.385) over both the seasons, respectively. None of the testers showed consistent significant gca effect over both the seasons. Among the parents, IC093655, EC169430 and EC169506 exhibited highly significant positive gca effects for this trait indicating their good general combining ability for number of seeds per fruit suggesting that these parents could be utilized for improving this trait. Whereas, two lines viz., IC117355 and IC117328 showed consistent significant negative gca effect for number of seeds per fruit over both the seasons indicating their poor general combining ability for this trait. Ahmed *et al.* (1997) and Nagesh *et al.* (2014) identified good general combiners for number of seeds per fruit.

Among thirty six crosses, sca effect ranged from 9.741 (EC169430 $\times$ VRO 6) to -9.143 (IC117355 $\times$ Pusa A4) and 13.02 (EC169430 $\times$ VRO 6) to -9.072 (IC117351 $\times$ Pusa A4) during summer and rainy season, respectively. Three cross combinations viz., EC169430 $\times$ VRO 6 (9.741 and 13.020), EC169435 $\times$ 15/RES-4 (6.107 and 6.882) and IC117351 $\times$ 15/RES-4 (5.866 and 9.559) exhibited consistent significant positive sca effect for number of seeds per fruit during both the seasons. However, four crosses namely EC169506 $\times$ Pusa A4 (-5.388 and -5.968), IC117123 $\times$ VRO 6 (-6.193 and -8.216), IC117123 $\times$ Parbhani Kranti (-8.233 and -5.100) and EC169506 $\times$ 15/RES-4 (-4.856 and -7.464) recorded significant negative sca effect for the same trait. Similar results were observed by Srivastava *et al.* (2008); and Paul *et al.* (2017).

Table 4.32: General and specific combining ability estimates for number of seeds per fruit

Character	Pusa A 4		VRO 6		Parbhani Kranti		15/RES-4		GCA Line	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
IC 093655	-0.373	0.061	-0.756	5.050*	-3.705	0.824	-1.587	-5.020*	3.833**	5.914**
EC 169430	0.422	9.031**	9.741**	13.020**	0.952	6.446**	-3.564	1.681	6.217**	4.288**
EC 169435	2.058	2.041	3.477	2.607	3.653	2.360	6.107*	6.882**	-1.315	2.044
EC 169506	-5.388*	-5.968**	-2.334	-2.503	5.458*	1.073	-4.856*	-7.464**	2.655*	4.507**
EC 169400	2.909	-5.104*	1.173	1.421	2.641	0.220	-3.797	-3.082	1.566	2.885*
EC 169408	1.388	6.278**	-2.316	-1.525	-4.395	-2.116	5.696*	3.909	0.575	1.349
IC 117123	4.214	-7.648**	-6.193**	-8.216**	-8.233**	-5.100*	-0.313	4.193	2.324	1.466
IC 117245	-5.229*	1.309	4.271	5.068*	9.153**	1.760	-3.957	-4.315	2.072	-1.588
IC 117351	4.481	-9.072**	2.678	-1.902	-0.460	3.168	5.866*	9.559**	-0.424	-2.276*
IC 117355	-9.143**	-1.078	-0.797	-1.372	-0.460	0.171	0.193	0.636	-8.264**	-8.276**
IC 117328	-5.079*	-2.870	-3.808	-7.435**	2.313	-1.099	-2.103	-5.880**	-9.238**	-10.313**
GCA Tester	0.938	-1.008	-1.385	-1.005	1.042	-0.016	-0.595	2.030**		

4.5.2 Variance components of combining ability

Variance components of general combining ability (gca) and specific combining ability (sca) are shown in table 4.33. Highest gca variance was observed for fruit yield per plant (1528.172 and 693.171) followed by total yield q/ha (679.183 and 213.937), plant height (63.451 and 31.311) and number of seeds per fruit (20.765 and 24.791) during both the season, respectively. Rest of the characters showed relatively smaller amount of gca variance.

Maximum variance for sca was observed for the trait fruit yield per plant (9243.900 and 3873.472) followed by total yield q/ha (4108.328 and 1195.527), plant height (428.888 and 72.815) and number of seeds per fruit (76.014 and 101.581) during both the season, respectively. However, rest of the characters showed relatively smaller amount of sca variance.

The estimates of $\sigma^2_{gca} / \sigma^2_{sca}$ indicated predominance of non-additive gene action for most of the characters except fruit diameter during summer season. Whereas, during rainy season, the estimate of $\sigma^2_{gca} / \sigma^2_{sca}$ indicated predominance of non-additive gene action for all thirteen different characters. Results presented earlier by Dahake and Bangar (2006); Kumar *et al.* (2006); Singh and Sanwal (2010); Adiger *et al.* (2013); Patel *et al.* (2015); Paul *et al.* (2017); and Punea and Garg (2019). also indicated preponderance of non-additive gene action in the expression of various quantitative traits.

Considering the above results, it may be concluded that there was predominant role of non-additive gene action in the inheritance of most of the traits except fruit diameter during summer season where additive gene actions seems to be involved in the inheritance. While during rainy season, all quantitative traits recorded non-additive gene action. It suggested that for the improvement of yield and other traits, the conventional methods may not be efficient in capitalizing the available genetic variability. The most efficient way for utilizing the non-additive genetic variance is through the exploitation of heterosis. Since it was observed that sca was the predominant contributor to genetic variance, thus, it is suggested that selection of sca is likely to be the most effective method to exploit hybrid vigour. Inbreeding and crossing will be the better means of improvement than selection without inbreeding in the presence of over-dominance. While, in case of additive (fixable) components such as fruit diameter (only during summer season), selection scheme would be useful to achieve homozygous lines.

Table 4.33: General and specific combining ability variances for thirteen characters of okra

Character	σ^2 (gca)		σ^2 (sca)		GCA/SCA ratio	
	Summer	Rainy	Summer	Rainy	Summer	Rainy
Days to 50% Flowering	3.200	0.047	4.613	0.869	0.694	0.054
First fruit producing node	0.080	0.210	1.608	0.282	0.050	0.744
Fruit length (cm)	0.305	0.181	1.804	1.884	0.169	0.096
Fruit diameter (mm)	1.846	0.163	1.842	1.701	1.002	0.096
Average Fruit weight (g)	0.695	0.716	6.076	3.312	0.114	0.216
Number of fruits per plant	5.550	1.229	40.644	9.187	0.137	0.134
Number of primary branches per plant	0.064	0.009	0.583	0.057	0.110	0.156
Stem diameter (mm)	4.011	0.592	8.503	2.997	0.472	0.198
Internodal length (cm)	0.158	0.088	2.176	0.389	0.073	0.226
Plant height (cm)	63.451	31.311	428.888	72.815	0.148	0.430
Fruit yield per plant (g)	1528.172	693.171	9243.900	3873.472	0.165	0.179
Total yield q/ha.	679.183	213.937	4108.328	1195.527	0.165	0.179
Number of seeds per fruit	20.765	24.791	76.014	101.581	0.273	0.244

4.6 Generation mean analysis

The estimation of genetic components requires the use of an appropriate method of analysis. Among all the breeding methods, generation mean analysis is one important method permitting estimation of epistatic components, in addition to additive and dominance components of total genetic variances. Generation mean analysis is commonly used in inheritance studies of qualitative and quantitative traits. In the present study, four families were developed from four parents, each family represented by six generations (P_1 , P_2 , F_1 , F_2 , BC_1 and BC_2) and the results for generation mean analysis have been discussed. The mean performance for six different generations of four crosses ($EC169430 \times 15/RES-4$, $IC117123 \times 15/RES-4$, $IC117328 \times 15/RES-4$ and $IC117123 \times IC117328$) for three quantitative characters are given in table 4.34.

4.6.1 Inheritance studies of YVMV

The resistance parent 15/RES-4 and susceptible parent IC117123 and IC117328 were crossed to study the inheritance pattern of YVMV resistance. The parents, F_1 , F_2 and backcrosses of both the parents were screened for YVMV reaction. The plant showing disease symptoms up to 75 days of sowing were considered as susceptible, whereas the plants with no symptoms of disease up to 75 days of sowing were considered as resistant. The segregation pattern of YVMV resistant and susceptible plants for all the generations under evaluation is presented in table 4.35. In Cross $EC169430 \times 15/RES-4$ (Resistant $\times$ Resistant), P_1 and P_2 population showed 0 and 4 susceptible plants, respectively, which is almost negligible and hence considered as resistant. F_1 population of this cross was also found complete resistant. Segregation analysis data for disease reaction in F_2 were compatible with a digenic control of the tolerance to YVMV disease, *i.e.* an approximate ratio of 15: 1 (Resistant: Susceptible). This was in agreement with the findings of Senjam *et al.* (2018) and Pullaiah *et al.* (1998). While, BC_1 (backcross with EC169430) population exhibited deviation from expected ratio of 1: 0 (Tolerant: Susceptible), however BC_2 (backcross with 15/RES-4) showed 1 tolerant: 0 susceptible ratio, which corroborated the observation of Ali *et al.* (2000). In Crosses $IC117123 \times 15/RES-4$ and $IC117328 \times 15/RES-4$ (Resistant $\times$ Susceptible), all F_1 progenies were found resistant. A ratio of 3:1 (Tolerant: Susceptible) was obtained for both F_2 generations indicating the involvement of a single dominant gene, which was further supported by an expected segregation pattern of 1:1

Table 4.34: Mean data for the three YVMV disease related traits in okra

Generations	Days of first appearance of YVMV disease	Node at which disease appeared	PDI of YVMV
EC169430 × 15/RES-4			
P1	57.67	11.00	9.17
P2	0.00	0.00	0.00
F1	0.00	0.00	0.00
F2	53.00	10.00	12.50
B1	46.67	9.00	19.17
B2	63.00	12.00	4.17
IC117123 × 15/RES-4			
P1	34.00	9.00	67.50
P2	0.00	0.00	0.00
F1	0.00	0.00	0.00
F2	37.00	10.00	29.17
B1	36.67	8.33	39.17
B2	49.00	11.00	22.50
IC117328 × 15/RES-4			
P1	41.00	9.00	74.17
P2	0.00	0.00	0.00
F1	0.00	0.00	0.00
F2	46.67	10.00	35.00
B1	40.00	8.00	43.33
B2	53.33	11.33	23.33
IC117123× IC117328			
P1	34.00	7.00	72.50
P2	36.67	7.67	70.00
F1	34.00	6.33	70.83
F2	39.00	8.00	69.17
B1	35.00	7.00	80.83
B2	41.33	8.00	75.00

PDI= Percent Disease Incidence

Table 4.35: Segregation ratio in crosses involving YVMV disease resistant and susceptible parents of okra

Generations	Resistance	Susceptible	Total	Genetic ratio R: S
EC169430 × 15/RES-4				
P1	33	4	37	
P2	26	0	26	
F1	22	0	22	
F2	264	26	290	15:01
B1	39	12	51	1:00
B2	45	2	47	1:00
IC117123 × 15/RES-4				
P1	2	22	24	
P2	28	0	28	
F1	23	0	23	
F2	212	89	301	3:01
B1	31	22	53	1:01
B2	37	11	48	1:00
IC117328 × 15/RES-4				
P1	29	1	30	
P2	26	0	26	
F1	22	0	22	
F2	205	79	284	3:01
B1	35	19	54	1:01
B2	36	11	47	1:00
IC117123× IC117328				
P1	0	21	21	
P2	0	28	28	
F1	0	19	19	
F2	0	270	270	
B1	0	46	46	
B2	0	49	49	

(Tolerant: Susceptible) in BC₁ generations (backcross with IC117123 and IC117328), but progenies of BC₁ did not fit into the expected ratio of 1: 0 (Resistant: Susceptible) plants in both the crosses, which was in accordance with findings of Arora *et al.* (2008) and Jambhale *et al.* (1981). In Cross IC117123 × IC117328 (Susceptible × Susceptible), no tolerant plant was found both in F₂ as well as in backcross populations.

Considering the segregation pattern of resistance and susceptible plants of all the crosses studied, it could be stated that a single dominant gene along with some minor factors governed the disease resistance in both the resistant parents. It was also observed that the two genes governing disease resistance in the resistant varieties were different and there is a scope of increasing the resistance level of the hybrid when these two genes were brought together in the F₁ generation due to the duplication effect. This confirmation of two different genes governing disease resistance in 15/RES-4 and EC169430 supported our earlier hypothesis that resistance mechanism against YVMV for these two varieties was different. It proved that at least at the genetical level genes governing tolerance trait was different and thus the huge variation in days to the first appearance of YVMV symptom between these two varieties. Hence, it is more of a complicated genetic inheritance rather than a simple one involved in this trait.

4.6.2 Quantitative genetic analysis

Mean data for six generations and the estimates for the scales 'A', 'B', 'C' and 'D' from the crosses were summarized in table 4.36. The estimates of the gene effects based on scaling tests for the six-parameter model were presented in table 4.37. Significant value of 'A' and 'B' scaling tests provided the evidence for the presence of additive × additive [i], additive × dominance [j] and dominance × dominance [l] types of gene interaction. Significant 'C' scaling tests provided evidence for [l] type epistasis, whereas 'D' scaling tests gave information about [i] types of gene interaction. Considering the sign of [h] and [l] it is possible to identify the nature of epistasis as duplicate (when they have different signs) and complementary (when they have the same sign).

4.6.2.1 Days to the first appearance of YVMV disease

In Cross I, A and C scale along with the gene effects, [M] and [h] were found to be significant, while Cross II data revealed significant value of A, B and C scales along with significant [d], [h], [i] values and Cross III showed significant values of A and C scale

along with gene effects, [M] and [h]. However, in Cross IV a complete absence of significance for all the scales and gene effects was observed.

Significance of the scale 'A' and 'C' in Cross I revealed the presence of all three types of non-allelic gene interactions, while significant values of [h] and [l] gene effects revealed the presence of dominance and dominance $\times$ dominance types of gene interactions. The values of [h] and [l] had the different sign which suggested duplicate type of epistasis for this trait in this particular cross.

In Cross II, significant estimates obtained for scales 'A', 'B' and 'C' indicated the presence of all the three types of non-allelic gene interactions viz. [i], [j], and [l] and significant values of [d], [h], [i] and [j] gene effects revealed the presence of additive, dominance, additive $\times$ additive and additive $\times$ dominance types of gene interactions, respectively. The values of [h] and [l] attained the different signs which suggested duplicate type of epistasis.

Significance of scale 'A' and 'C' along with the gene effects, [M] and [h] in Cross III indicated the presence of dominance gene action. Positive significant [h] effects in this cross combination suggested that heterosis breeding would be effective for this trait.

While non-significant values of all the four scales and gene effects in the case of Cross IV suggested the absence of epistasis in the expression of this character in this particular cross.

4.6.2.2 Node at which the first disease appeared

Significance A, B and C scale along with the gene effects, [M], [d], [h], [j] and [l] were exhibited by cross I and cross II, while cross III showed significant values of C scale along with gene effects, [M], [d], [h], [j] and [l]. However, in Cross IV a complete absence of significance for all the scales and gene effects was observed.

Significant values of A, B and C scales in case of Cross I and II revealed the presence of additive $\times$ additive, additive $\times$ dominance, and dominance $\times$ dominance types of epistasis while significant values of [h] and [l] indicated the influence of dominance and dominance $\times$ dominance types of gene interactions, respectively. A different sign of [h] and [l] revealed duplicate type of epistasis. While the significance of scale C along with

significant values of [h] and [l] in Cross III also suggest the presence of dominance and dominance $\times$ dominance types of gene interactions, respectively.

While non-significant values of all the four scales and gene effects in the case of Cross IV suggested the absence of epistasis in the expression of this character in this particular cross.

4.6.2.3 Percent Disease Incidence (PDI) of YVMV

Significant A and C scales along with [M], [d], [h], [j] and [l] values were exhibited in Cross I. B scale in addition to [M], [h], [i], [j] and [l] gene effects showed significant values in Cross II while significant A, B and C scales along with [M], [i], [j] and [l] were observed in Cross III. Cross IV data revealed a complete absence of significance for all the scales.

In Cross I, the scales 'A' and 'C' were found significant, which revealed the presence of all three types of non-allelic gene interactions, while significant values of [d], [h], [j] and [l] gene effects revealed the presence of additive, dominance, additive $\times$ dominance and dominance $\times$ dominance types of gene interactions. The values of [h] and [l] had the different sign which suggested duplicate type of epistasis for this trait in this particular cross.

B scale in addition to [h], [i], [j] and [l] gene effects showed significant values in Cross II exhibited that dominance, additive $\times$ additive, additive $\times$ dominance and dominance $\times$ dominance types of gene interactions. The values of [h] and [l] had the different sign which suggested duplicate type of epistasis for this trait in this particular cross.

Significant values of A, B and C scales in case of Cross III revealed the presence of three types of epistasis while significant values of [i], [j] and [l] indicated the influence of additive $\times$ additive, additive $\times$ dominance and dominance $\times$ dominance types of gene interactions, respectively. A different sign of [h] and [l] revealed duplicate type of epistasis.

While non-significant values of all the four scales and gene effects in the case of Cross IV suggested the absence of epistasis in the expression of this character in this particular cross.

In the present study, it was observed that both the additive and non-additive type of gene effects played the key role in the expression of both the YVMV resistance-related characters. Higher magnitude of dominance gene effects as compared to the corresponding additive effects in two crosses (I, II and III) for days to the first appearance of YVMV disease suggested that heterosis breeding method would be a useful approach for this trait. In the case of PDI, the magnitude of dominance effect was higher compared to additive effect along with a higher magnitude of dominance $\times$ dominance but mostly with a negative sign, compared to the other two interactions. This revealed heterosis breeding and recombination breeding followed by selection of transgressive segregants to be the most suitable breeding method for improvement of this population for this character.

The prevalence of duplicate epistasis revealed that the pace of progress through conventional selection process would be hindered as duplicate epistasis might result in decreased variation in F_2 and subsequent generations. Recurrent selection in biparental progenies would be helpful for exploiting this type of non-allelic interaction through the generation of high frequency of desirable recombination and concentration of genes having cumulative effects in the population.

Table 4.36: Estimates of gene effects based on scaling test for YVMV related traits in okra

Crosses	Genetic components			
	A	B	C	D
	Days to first appearance of YVMV disease			
EC169430 × 15/RES-4	4.87** ± 7.33	63.00 ± 2.00	18.67** ± 8.27	-0.68 ± 5.42
IC117123 × 15/RES-4	10.39** ± 3.79	12.25** ± 8.00	7.00** ± 16.28	-1.29 ± 9.02
IC117328 × 15/RES-4	13.79** ± 2.83	92.38 ± 1.15	10.27** ± 14.19	0.00 ± 7.12
IC117123× IC117328	0.32 ± 6.16	1.93 ± 6.22	1.71 ± 10.12	0.33 ± 5.03
	Node at which first disease appeared			
EC169430 × 15/RES-4	7.00** ± 1.00	6.93** ± 3.46	7.03** ± 4.12	-0.38 ± 2.65
IC117123 × 15/RES-4	5.02** ± 1.53	11.00** ± 2.00	7.52** ± 4.12	0.29 ± 2.31
IC117328 × 15/RES-4	0.00 ± 0.00	19.63 ± 1.15	7.75** ± 4.00	0.32 ± 2.08
IC117123× IC117328	0.58 ± 1.15	0.84 ± 2.38	0.57 ± 8.16	0.24 ± 4.12
	Percent Disease Incidence (PDI) of YVMV			
EC169430 × 15/RES-4	4.52** ± 6.45	1.44 ± 5.77	3.92** ± 10.41	0.26 ± 6.45
IC117123 × 15/RES-4	0.64 ± 16.83	3.40** ± 13.23	1.68 ± 29.30	-0.23 ± 14.72
IC117328 × 15/RES-4	2.61* ± 4.79	4.04** ± 11.55	6.15** ± 10.70	0.43 ± 7.77
IC117123× IC117328	1.80 ± 10.21	0.94 ± 9.79	-0.33 ± 22.87	-1.54 ± 11.37

Table 4.37: Estimates of gene effects based on scaling test for six parameter model in inter-varietal crosses for YVMV disease related traits in okra

Crosses	Genetic components					
	M	d	h	i	j	l
	Days to first appearance of YVMV disease					
EC169430 × 15/RES-4	4.97** ± 4.32	24.01 ± 1.20	13.15** ± 11.22	1.77 ± 4.15	-23.69** ± 3.81	-24.06 ± 7.02
IC117123 × 15/RES-4	-1.72 ± 3.69	18.44** ± 0.92	17.32** ± 9.64	6.53** ± 3.57	-18.32** ± 3.20	-26.51 ± 6.06
IC117328 × 15/RES-4	5.13 ** ± 3.99	20.25 ± 1.01	12.14 ** ± 10.31	0.00 ± 3.86	-19.90 ± 3.40	-22.63 ± 6.44
IC117123× IC117328	10.29 ** ± 3.76	-1.00 ± 1.33	0.60 ± 9.96	-0.95 ± 3.51	-2.76* ± 3.63	-1.49 ± 7.16
	Node at which first disease appeared					
EC169430 × 15/RES-4	1.86 ± 1.89	10.49** ± 0.52	6.02** ± 4.90	1.10 ± 1.81	-10.20** ± 1.67	-10.75** ± 3.07
IC117123 × 15/RES-4	3.18* ± 1.84	9.49** ± 0.47	4.76** ± 4.73	-0.75 ± 1.77	-9.16** ± 1.56	-9.61** ± 2.95
IC117328 × 15/RES-4	3.18** ± 1.84	9.49** ± 0.47	4.76** ± 4.73	-0.75 ± 1.77	-10.02** ± 1.56	-9.61** ± 2.95
IC117123× IC117328	5.53** ± 1.69	-0.55 ± 0.61	-0.52 ± 4.46	-1.27 ± 1.57	-0.82 ± 1.63	-0.21 ± 3.17
	Percent Disease Incidence (PDI) of YVMV					
EC169430 × 15/RES-4	3.91** ± 2.02	9.57** ± 0.48	5.06** ± 5.18	-1.70 ± 1.97	12.49** ± 1.67	-10.60** ± 3.22
IC117123 × 15/RES-4	8.06** ± 3.36	25.98 ± 1.30	4.00** ± 8.85	2.15* ± 3.10	-10.00** ± 3.42	-11.20** ± 5.58
IC117328 × 15/RES-4	12.23** ± 3.58	27.23 ± 1.36	0.94 ± 9.33	-2.02* ± 3.31	-9.57** ± 3.57	-8.96** ± 5.86
IC117123× IC117328	6.96** ± 5.21	0.66 ± 1.89	6.94** ± 13.99	7.21** ± 4.85	1.77 ± 5.17	-6.14** ± 10.17



EC169430 (P_1)



15/RES-4 (P_2)



EC169430 $\times$ 15/RES-4 (F_1)



(EC169430 $\times$ 15/RES-4) (F_2)



(EC169430 $\times$ 15/RES-4) $\times$ EC169430 (BC_1)



(EC169430 $\times$ 15/RES-4) $\times$ 15/RES-4 (BC_2)

Plate 2: Generations of (Resistant $\times$ Resistant) Parent



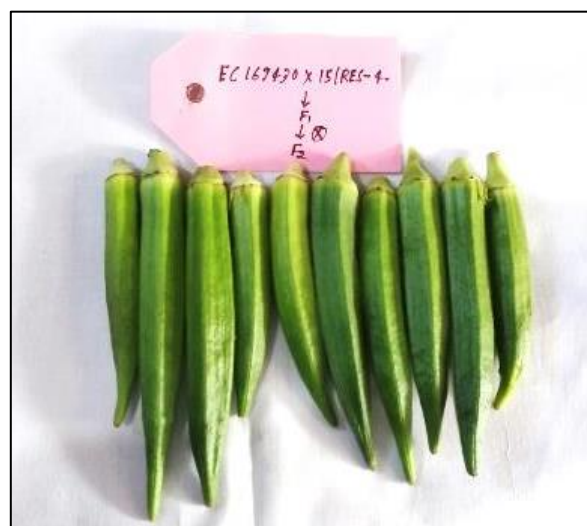
EC169430 (P_1)



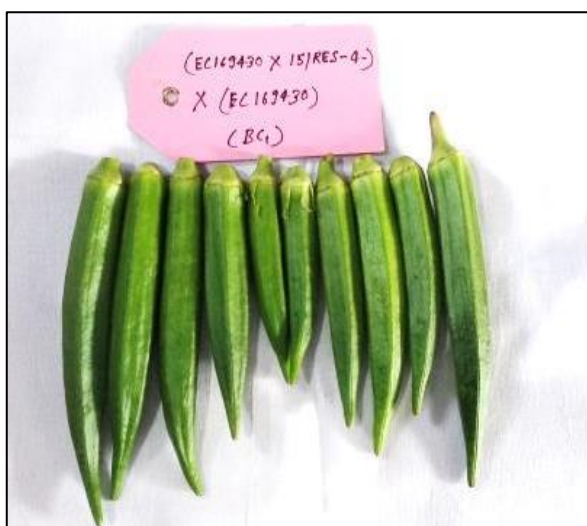
15/RES-4 (P_2)



EC169430 $\times$ 15/RES-4 (F_1)



(EC169430 $\times$ 15/RES-4) (F_2)



(EC169430 $\times$ 15/RES-4) $\times$ EC169430 (BC_1)



(EC169430 $\times$ 15/RES-4) $\times$ 15/RES-4 (BC_2)

Plate 3: Generations of (Resistant $\times$ Resistant) Parent



IC117123 (**P₁**)



15/RES-4 (**P₂**)



IC117123 × 15/RES-4 (**F₁**)



IC117123 × 15/RES-4 (**F₂**)



(IC117123 × 15/RES-4) × IC117123 (**BC₁**)



(IC117123 × 15/RES-4) × 15/RES-4 (**BC₂**)

Plate 4: Generations of (Resistant × Susceptible) Parent



IC117123 (P_1)



15/RES-4 (P_2)



IC117123 $\times$ 15/RES-4 (F_1)



IC117123 $\times$ 15/RES-4 (F_2)



(IC117123 $\times$ 15/RES-4) $\times$ IC117123 (BC_1)



(IC117123 $\times$ 15/RES-4) $\times$ 15/RES-4 (BC_2)

Plate 5: Generations of (Resistant $\times$ Susceptible) Parent



Summary and Conclusions



The present investigation entitled, “Genetic studies for yield and YVMV resistance in okra [*Abelmoschus esculentus* (L.) Moench]” was carried out at Vegetable Research Center of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The major objectives of the study were to know the various genetic parameters associated with yield, the extent of heterosis, combining ability, gene action and inheritance of resistance to YVMV in okra.

The experimental material for the present study comprised of 15 genetically diverse parents (11 lines and 4 testers) for yield, earliness and YVMV resistance of okra. These parents were collected from the National Bureau of Plant Genetic Resources (NBPGR), New Delhi and Indian Institute of Vegetable Research (IIVR), Varanasi. From these 15 genotypes, 44 crosses were evolved in a line x tester mating design with 11 genotypes as female parents (lines) and 4 genotypes as male parents (testers). Male parents used as testers were Pusa A 4, VRO 6, Parbhani Kranti and 15/RES-4. Female parents used as lines were, IC093591, EC169430, EC169435, EC169506, EC169400, EC169408, IC117123, IC117245, IC117351, IC117355 and IC117328. Thus, the experimental materials finally consisted of 60 treatments [(44 F_1 s, 15 parents and 1 check (Arka Anamika)] which were evaluated for combining ability and heterosis studies. The genotypes were studied for characters viz., Days to 50% flowering, first fruit-producing node, fruit length (cm), fruit diameter (mm), average fruit weight (g), number of fruits per plant, number of primary branches per plant, stem diameter (mm), inter-nodal length (cm), plant height (cm), fruit yield per plant (g), total yield q/ha and number of seeds per fruit. The observations were recorded on five randomly selected plants. The salient findings of the investigation are summarized as follows:

- The analysis of variance revealed that significant genetic differences were present among the okra genotypes for the 13 characters studied, which showed the existence of the significant amount of variability among the experimental material and hence, greater scope for the improvement of concerned characters through selection.

- Moderate to a wide range of mean values among the genotypes for different characters were observed. The value of PCV estimates was higher than the corresponding GCV estimates for all the characters, indicating the considerable influence of environmental factors on the performance of genotypes for different characters.
- Moderate to high GCV together with moderate to high heritability and genetic advance as per cent of mean was reported for the majority of the characters under study except days to 50% flowering and fruit length which indicated predominant additive gene action thus these traits has ample scope for the improvement of concerned traits through selection.
- For yellow vein mosaic virus incidence, parent 15/RES-4 and there all 11 F₁s hybrids showed a highly resistant reaction. Whereas, parents EC 169430, EC 169435 and their crosses EC 169430 × Pusa A 4, EC 169430 × VRO 6; EC 169435 × Pusa A 4, EC 169435 × VRO 6, EC 169435 × Parbhani Kranti and EC169408 × Pusa A 4 showed moderate resistant reaction at 75 days after showing. The moderately susceptible reaction was exhibited by parents IC 117355, IC 117328, Parbhani Kranti, Arka Anamika (Check), and F₁ hybrids such as EC 169430 × Parbhani Kranti and EC169408 × VRO 6 at 75 days after showing. The remaining 49 genotypes including parents and F₁ hybrids showed a susceptible reaction. Therefore, 15/RES-4 genotypes and their F₁ hybrid studied in this investigation showed highly resistant reaction against yellow vein mosaic virus. So, these hybrids can be used as a commercial scale.
- In the present study, the extent of heterosis was studied in 44 F₁ hybrids of okra. For the development of early fruiting genotypes, negative heterosis is desirable for days to 50 per cent flowering and first fruit-producing node. While heterosis is also desirable for inter-nodal length in a negative direction. Most of the crosses manifested highly significant heterosis over mid, better parent and standard parent for all the characters under study.
- For days to 50% flowering most promising crosses were EC169400 × Pusa A4, IC117245 × Pusa A4, IC117351 × VRO 6 and IC117355 × Parbhani Kranti over both the season, respectively. While none of the cross combinations exhibited consistent significant negative desired heterosis for first fruit-producing node. EC169430 × Parbhani Kranti and EC169435 × Parbhani Kranti during summer and rainy season

respectively were most promising cross for fruit length, which exhibited significant positive heterosis over mid parent, a better parent and standard check, respectively while none of the cross combinations exhibited consistent significant heterosis over both seasons consistently. EC 169408 $\times$ 15/RES-4 during summer was most promising cross for fruit diameter, which exhibited significant positive heterosis over mid parent, a better parent and standard check, respectively while none of the cross combinations exhibited consistent significant heterosis over both seasons consistently. Average fruit weight directly affects the total fruit yield per plant, so this character is very important for improvement. Among the hybrids evaluated, during both the seasons consistently, three promising cross combinations viz., EC169430 $\times$ VRO 6, EC169430 $\times$ 15/RES-4 and EC169435 $\times$ Parbhani Kranti recorded significant positive desired heterosis over mid parent as well as standard check for average fruit weight. Whereas, only one cross combinations EC169430 $\times$ VRO 6 were exhibited significant positive desired heterosis over better parent for the same trait during both the seasons consistently. Based on *per se* performance four promising cross combinations viz., EC169430 $\times$ VRO 6, EC169435 $\times$ VRO 6, EC169408 $\times$ Pusa A4 and EC169408 $\times$ VRO 6 showed significant positive desired heterosis over both mid parents as well as the better parent for number of fruits per plant. EC169408 $\times$ Pusa A4 also exhibited significant standard heterosis during both the season consistently. None of the cross combinations exhibited consistent significant heterosis over both seasons for primary branches per plant, while EC169408 $\times$ VRO 6 during summer and EC169430 $\times$ 15/RES-4 during rainy season showed significant heterosis over mid, better and standard parent, respectively. For stem diameter, out of all crosses, only one cross combination EC169408 $\times$ Pusa A4 had exhibited consistent significant positive heterosis over mid parent during both the season, while this cross combination also showed significant positive heterosis over better parent and standard parent during summer season consistently. IC117355 $\times$ VRO 6 promising cross combination was identified for inter-nodal length which exhibited significant negative desired heterosis over mid parent, a better parent and standard parent during both seasons consistently. Five most promising cross combinations for plant height were EC 169430 $\times$ VRO 6, EC 169430 $\times$ P. Kranti, EC 169435 $\times$ P. Kranti, IC 117123 $\times$ P. Kranti and IC 117351 $\times$ P. Kranti which showed consistent significant positive heterosis over mid parent, better parent and standard parent during summer

season while none of the cross combinations was showed significant positive heterosis for same traits.

- Fruit yield per plant is an important trait and should be given prime importance in okra breeding for hybrid development. Among the entire cross combinations, five promising hybrids identified for fruit yield per plant were EC169430 × VRO 6, EC169435 × VRO 6, EC169435 × Parbhani Kranti, EC169408 × Pusa A4 and EC169408 × VRO 6 exhibited significant positive desired relative heterosis, heterobeltiosis and standard heterosis consistently over both the seasons.
- Among crosses, two most promising cross combinations for number of seeds per fruit were identified *i.e.* EC169430 × VRO 6 and EC169435 × Parbhani Kranti which exhibited consistent significant positive heterosis over mid parent, a better parent and standard parent consistently.
- Among forty-four crosses, the most promising cross combinations *viz.*, EC169430 × VRO 6, EC169435 × Parbhani Kranti and EC169408 × VRO 6 were identified based on better parent and standard parent heterosis for many traits like fruit yield per plant, number of fruits per plant, number of primary branches per plant, average fruit weight, stem diameter and number of seeds per fruit. The *per se* performance of these crosses was also superior over other crosses studied hence these crosses could be utilized as commercial hybrids.
- IC093655 was identified as a best general combiner for maximum number of traits *viz.*, days to 50% flowering, fruit length, average fruit weight, number of fruits per plant, stem diameter, fruit yield per plant and number of seeds per fruit during the summer season. Whereas, during the rainy season, EC169430 was recognized as a good general combiner for average fruit weight, number of fruits per plant, plant height, fruit yield per plant and number of seeds per fruit followed by EC169400 for average fruit weight, number of fruits per plant, stem diameter and fruit yield per plant. Over both the seasons, EC169400 was identified as a consistent best general combiner for four traits *viz.*, average fruit weight, number of fruits per plant, stem diameter and fruit yield per plant. For earliness character (days to 50 per cent flowering) IC093655, IC117245 and IC117123 were identified as good general combiners. Ranking of desirable parents

based on *per se* performance, GCA and sca effects for 12 characters (Table 5.1 and 5.2) revealed that it was difficult to pick up a single good combiner for all the characters.

- In the present study, during summer season the best specific crosses were IC117328 × P. Kranti, EC169408 × 15/RES-4 and IC117123 × 15/RES-4 for earliness, IC117328 × VRO 6 for first fruit-producing node, IC117123 × P. Kranti for fruit length, IC117123 × P. Kranti for average fruit weight, EC169430 × VRO 6, EC169408 × VRO 6 and EC169408 × Pusa A4 for number of fruits per plant, EC169435 × P. Kranti for number of primary branches per plant, EC169408 × VRO 6 for stem diameter, EC169400 × Pusa A4 for inter-nodal length, EC169408 × Pusa A4 for plant height, EC169430 × VRO 6 EC169408 × P. Kranti and EC169435 × VRO 6 for fruit yield per plant and EC169430 × VRO 6 for number of seeds per fruit.
- However, during rainy season best specific cross combinations were identified as IC093655 × VRO 6, EC169435 × P. Kranti and EC169430 × VRO 6 for average fruit weight, EC169430 × P. Kranti, EC169430 × VRO 6 and IC093655 × VRO 6 for number of fruits per plant, IC093655 × VRO 6 for stem diameter, IC117245 × VRO 6 for inter-nodal length, IC093655 × VRO 6, EC169430 × VRO 6 and EC169430 × P. Kranti for fruit yield per plant and EC169430 × VRO 6 for number of seeds per fruit.
- Over both the seasons consistently, cross combinations viz., EC169430 × VRO 6 and EC169408 × 15/RES-4 for fruit yield per plant, EC169408 × VRO 6, EC169408 × Pusa A4 and EC169408 × 15/RES-4 for number of fruits per plant, EC169430 × VRO 6 and EC169408 × 15/RES-4 for average fruit weight and EC169430 × VRO 6 and EC169435 × 15/RES-4 for number of seeds per fruit were identified.
- The estimates of σ^2 GCA/ σ^2 SCA indicated predominance of non-additive gene action for most of the characters except fruit diameter during the summer season. Whereas, during the rainy season, the estimate of σ^2 GCA/ σ^2 SCA indicated predominance of non-additive gene action for all thirteen different characters.
- The inheritance pattern suggested that resistance to YVMV is controlled by two duplicate dominant genes in resistant × resistant (R × R) and single dominant gene along with some minor effects in resistant × susceptible (R × S) cross combinations.

Conclusion

Thus, based on finding of present investigation, it can be concluded that EC169430 × VRO 6, EC169435 × Parbhani Kranti and EC169408 × VRO 6 were identified as most promising cross combinations in among 44 crosses for many traits viz., fruit yield per plant, number of fruits per plant, number of primary branches per plant, average fruit weight, stem diameter and number of seeds per fruit. The *per se* performance of these crosses was also superior over other crosses studied hence these crosses could be utilized as commercial hybrids.

Table 5.1: Ranking of parents and crosses based on *per se* performance during summer and rainy season of 2018

S.No.	Character	Mean basis			
		Best parent		Best F ₁	
		Summer	Rainy	Summer	Rainy
1.	Days to 50% flowering	IC 117245 (44.67) IC 117355 (44.67) P. Kranti (44.67)	IC 117245 (47.33) IC 117355 (46.67) P. Kranti (47.33)	EC 169400 × P. Kranti (44.00) IC 117123 × Pusa A 4 (44.33) IC 117123 × P. Kranti (44.33)	EC 169435 × 15/RES-4 (47.00) EC 169400 × P. Kranti (47.00) IC 117123 × P. Kranti (47.33)
2.	First fruit producing node	IC 117245 (3.67) IC 117355 (3.77) IC 117328 (3.78)	EC 169435 (5.56) EC 169506 (5.89) EC 169430 (6.00)	IC 093655 × Pusa A 4 (3.32) IC 117245 × Pusa A 4 (3.33) IC 117328 × Pusa A 4 (3.40)	EC 169506 × 15/RES-4 (4.67) IC 117355 × 15/RES-4 (4.78) EC 169400 × 15/RES-4 (4.89)
3.	Fruit length (cm)	VRO 6 (10.00) IC 117245 (9.55) EC 169435 (9.50)	IC 117351 (15.91) EC 169430 (15.57) IC 117355 (14.74)	EC 169430 × P. Kranti (11.61) EC 169400 × P. Kranti (11.39) IC 117123 × P. Kranti (11.15)	EC 169430 × 15/RES-4 (15.66) EC 169408 × 15/RES-4 (15.56) EC 169435 × P. Kranti (14.91)
4.	Fruit diameter (mm)	IC 093655 (14.49) IC 117328 (14.35) Pusa A 4 (14.22)	EC 169430 (16.50) IC 117351 (16.16) Pusa A 4 (16.15)	EC 169506 × Pusa A 4 (15.09) EC 169408 × P. Kranti (15.03) IC 117351 × VRO 6 (15.01)	EC 169408 × 15/RES-4 (16.81) EC 169430 × 15/RES-4 (16.22) EC 169506 × P. Kranti (15.88)
5.	Average Fruit weight (g)	IC 093655 (13.34) Pusa A 4 (12.73) IC 117355 (12.67)	EC 169408 (13.78) EC 169400 (13.64) EC 169435 (13.50)	EC 169435 × VRO 6 (15.10) IC 117123 × P. Kranti (14.83) IC 117328 × VRO 6 (14.23)	IC 093655 × VRO 6 (14.23) EC 169430 × Pusa A 4 (14.08) EC 169506 × P. Kranti (13.54)
6.	Number of fruits per plant	EC 169435 (14.53) EC 169430 (14.49) IC 117355 (13.31)	P. Kranti (19.33) IC 117245 (19.22) IC 117351 (19.22)	EC 169408 × VRO 6 (25.67) IC 117355 × VRO 6 (24.07) EC 169435 × VRO 6 (22.07)	EC 169408 × Pusa A 4 (20.67) EC 169430 × P. Kranti (20.22) EC 169430 × VRO 6 (19.89)
7.	Number of primary branches per plant	IC 117123 (2.81) Pusa A 4 (2.81) VRO 6 (2.72)	EC 169506 (2.14) EC 169400 (2.11) EC 169408 (2.11)	EC 169408 × VRO 6 (3.33) EC 169435 × P. Kranti (3.19) EC 169408 × 15/RES-4 (3.19)	EC 169408 × 15/RES-4 (2.56) EC 169430 × 15/RES-4 (2.56) EC 169435 × P. Kranti (2.33)

8.	Stem diameter (mm)	EC 169430 (18.78) EC 169408 (18.42) EC 169435 (17.63)	IC 117123 (19.60) IC 117328 (19.34) P. Kranti (18.80)	EC 169408 × VRO 6 (20.89) EC 169435 × P. Kranti (20.17) EC 169430 × Pusa A 4 (19.80)	EC 169430 × 15/RES-4 (20.29) EC 169435 × 15/RES-4 (19.84) EC 169408 × 15/RES-4 (19.70)
9.	Internodal length (cm)	15/RES-4 (4.27) IC 117328 (4.77) IC 117355 (4.85)	15/RES-4 (6.21) VRO 6 (6.28) EC 169506 (6.29)	IC 117355 × Pusa A 4 (4.15) IC 117355 × VRO 6 (4.23) IC 117328 × P. Kranti (4.25)	IC 117245 × VRO 6 (5.16) IC 117351 × 15/RES-4 (5.51) IC 093655 × 15/RES-4 (5.59)
10.	Plant height (cm)	EC 169400 (86.74) EC 169435 (82.43) EC 169430 (80.22)	EC 169430 (117.08) IC 117123 (112.20) IC 093655 (108.18)	EC 169408 × VRO 6 (87.57) EC 169430 × P. Kranti (87.03) EC 169408 × Pusa A 4 (87.03)	EC 169430 × Pusa A 4 (107.18) EC 169435 × Pusa A 4 (103.36) EC 169506 × Pusa A 4 (101.83)
11.	Fruit yield per plant (g)	EC 169435 (172.62) IC 117355 (169.00) EC 169430 (164.75)	P. Kranti (240.64) IC 117123 (235.62) EC 169408 (231.45)	EC 169435 × VRO 6 (333.14) EC 169408 × VRO 6 (316.23) IC 117355 × VRO 6 (316.22)	EC 169430 × Pusa A 4 (278.18) IC 093655 × VRO 6 (269.14) EC 169430 × VRO 6 (265.98)
12.	Total yield q/ha.	EC 169435 (115.08) IC 117355 (112.66) EC 169430 (109.83)	P. Kranti (133.69) IC 117123 (130.90) EC 169408 (128.58)	EC 169435 × VRO 6 (222.09) EC 169408 × VRO 6 (210.82) IC 117355 × VRO 6 (210.81)	EC 169430 × Pusa A 4 (154.54) IC 093655 × VRO 6 (149.52) EC 169430 × VRO 6 (147.77)
13.	Number of seeds per fruit	Pusa A 4 (62.13) VRO 6 (61.03) P. Kranti (58.75)	EC 169408 (67.16) EC 169435 (66.28) P. Kranti (61.43)	EC 169430 × VRO 6 (67.34) IC 117245 × P. Kranti(65.38) EC 169506 × P. Kranti (64.26)	EC 169430 × VRO 6 (74.59) EC 169430 × P. Kranti (67.38) EC 169430 × Pusa A 4 (67.34)

Table 5.2: Ranking of parents and crosses based on gca and sca effects during summer and rainy season of 2018

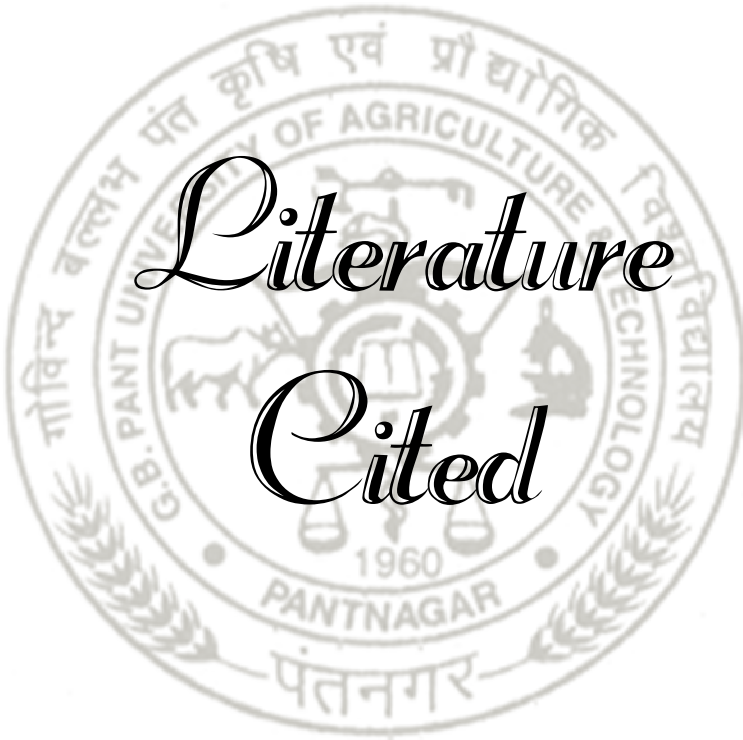
Character	Estimates basis					
	Best general combiner			Best specific combiner		
	Summer	Rainy	During both season	Summer	Rainy	During both season
Days to 50% flowering	IC093655 (-1.485**) IC117245 (-1.485**) IC117123 (-1.318**)	-	-	IC117328 × P. Kranti (-3.008**) EC169408 × 15/RES-4 (-2.00**) IC117123 × 15/RES-4 (-1.727*)	-	-
First fruit producing node	IC117328 (-0.412*)	IC117328 (-0.770**) IC117355 (-0.688**)	IC117328	IC117328 × VRO 6 (-1.135**) EC169400 × Pusa A4 (-0.981**) EC169506 × VRO 6 (-0.937**)	-	-
Fruit length (cm)	IC093655 (1.076**) IC117123 (0.972**)	-	-	IC117123 × P. Kranti (1.610**)	-	
Fruit diameter (mm)	IC117123 (1.384**) EC169430 (1.047*)	-	-	-	EC169430 × 15/RES-4 (1.504)	
Average Fruit weight (g)	IC093655 (1.717**) EC169400 (1.002**)	EC169430 (1.099**) EC169400 (0.981**) IC117123 (0.753**)	EC169400	IC117123 × P. Kranti (3.013**) EC169435 × VRO 6 (2.290**) EC169430 × VRO 6 (1.796**)	IC093655 × VRO 6 (2.679**) EC169435 × P. Kranti (1.915**) EC169430 × VRO 6 (1.431*)	EC169430 × VRO 6 EC169408 × 15/RES-4
Number of fruits per plant	EC169400 (4.678**) IC093655 (4.292**) Pusa A4 (1.182**)	EC169400 (1.859**) EC169435 (1.219**) EC169430 (1.080**)	EC169400	EC169430 × VRO 6 (6.950**) EC169408 × VRO 6 (6.950**) EC169408 × Pusa A4 (5.460**)	EC169430 × P. Kranti (3.750**) EC169430 × VRO 6 (3.090**) IC093655 × VRO 6 (2.879**)	EC169408 × VRO 6 EC169408 × Pusa A4 EC169408 × 15/RES-4
Number of primary branches per plant	EC169400 (0.650**)	-	-	EC169435 × P. Kranti (0.910**) EC169408 × 15/RES-4 (0.772**) EC169430 × Pusa A4 (0.696*)	-	-

Stem diameter (mm)	IC093655 (1.915**) IC117123 (1.880**) EC169430 (1.560**)	EC169400 (1.135**) IC117351 (1.059**)	EC169400	EC169408 × VRO 6 (3.490**) EC169435 × 15/RES-4 (2.223*) IC117351 × Pusa A4 (2.199*)	IC093655 × VRO 6 (1.880*) EC169408 × 15/RES-4 (1.809*) EC169435 × P. Kranti (1.749*)	-
Internodal length (cm)	IC117328 (-0.647**) EC169506 (-0.462**) IC117245 (-0.299**)	IC117328 (-0.481*)	IC117328	EC169400 × Pusa A4 (-1.421**) IC117355 × VRO 6 (-1.409**) IC117328 × P. Kranti (-1.018*)	IC117245 × VRO 6 (-0.858*)	-
Plant height (cm)	EC169430 (11.232**) EC169400 (10.357**)	EC169430 (13.980**)	EC169430	EC169408 × Pusa A4 (20.363**) EC169430 × P. Kranti (15.498*) EC169430 × 15/RES-4 (15.135*)	-	-
Fruit yield per plant (g)	IC093655 (76.435**) EC169400 (73.883**)	EC169400 (38.738**) EC169430 (30.909**) IC117123 (22.447**)	EC169400	EC169430 × VRO 6 (114.187**) EC169408 × P. Kranti (82.734**) EC169435 × VRO 6 (82.701**)	IC093655 × VRO 6 (79.794**) EC169430 × VRO 6 (63.458**) EC169430 × P. Kranti (60.979**)	EC169430 × VRO 6 EC169408 × 15/RES-4
Number of seeds per fruit	EC169430(6.217**) IC093655 (3.833) EC169506 (2.655*)	IC093655 (5.914**) EC169506 (4.507*) EC169430(4.288**)	EC169430 IC093655 EC169506	EC169430 × VRO 6 (9.741**) IC117245 × P. Kranti (9.153**) EC169435 × 15/RES-4 (6.107**)	EC169430 × VRO 6 (13.020**) IC117351 × 15/RES-4 (9.559**) EC169430 × VRO 6 (9.031**)	EC169430 × VRO 6 EC169435 × 15/RES-4 IC117351 × 15/RES-4

Table 5.3: Ranking of parents and crosses based on heterosis during summer and rainy season of 2018

Characters	Heterosis summary					
	Mid parent		Better parent		Standard Heterosis	
	Summer	Rainy	Summer	Rainy	Summer	Rainy
Days to 50% flowering	IC 117351 × VRO 6 (-7.85) IC 117245 × Pusa A 4 (-7.22) EC 169435 × P. Kranti (-7.22)	EC 169400 × Pusa A 4 (-4.98) IC 117245 × Pusa A 4 (-4.64) IC 117351 × VRO 6 (-3.63)	EC 169435 × P. Kranti (-12.90) EC 169400 × Pusa A 4 (-12.90) IC 117245 × Pusa A 4 (-12.90)	EC 169400 × Pusa A 4 (-9.49) EC 169430 × VRO 6 (-8.86) EC 169435 × P. Kranti (-8.86)	-	-
First fruit producing node	IC 117245 × Pusa A 4 (-23.78) IC 093655 × Pusa A 4 (-23.75) IC 117328 × Pusa A 4 (-18.66)	IC 117328 × 15/RES-4 (-32.80) EC 169506 × 15/RES-4 (-30.03) IC 117355 × 15/RES-4 (-28.92)	IC 093655 × Pusa A 4 (-28.88) IC 117245 × Pusa A 4 (-28.52) IC 117328 × Pusa A 4 (-23.48)	IC 117355 × 15/RES-4 (-35.83) EC 169506 × 15/RES-4 (-34.36) IC 117351 × 15/RES-4 (-34.30)	IC 117245 × Pusa A 4 (-19.48) IC 093655 × Pusa A 4 (-19.89)	EC 169506 × 15/RES-4 (-26.32) IC 117355 × 15/RES-4 (-24.58) EC 169400 × 15/RES-4 (-22.79)
Fruit length (cm)	EC 169430 × P. Kranti (28.30) EC 169400 × P. Kranti (23.17) EC 169506 × Pusa A 4 (20.44)	EC 169435 × P. Kranti (14.65) EC 169408 × 15/RES-4 (11.25)	EC 169430 × P. Kranti (22.43) EC 169506 × Pusa A 4 (20.37) EC 169408 × P. Kranti (18.89)	-	EC 169430 × P. Kranti (24.94) EC 169400 × P. Kranti (22.57) IC 117123 × P. Kranti (19.99)	EC 169430 × 15/RES-4 (24.36) EC 169408 × 15/RES-4 (23.56) EC 169435 × P. Kranti (18.43)
Fruit diameter (mm)	-	EC 169408 × 15/RES-4 (17.92) IC 093655 × Pusa A 4 (15.07) EC 169408 × VRO 6 (12.60)	-	EC 169408 × 15/RES-4 (14.61) IC 093655 × Pusa A 4 (12.04)	EC 169506 × Pusa A 4 (19.42) EC 169408 × P. Kranti (18.94) IC 117351 × VRO 6 (18.79)	EC 169408 × 15/RES-4 (16.90) EC 169430 × 15/RES-4 (12.82)
Average Fruit weight (g)	EC 169430 × VRO 6 (33.59) IC 117123 × P. Kranti (33.08) IC 117351 × P. Kranti (30.35)	EC 169430 × VRO 6 (17.23) EC 169430 × Pusa A 4 (16.41) EC 169430 × 15/RES-4 (15.59)	EC 169430 × VRO 6 (29.19) IC 117351 × P. Kranti (23.00) EC 169435 × VRO 6 (18.56)	EC 169430 × 15/RES-4 (14.57) EC 169430 × Pusa A 4 (11.86) EC 169430 × VRO 6 (11.67)	EC 169435 × VRO 6 (39.23) IC 117123 × P. Kranti (36.77) IC 117328 × VRO 6 (31.20)	IC 093655 × VRO 6 (28.16) EC 169430 × Pusa A 4 (26.81) EC 169435 × P. Kranti (21.44)
Number of fruits per plant	EC 169408 × VRO 6 (174.02) IC 117355 × VRO 6 (158.83) EC 169430 × VRO 6 (144.53)	EC 169408 × Pusa A 4 (28.26) EC 169430 × VRO 6 (24.75) EC 169430 × P. Kranti (17.42)	IC 117355 × VRO 6 (134.49) EC 169408 × VRO 6 (120.00) EC 169435 × P. Kranti (110.40)	EC 169408 × Pusa A 4 (23.16) EC 169435 × VRO 6 (16.55) EC 169430 × VRO 6 (12.58)	EC 169408 × VRO 6 (151.88) IC 117355 × VRO 6 (136.18) EC 169435 × VRO 6 (116.55)	EC 169408 × Pusa A 4 (9.41)

Number of primary branches per plant	EC 169408 × VRO 6 (50.04) EC 169435 × VRO 6 (40.16) EC 169435 × P. Kranti (28.81)	EC 169430 × 15/RES-4 (27.94) EC 169408 × 15/RES-4 (27.83)	EC 169408 × VRO 6 (42.86) EC 169435 × P. Kranti (36.86)	EC 169430 × 15/RES-4 (27.83) EC 169408 × 15/RES-4 (27.83)	EC 169408 × VRO 6 (24.69)	EC 169430 × 15/RES-4 (35.27) EC 169408 × 15/RES-4 (35.27)
Stem diameter (mm)	EC 169408 × VRO 6 (42.24) EC 169435 × P. Kranti (36.03) EC 169408 × P. Kranti (21.19)	EC 169430 × 15/RES-4 (15.39) EC 169435 × VRO 6 (13.98) EC 169506 × VRO 6 (13.33)	EC 169408 × VRO 6 (39.02) EC 169435 × P. Kranti (31.74) IC 117355 × VRO 6 (20.89)	EC 169430 × 15/RES-4 (13.29)	EC 169408 × VRO 6 (33.43) EC 169435 × P. Kranti (28.85) EC 169430 × Pusa A 4 (26.46)	-
Inter-nodal length (cm)	IC 117328 × P. Kranti (-23.41) IC 117355 × Pusa A 4 (-19.77) IC 117355 × VRO 6 (-18.30)	IC 117245 × VRO 6 (-19.81) IC 093655 × 15/RES-4 (-15.74) IC 117355 × VRO 6 (-15.13)	IC 117245 × Pusa A 4 (-29.63) EC 169400 × Pusa A 4 (-27.52) IC 117328 × P. Kranti (-25.21)	IC 117245 × VRO 6 (-20.53) IC 093655 × 15/RES-4 (-17.44) IC 117355 × VRO 6 (-17.36)	IC 117355 × Pusa A 4 (-16.32) IC 093655 × 15/RES-4 (-14.84) IC 117328 × P. Kranti (-14.30)	IC 117245 × VRO 6 (-22.09) IC 117351 × 15/RES-4 (-16.76) IC 093655 × 15/RES-4 (-15.65)
Plant height (cm)	IC 117123 × P. Kranti (49.01) EC 169435 × P. Kranti (47.47) EC 169430 × P. Kranti (42.93)	-	IC 117123 × P. Kranti (44.13) IC 117351 × P. Kranti (39.66) EC 169430 × P. Kranti (30.75)	-	EC 169408 × VRO 6 (43.04) EC 169430 × P. Kranti (42.16) IC 117123 × Pusa A 4 (42.16)	-
Fruit yield per plant (g)	EC 169430 × VRO 6 (223.44) EC 169408 × VRO 6 (201.13) IC 117355 × VRO 6 (161.98)	EC 169430 × VRO 6 (46.74) EC 169435 × P. Kranti (33.23) EC 169430 × Pusa A 4 (30.52)	EC 169430 × VRO 6 (168.03) IC 117355 × VRO 6 (142.51) EC 169435 × VRO 6 (137.28)	EC 169430 × VRO 6 (38.65) EC 169435 × P. Kranti (32.60) EC 169408 × Pusa A 4 (23.41)	EC 169435 × VRO 6 (204.29) EC 169408 × VRO 6 (188.85) IC 117355 × VRO 6 (188.85)	EC 169430 × Pusa A 4 (32.44) IC 093655 × VRO 6 (28.13) EC 169430 × VRO 6 (26.63)
Number of seeds per fruit	EC 169435 × P. Kranti (34.25) EC 169430 × VRO 6 (31.85) EC 169400 × Pusa A 4 (23.75)	EC 169430 × VRO 6 (54.30) EC 169435 × P. Kranti (50.71) EC 169430 × P. Kranti (27.46)	EC 169435 × P. Kranti (30.13) EC 169430 × VRO 6 (17.90) IC 117351 × VRO 6 (13.29)	EC 169435 × P. Kranti (47.52) EC 169430 × VRO 6 (37.45) IC 117355 × P. Kranti (19.51)	EC 169430 × VRO 6 (12.06) IC 117245 × P. Kranti (8.80)	EC 169430 × VRO 6 (25.54) EC 169430 × Pusa A 4 (13.34) EC 169430 × P. Kranti (13.40)



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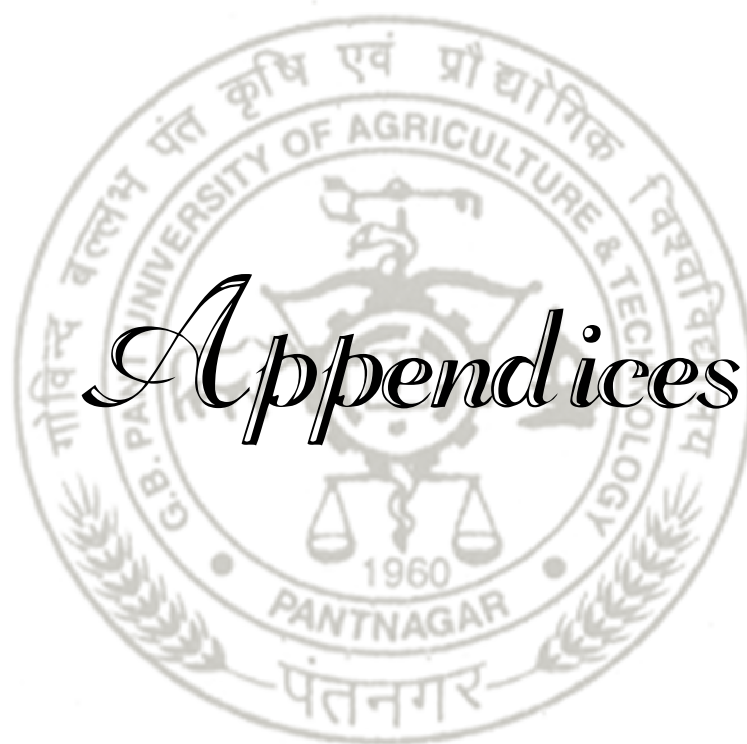
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APPENDIX

Weekly weather data during 2018

STATION NAME : PANTNAGAR
LATITUDE : 29 deg. N

LONGITUDE : 79 deg. 30' E
ALTITUDE : 243.84 m. AMSL

Month	Date	Year	Metro Week No. (2017)	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of Rainy Days	Sun-Shine Hrs.	Wind Velocity (km/hr.)	Evap. (mm)
				Max.	Min.	0712 am	1412 pm					
Jan	01-07	2018	1	22.6	9.3	92	59	000.0	0	06.3	3.6	1.8
Jan	08-14	2018	2	18.2	4.3	93	52	013.0	1	06.2	4.3	1.4
Jan	15-21	2018	3	19.2	7.0	95	59	000.0	0	04.5	4.9	1.3
Jan	22-28	2018	4	22.6	8.5	92	55	047.4	2	05.3	4.7	1.8
Jan-Feb	29-04	2018	5	21.2	9.4	93	60	000.0	0	05.3	3.3	1.6
Feb	05-11	2018	6	23.2	8.5	92	47	000.0	0	05.9	5.3	1.9
Feb	12-18	2018	7	25.2	9.3	91	49	000.0	0	07.1	2.8	1.6
Feb	19-25	2018	8	26.9	10.4	92	45	000.0	0	07.2	5.3	2.8
Feb-Mar	26-04	2018	9	27.4	9.5	87	39	000.8	1	08.0	4.4	2.9
Mar	05-11	2018	10	25.9	10.0	86	50	002.8	1	07.8	5.0	3.3
Mar	12-18	2018	11	25.6	7.9	88	36	000.0	0	08.4	6.3	3.6
Mar	19-25	2018	12	30.5	13.9	82	38	000.0	0	08.3	5.0	3.6
Mar-Apr	26-01	2018	13	34.6	16.9	82	34	000.0	0	09.1	6.0	4.8
Apr	02-08	2018	14	35.5	17.6	72	28	001.0	1	07.3	7.5	6.8
Apr	09-15	2018	15	35.3	15.1	66	21	000.0	0	09.5	7.1	7.0
Apr	16-22	2018	16	36.7	24.5	57	40	000.0	0	07.9	8.0	7.9
Apr	23-29	2018	17	37.4	20.5	61	23	003.0	1	09.0	8.2	9.0
Apr-May	30-06	2018	18	37.4	19.7	55	21	000.0	0	09.5	6.6	7.7
May	07-13	2018	19	37.3	23.7	62	40	006.0	1	10.1	8.1	8.1
May	14-20	2018	20	38.3	22.8	69	36	029.0	1	09.1	7.2	8.9
May	21-27	2018	21	38.6	23.8	65	35	003.6	2	09.4	6.9	8.9
May-Jun	28-03	2018	22	36.0	23.5	66	39	000.4	1	08.0	8.4	8.5
Jun	04-10	2018	23	37.4	25.4	66	50	007.0	1	05.9	8.5	7.8
Jun	11-17	2018	24	38.2	24.7	66	44	010.2	1	09.6	7.3	8.6
Jun	18-24	2018	25	35.9	25.6	76	54	001.0	1	06.8	5.8	6.3
Jun-Jul	25-01	2018	26	35.8	26.4	82	63	054.8	3	06.4	7.9	7.7
Jul	02-08	2018	27	31.0	25.4	94	83	207.2	7	02.1	5.6	4.8
Jul	09-15	2018	28	31.7	25.9	90	83	072.0	5	04.5	6.1	4.1
Jul	16-22	2018	29	33.9	26.2	87	75	080.4	5	06.6	5.2	4.7
Jul	23-29	2018	30	32.3	25.2	88	70	042.8	4	05.0	8.3	4.3
Jul-Aug	30-05	2018	31	31.2	25.7	91	82	203.8	6	02.6	6.5	3.7
Aug	06-12	2018	32	31.8	26.0	91	77	147.8	6	02.8	5.5	4.7
Aug	13-19	2018	33	32.7	25.6	92	71	118.8	5	03.4	6.5	4.2
Aug	20-26	2018	34	31.8	25.6	88	77	057.6	3	05.4	4.9	3.7
Aug-Sep	27-02	2018	35	31.8	25.0	89	76	120.8	4	04.8	5.0	3.9
Sep	03-09	2018	36	32.0	24.0	90	66	056.0	2	07.3	3.4	4.0
Sep	10-16	2018	37	34.0	25.2	86	64	000.0	0	08.5	3.0	4.2
Sep	17-23	2018	38	32.6	24.6	92	74	168.0	3	05.9	4.0	3.2
Sep	24-30	2018	39	32.3	23.4	88	65	007.2	1	05.4	3.5	3.2
Oct	01-07	2018	40	33.1	23.8	88	61	000.0	0	05.2	2.5	2.6
Oct	08-14	2018	41	33.6	20.3	78	48	000.0	0	08.3	2.4	3.2
Oct	15-21	2018	42	33.5	18.0	86	50	000.0	0	09.0	2.1	3.1
Oct	22-28	2018	43	30.8	14.5	87	46	000.0	0	07.9	2.5	2.7
Oct-Nov	29-04	2018	44	28.4	14.7	90	53	000.0	0	04.4	1.9	2.3
Nov	05-11	2018	45	28.7	12.8	94	52	000.0	0	04.8	1.3	2.0
Nov	12-18	2018	46	27.9	11.3	86	40	000.0	0	06.9	2.5	2.0
Nov	19-25	2018	47	26.1	8.6	93	43	000.0	0	07.3	4.2	2.5
Nov-Dec	26-02	2018	48	24.7	7.8	92	48	000.0	0	07.1	1.8	1.9
Dec	03-09	2018	49	23.3	10.9	93	60	000.0	0	03.7	2.5	1.6
Dec	10-16	2018	50	23.1	11.4	94	66	002.8	1	05.0	5.5	1.6
Dec	17-23	2018	51	21.3	8.3	95	64	000.0	0	05.6	3.0	1.4
Dec	24-31	2018	52	22.5	7.2	96	66	000.0	0	06.2	1.8	1.0

Weekly weather data during 2019

STATION NAME : PANTNAGAR

LONGITUDE : 79 deg. 30' E

LATITUDE : 29 deg. N

ALTITUDE : 243.84 m. AMSL

Month	Date	Year	Metro Week No. (2018)	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of Rainy Days	Sun- Shine Hrs.	Wind Velocity (km/hr.)	Evap. (mm)
				Max.	Min.	0712 am	1412 pm					
Jan	01-07	2019	1	15.2	6.0	95	81	000.0	0	02.5	3.0	0.8
Jan	08-14	2019	2	12.9	5.3	95	79	000.0	0	01.2	2.6	0.8
Jan	15-21	2019	3	20.2	4.2	93	65	000.0	0	05.5	2.7	1.2
Jan	22-28	2019	4	18.6	6.4	94	70	006.8	1	03.6	4.2	1.1
Jan-Feb	29-04	2019	5	20.6	6.9	94	60	000.0	0	05.8	3.9	1.2
Feb	05-11	2019	6	23.2	5.6	95	50	000.0	0	06.4	5.4	1.8
Feb	12-18	2019	7	23.0	9.2	93	61	004.0	2	06.1	5.3	1.9
Feb	19-25	2019	8	26.9	11.5	89	51	000.0	0	07.7	3.0	2.3
Feb-Mar	26-04	2019	9	28.7	11.5	91	44	000.0	0	07.5	5.6	3.1
Mar	05-11	2019	10	29.5	10.7	92	39	000.0	0	08.8	5.5	4.0
Mar	12-18	2019	11	31.1	11.8	81	44	000.0	0	08.5	4.9	4.3
Mar	19-25	2019	12	31.9	12.7	83	40	000.0	0	09.0	4.6	4.3
Mar-Apr	26-01	2019	13	33.6	14.5	78	47	000.0	0	08.2	5.3	5.8
Apr	02-08	2019	14	33.4	18.7	78	52	029.2	1	08.0	5.2	6.0
Apr	09-15	2019	15	31.3	16.2	81	49	013.0	2	06.4	4.6	4.8
Apr	16-22	2019	16	37.2	17.2	73	19	000.0	0	09.4	6.1	7.4
Apr	23-29	2019	17	36.2	19.5	65	36	000.0	0	09.2	7.1	7.7
Apr-May	30-06	2019	18	35.1	22.0	70	41	002.8	1	09.2	9.6	7.2
May	07-13	2019	19	37.0	21.1	67	32	000.0	0	08.4	7.5	8.3
May	14-20	2019	20	35.6	23.1	76	52	005.8	1	08.4	7.6	7.9
May	21-27	2019	21	39.7	22.5	65	34	000.0	0	09.3	7.8	9.4
May-Jun	28-03	2019	22	35.5	23.0	70	55	038.4	4	07.1	9.6	8.3
Jun	04-10	2019	23	35.1	26.0	82	64	087.6	2	07.7	7.5	8.0
Jun	11-17	2019	24	34.6	26.2	85	63	042.8	2	05.2	5.0	5.7
Jun	18-24	2019	25	37.2	26.1	76	45	000.0	0	07.9	6.0	6.8
Jun-Jul	25-01	2019	26	35.9	26.6	81	68	018.2	1	06.4	7.5	7.3
Jul	02-08	2019	27	32.6	25.4	90	70	180.8	3	06.0	3.5	5.6
Jul	09-15	2019	28	32.5	26.0	88	78	173.2	3	03.1	6.1	4.2
Jul	16-22	2019	29	33.3	26.9	82	73	079.6	2	06.7	3.7	6.6
Jul	23-29	2019	30	31.2	25.7	91	80	169.0	5	02.2	5.6	4.6
Jul-Aug	30-05	2019	31	29.7	24.1	94	84	218.1	7	01.0	2.2	3.5
Aug	06-12	2019	32	30.9	24.9	90	80	126.4	3	03.6	2.6	4.3
Aug	13-19	2019	33	31.9	26.1	89	72	073.4	3	04.0	1.5	3.3
Aug	20-26	2019	34	30.9	25.5	95	83	160.8	5	03.2	1.1	4.4
Aug-Sep	27-02	2019	35	30.7	25.5	92	81	086.8	5	02.0	3.3	2.7
Sep	03-09	2019	36	32.3	25.3	90	76	076.6	3	06.0	4.9	4.1
Sep	10-16	2019	37	31.9	24.3	93	78	015.6	2	05.6	6.0	3.9
Sep	17-23	2019	38	32.1	22.6	90	73	049.2	3	06.8	6.6	4.0
Sep	24-30	2019	39	30.4	22.0	91	70	080.6	2	04.6	5.4	3.1
Oct	01-07	2019	40	32.3	18.5	84	60	000.0	0	09.1	4.6	4.0
Oct	08-14	2019	41	30.9	17.1	83	61	002.6	1	07.3	4.7	3.5
Oct	15-21	2019	42	30.7	14.3	87	59	000.0	0	07.8	3.5	3.3
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Nov	05-11	2019	45	27.5	11.7	94	54	000.0	0	07.7	2.8	2.4
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Nov	19-25	2019	47	26.3	10.5	93	53	000.0	0	07.7	1.8	2.6
Nov-Dec	26-02	2019	48	25.8	10.7	95	61	000.0	0	06.4	1.9	2.3
Dec	03-09	2019	49	23.9	7.8	93	61	000.0	0	06.2	1.8	1.9
Dec	10-16	2019	50	22.6	6.6	95	60	000.8	0	06.3	1.9	2.0
Dec	17-23	2019	51	22.5	5.0	97	51	000.0	0	06.8	2.0	1.9
Dec	24-31	2019	52	20.3	3.9	97	52	000.0	0	06.7	2.0	1.5

The author was born on 15 August, 1991. He completed his graduation from N. D. University of Agriculture and Technology, Kumarganj, Ayodhya, U. P. in the year 2014. He had awarded best poster presentation in International Conference held at BHU, Varanasi and he is an author of a book “Vegetable Science” for competitive exam i.e. JRF, SRF and ARS. He had completed post graduate studies in B. A. U. Sabour, Bhagalpur, Bihar for M.Sc. Ag. Degree with major in Horticulture (Vegetable Science) in June 2016. He qualified ASRB NET(I)-2016 with 62%. He then joined Doctor of Philosophy in G.B. Pant University of Agriculture and Technology, Pantnagar, for Ph.D. degree with major in Horticulture (Vegetable Science) and minor in Genetics and Plant Breeding in 2016-17 and completed all the requirements for the same in February 2020.

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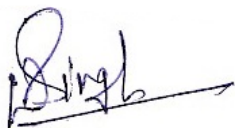
ABSTRACT

Name	: Ashish Kumar Singh	Id. No.	: 51243
Sem. and Year of Admission	: 2 nd Sem., 2016-17	Degree	: Ph.D.
Major	: Horticulture (Vegetable Science)	Department	: Vegetable Science
Minor	: Genetics and Plant Breeding		
Thesis Title	: GENETIC STUDIES FOR YIELD AND YVMV RESISTANCE IN OKRA [<i>Abelmoschus esculentus</i> (L.) Moench]		
Advisor	: Dr. Dharendra Kumar Singh		

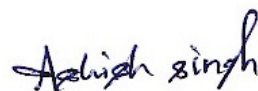
The present investigation was carried out during summer (2018) and rainy season (2018 and 2019) at Vegetable Research Center of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, with the objectives to assess genetic variability, heritability, genetic advance, heterosis, combining ability, gene action for different quantitative traits and inheritance study for YVMV resistance. The experimental material utilized for this study consists of 15 genotypes (11 lines and 4 testers) which were selected based on their diversity for various traits. From these fifteen parents, forty-four crosses were evolved in a line $\times$ tester mating design with eleven genotypes as female parents (lines) and four genotypes as male parents (testers).

The analysis of variance revealed that significant genetic differences were present among the okra genotypes for the thirteen characters studied. Moderate to wide range of mean values among the genotypes for different characters were observed. Moderate to high genotypic coefficient of variation together with moderate to high heritability and genetic advance as per cent of mean was reported for majority of the characters under study except days to 50 % flowering and fruit length which indicated predominant additive gene action thus these traits has ample scope for the improvement of concerned traits through selection. Parent 15/RES-4 and there all 11 F_1 s hybrid showed highly resistant reaction against YVMV.

Based on extent of heterosis, EC169430 $\times$ VRO 6, EC169435 $\times$ Parbhani Kranti and EC169408 $\times$ VRO 6 were identified most promising cross combinations among 44 crosses for many traits viz., fruit yield per plant, number of fruits per plant, number of primary branches per plant, average fruit weight, stem diameter and number of seeds per fruit. The *per se* performance of these crosses was also superior over other crosses studied hence these crosses could be utilized as commercial hybrids. EC169400 was identified as consistent best general combiner for four traits viz., average fruit weight, number of fruits per plant, stem diameter and fruit yield per plant. For earliness character (days to 50 per cent flowering) IC093655, IC117245 and IC117123 were identified as good general combiners. Ranking of desirable parents based on *per se* performance, gca and sca effects for 12 characters revealed that it was difficult to select a single good combiner for all the characters. Over both the seasons consistently, cross combinations viz., EC169430 $\times$ VRO 6 and EC169408 $\times$ 15/RES-4 for fruit yield per plant, EC169408 $\times$ VRO 6, EC169408 $\times$ Pusa A4 and EC169408 $\times$ 15/RES-4 for number of fruits per plant, EC169430 $\times$ VRO 6 and EC169408 $\times$ 15/RES-4 for average fruit weight and EC169430 $\times$ VRO 6 and EC169435 $\times$ 15/RES-4 for number of seeds per fruit showed specific combining ability effects of higher order. The estimates of σ^2 GCA/ σ^2 SCA indicated predominance of non-additive gene action for most of the characters over both the season consistently. The inheritance pattern suggested that resistance to YVMV is controlled by two duplicate dominant genes in resistant $\times$ resistant ($R \times R$) and single dominant gene along with some minor effects in resistant $\times$ susceptible ($R \times S$) cross combinations.



(Dhirendra Kumar Singh)
Advisor



(Ashish Kumar Singh)
Author

सारांश

नाम	: आशीष कुमार सिंह	परिचायक	: 51243
सत्र एवं प्रवेश वर्ष	: द्वितीय, २०१६-१७	उपाधि	: पीएच डी उद्यानिकी (सब्जी विज्ञान)
मुख्या विषय	: सब्जी विज्ञान	विभाग	: सब्जी विज्ञान
गोड़ विषय	: आनुवांशिकी एवं पादप प्रजनन		
शोध ग्रन्थ शीर्षक	: भिण्डी एबेलमोस्कोस एस्क्युलेंटस (एल) मोंच में उपज और वाई वी एम वी प्रतिरोधक के लिये आनुवांशिकी अध्ययन,		
सलाहकार	: डॉ धीरेन्द्र कुमार सिंह		

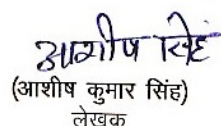
वर्तमान अन्वेषण गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय, पंतनगर, उधम सिंह नगर, उत्तराखंड के सब्जी अनुसंधान केंद्र में ग्रीष्म ऋतु (२०१८) और वर्षा ऋतु (२०१८ और २०१९) के दौरान तेरह मात्रात्मक गुणों के लिए आनुवंशिक विविधता, संकर ओज, संयोजन क्षमता, जीन क्रिया और वाई वी एम वी प्रतिरोधी आनुवंशिकी अध्ययन के उद्देश्य के साथ संपन्न किया गया। इस अध्ययन के लिए उपयोग की जाने वाली प्रायोगिक सामग्री में १५ जनद्रव्य (११ लाइन और ४ टेस्टर) शामिल हैं, जिन्हें विभिन्न लक्षणों के लिए उनकी विविधता के आधार पर चुना गया था। इन १५ जनद्रव्यों से लाइन × टेस्टर अभिकल्पना के माध्यम से ४४ संकर का उत्पादन किया गया।

विभिन्न विश्लेषण द्वारा यह प्रदर्शित हुआ कि सभी अवलोकित भिण्डी जनद्रव्य के तेरह गुणों के लिए सार्थक आनुवंशिक भिन्नता पायी गई। सभी जनद्रव्यों के अलग-अलग लक्षणों में मध्य से विस्त्रित श्रेणी के मध्यम मूल्य देखे गए। मध्यम से उच्च आनुवांशिकी विकास औसत के प्रति भिण्डी के लगभग सभी लक्षणों में प्रतिपदित किया गया, केवल ५० प्रतिशत फूल दिवस और फल कि लम्बाई को छोड़कर जोकि जोड़ युक्त जीन क्रिया का संकेत करता है। अतः इस प्रकार के सम्बंधित गुणों में वरन विधि से सुधर किया जा सकता है। जनद्रव्य १५/आरईएस-४ और इसके सभी ११ संकर में पित शिरा विन्यास विषाणु रोग के लिए प्रतिरोधी पाया गया।

संकर ओज कि मात्रा के आधार पर सभी ४४ संकरों में ईसी १६६४३० × वीआरओ ६, ईसी १६६४३० × परभनी क्रान्ती और ईसी १६६४०८ × वीआरओ ६ को सबसे उत्कृष्ट आशाजनक पारस्परिक संयुग्मन के रूप में कई पारस्परिक लक्षणों जैसे फल उपज प्रति पौधा, फल संख्या प्रति पौधा, फल का औसत भार, प्रति पौधा प्राथमिक शाखाओं कि संख्या और बीज कि संख्या प्रति फल में पहचाना गया। इन संकर का औसत प्रदर्शन भी अन्य संकरों से बेहतर थे, इस लिए इन संकरों को व्यावसायिक संकर के रूप में उपयोग किया जा सकता है। ईसी १६६४०० को चार गुणों जैसे फल को औसत भार, फल संख्या प्रति पौधा, तने कि चौड़ाई और फल उपज प्रति पौध तथा आईसी ०६३६५५, आईसी ११७२४५ और आईसी ११७१२३ को अगेती लक्षणों (५० प्रतिशत फूल दिवस) के लिए सुसंगत सर्वश्रेष्ठ सामान्य संयोजक के रूप में पहचान कि गई। १२ गुणों के प्रति औसत प्रदर्शन, सामान्य संयोजन छमता और विशेष संयोजन छमता के आधार पर वांछनीय जनक कि श्रेणी यह दर्शाता है कि सभी लक्षणों के लिए एक अच्छे संयोजन और संकर संयोजन को चुनना मुश्किल था। दोनों वर्षों में लगातार, संकर संयोजक जैसे ईसी १६६४३० × वीआरओ ६ और ईसी १६६४०८ × १५/आरईएस-४ फल उपज प्रति पौध के लिये, ईसी १६६४३० × वीआरओ ६, ईसी १६६४०८ × पूसा ए ४ और ईसी १६६४०८ × १५/आरईएस-४ को फल संख्या प्रति पौध, ईसी १६६४३० × वीआरओ ६ और ईसी १६६४०८ × १५/आरईएस-४ को फल कि औसत भार के लिये तथा ईसी १६६४३० × वीआरओ ६ और ईसी १६६४३० × १५/आरईएस-४ बीज संख्या प्रति फली के लिये विशेष संयोजन छमता प्रभाव उच्च क्रम में दर्शाया। σ^2 जीसीए/ σ^2 एससीए के अनुमानों ने सभी लक्षणों के लिये गैर-जोड़ युक्त जीन क्रिया कि प्रबलता को संकेत दोनी ऋतुओं में प्रदर्शित हुआ। इन्हेरिटेंस पैटर्न से पता चला कि, वाई वी एम वी के प्रतिरोध को प्रतिरोधी × प्रतिरोधी (आर × आर) में दो डुप्लीकेट प्रमुख जीनो द्वारा तथा प्रतिरोधी × संवेदनशील (आर × एस) में कुछ मामूली प्रभावों के साथ एकल प्रमुख जीन नियंत्रित करता है।



(धीरेन्द्र कुमार सिंह)
सलाहकार


(आशीष कुमार सिंह)
लेखक