DEVELOPMENT OF F_1 HYBRIDS IN OKRA

[*Abelmoschus esculentus* L. Moench]

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(2017-11-104)

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by

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THESIS

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KERALA, INDIA

2019

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DECLARATION

I, hereby declare that this thesis entitled **"Development of F_1 hybrids in okra [*Abelmoschus esculentus* L. Moench]"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Padannakkad

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CERTIFICATE

Certified that this thesis, entitled **"Development of F_1 hybrids in okra [*Abelmoschus esculentus* L. Moench]"** is a record of research work done independently by Ms. Jaseera U.A (2017-11-104) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Jaseera U.A

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Percent
AE	*Abelmoschus esculentus*
ANOVA	Analysis of Variance
POP	Package of Practices
SE	Standard error
CD	Critical difference
c.m	Centimetre
C.V	Coefficient of Variation
No.of	Number of
DAS	Days after sowing
viz.	Namely
et al.	Co- workers/ Co-authors
Fig.	Figure
G	Gram
i.e.	that is
IPGRI	International Plant Genetic Resources Institute
KAU	Kerala Agricultural University

Introduction

1. INTRODUCTION

Vegetables are the protective supplementary food as they are abundant in minerals, vitamins and essential amino acids necessary for the normal human metabolic processes (Ameta, 2007). Okra [*Abelmoschus esculentus* (L.) Moench] commonly known as bhendi or lady's finger in India, is a fast growing annual having prominent position among the vegetable crops. It is a malvaceae family member originated in tropical Africa and cultivated on large scale in tropics and sub-tropics (Ali *et al,* 2012). Okra is an allopolyploid (Joshi and Hardas, 1956) with most commonly occurring somatic chromosome number as 2n=130. Datta and Naug (1968) observed the somatic chromosome numbers such as 2n=72, 108, 120, 132 and 144 occurring in regular series of polyploids with n=12.

Okra is rich in vitamins, minerals, proteins and carbohydrates with Average Nutritive Value (ANV) 3.21 that is highest, compared to tomato, brinjal and majority of the cucurbitaceous vegetables (Grubben, 1977). The tender pods of okra are preferred as fresh vegetable, canned and dried vegetable, and also used in curry preparation (Shwetha *et al.,* 2018). Crude fiber extracted from the mature pods and stems of okra used in paper manufacture. The plant extract used as juice clarificant in jaggery manufacture process. Okra dry seeds contain 13-22 percent of good quality edible oil and 20-24 percent protein. The protein can be used in fortified feed production and oil utilised in soap and cosmetic industry. Okra is also known for its medicinal property. It relieves urinary disorders, spermatorrhoea and chronic dysentery. In Turkey, inflammations are treated with medicines made from okra leaves (Mehta, 1959).

Existence of variable number of okra cultivars in India, showing wide variations in qualitative and quantitative characters is due to the available diverse climatic conditions and also it's often cross-pollinated nature offering considerable genetic diversity (Duggi *et al.*, 2013). Okra production is highest in India with 62 percent share of world production. India was having production of 60.95 lakh mt during 2017-18, with a cultivation area of about 5.09 lakh ha and productivity of .012 lakh mt/ha (NHB, 2018). Its popularity in the country is due to easiness of cultivation, higher yield and adaptability to the fluctuating moisture conditions. Okra is considered as a potential foreign exchange earner vegetable crop as it shares 60 percent of the green vegetables export from India (Shete, 2000).

Improvement of genetic yield potential of okra requires exploitation of hybrid vigour. Vijayaraghavan and Warrier (1946) were earliest to report heterosis in okra. The key characters which make commercial exploitation of hybrid vigour easier in okra are fast growing nature, short duration, large size of flower, and monoadelphous nature of the stamens. The prerequisites considered for breeding a good okra variety are high yielding potential, producing medium, tender, spineless, light green pods and resistance to pest and disease as well as abiotic stress. Hybrid seeds provide one of the fastest ways to increase productivity hence, it is produced and used widely (Paterniani, 1974). Even though hybrid seeds are more expensive than varieties they are more productive and source of greater income (Reddy *et al.*, 2012).

Heterosis in okra can be exploited in okra by choosing appropriate combination of parents for hybridization. But sometimes high yielding parents may not combine well and hence it is also important to test the parents for combining ability and expression of heterosis so that they combine well to give good hybrids. Desired heterosis in crosses can be obtained only through useful gene combinations between parents. The extent of gene effects and combining ability of parents for yield and yield contributing traits determine the success of recombining desirable traits of importance (Ameta, 2007).

Okra production in Kerala is about 0.03 lakh mt and productivity 13.96×10^{-6} lakh mt/ha within an area of 0.002 lakh ha (NHB, 2018). Even though okra is cultivated in Kerala from past many years, its production is low compared to other okra producing states. One of the significant problems with its production is non availability of appropriate location specific high yielding cultivars. The perfect way to overcome this problem is the exploitation of heterosis or hybrid vigour. Kerala Agricultural University has developed an F_1 hybrid recommended for cultivation in southern Kerala. So it is necessary to develop okra hybrids suitable for cultivation in North Kerala. Prasad (2017) evaluated germplasm of okra collected from North Kerala and identified few promising accessions with high yield and pod quality characters. It was in this background that the present study taken up to develop F_1 hybrids using these promising accessions as parents.

Hence the present study was undertaken with following objectives:

- To develop F_1 hybrids in okra
- To evaluate the okra hybrids for combining ability and heterosis

Review of Literature

2. REVIEW OF LITERATURE

The present investigation was carried out to develop hybrids that are suitable for cultivation under Northern Kerala conditions. Literature related to the present study on heterosis and combining ability in okra has been discussed under the following titles.

2.1 Combining ability and gene action

2.2 Heterosis

2.1 Combining ability

Hybridization using an elite parent may not produce better hybrids. Similarly, one parent from the least performing cross may give the best combination, if crossed with another elite parent selected properly. Hence, framing of effective breeding programe requires good parental choice as well as choice of outstanding cross combination through combining ability analysis (Allard, 1960). The idea of combining ability was developed by Sprague and Tatum (1942) and they introduced two terms *viz.* general combining ability (GCA) and specific combining ability (SCA). Combining ability of crosses can be defined as the ability of cultivars or parents to combine well with each other during hybridization so that desirable genes or characters are passed on to their progenies or it is the assessment of genotypic value of parents based on the performance of the progeny in some definite mating design. Hence, parental selection should be based on *sca* effect along with good hybrid performance and at least one parent having high *gca* value (Desai, 1990; Patel *et al.,* 1990; Poshiya and Vashi, 1995; Pawar *et al.,* 1999).

GCA of a genotype is its average performance in a series of cross combinations and SCA is the measure of deviation of a specific cross in such a series that would be expected from average performance of the parental inbred lines (Sprague and Tatum, 1942). Parental plants or lines with good combining ability will produce potent offspring (Vasal *et al.*, 1986). Hence knowledge about the combining ability of parents will aid in selection of best parental combinations for hybrid development.

Combining ability analysis also helps in the assessment of gene action governing the expression of a particular trait which in turn helps to decide the breeding procedure that has to be followed to exploit that trait. According to Sprague and Tatum, *gca* indicates additive gene action as well as additive × additive interactions (Griffing, 1956). Specific combining ability indicates dominance variance (non-additive gene actions) and all the known types of epistatic interaction components if present (additive × dominance and dominance × dominance interactions).

Combining ability can be estimated through diallel analysis. The importance of specific combining ability and the predictability of hybrid performance using general combining ability or parental performance can be determined by using statistical description provided by diallel analysis. This approach of diallel analysis was developed by Griffing in 1956 and it operates on sole assumption that the parents of the diallel cross are inbreds.

In this model of diallel analysis, three sets of materials are involved *viz.* parents, F_1 crosses and reciprocals. He has given four methods of diallel depending on the biological materials involved in the analysis. One among them is half diallel where, biological materials involved are parents and direct crosses only. Half diallel analysis has been used in many combining ability studies of okra. The present study uses half diallel analysis for combining ability estimation. Keeping in view the objectives of the present investigation, some of the important findings of earlier studies of combining ability in okra are discussed here.

Okra genotypes with the highest *gca* effects were reported by Nichal *et al.*(2000) for characters like plant height, number of primary branches on main stem, days to first flowering, number of fruiting nodes on main stem, average fruit weight, number of fruits per plant, fruit length, and yield per plant and also identified those genotypes as the best general combiners. They reported highly significant *gca* and *sca* mean squares for all the traits except average fruit weight. This indicated the predomination of additive and non-additive variance. The greater mean squares for *gca* showed the significance of additive variance during inheritance of characters under their study.

In okra, Kumar (2001) observed that high *gca* of parental lines for some of the yield attributing traits contribute to high *gca* effects for total yield and marketable yield per plant in okra.

Sood and Kalia (2001) reported the role of additive gene action for all the characters except plant height and yield characters such as fruit yield and fruits per plant which were influenced by non additive gene action.

Gene action in okra was studied through 7 x 7 half diallel analysis by Rani *et al.* (2002a). They reported the influence of over dominance in majority of the characters including yield traits. They also reported the relevance of involvement of non-additive gene action for the characters such as plant height at first flowering and at final harvest, fruit length, fruit girth, fruit weight, yield per plant and protein content.

Mitra and Das (2003) conducted l0 x 10 half diallel cross in okra and reported highly significant *gca* and *sca* variances for all the traits. The *gca* variance was higher than *sca* variance for all the characters except for days to 50 percent flowering, number of branches per plant and number of fruits per plant, showing the influence of additive gene action.

Topal *et al.* (2004) reported that high *gca* value indicates high heritability and less environmental effects leading to low gene interactions and higher rate of success in selection.

Weerasekara (2006) assessed combining ability in okra. Their study showed significant amount of variability among the genotypes for yield and yield attributing traits. They observed that the *sca* variance was higher than *gca* variance indicating predominance of non-additivity for all the characters except for fruit diameter. They identified good general combiners and specific combiners for different characters that were studied.

Mehta *et al.* (2007) reported *sca* variance higher than *gca* variance for the characters such as plant height, for earliness traits like days to first flower and days to 50 percent flowering, yield traits like fruit weight and fruit length, number of seeds per fruit and 100-seed weight which indicated the influence of non-additive gene action. They also observed predominance additive gene action for the character fruit yield per plant

Vachhani and Shekhat (2008) carried out a 10x10 half diallel analysis in okra. Their study revealed the involvement of both additive and dominance variances in the inheritance of majority of the characters studied with predominance of non-additive gene actions for all the traits.

Studies on okra by Balakrishnan *et al.* (2009) identified Arka Anamika as a good general combiner for fruit length, fruit weight and fruit number. They reported high general combining ability for internode number, days to first flowering and fruit weight. They also reported presence of over dominance for most of the yield components.

Pal and Sabesan (2009) carried out 12x12 half diallel analysis in okra. They reported significant values for *gca* and *sca* variances for all traits indicating influence of both additive and non additive gene actions. The characters *viz.* primary branches per plant, ridges/fruit and fruit diameter were highly influenced by additive gene action where as characters like plant height, nodes on main stem, days to first flowering, number of fruits per plant, fruit length, fruit weight and fruit yield per plant were highly influenced by non additive gene action. They identified good specific combiners for fruit yield per plant and associated characters.

Wammanda *et al.* (2010) identified some lines as parents which consistently gave high general combining ability effects for most of the traits, showing that such crosses will produce desirable gene combinations for the yield improvement. They also observed significant *gca* and *sca* variances for all the characters, suggesting that both the additive and non-additive gene effects controlled the genotypic expression of the characters. In their study *gca* and *sca* ratios for all the characters were less than unity indicating greater effect of non additive gene action. High specific combining ability of crosses for high yield and yield attributes of okra obtained by Dabhi *et al.* (2010).

Kachhadia *et al.* (2011) suggested that when *sca* variances are higher than *gca* variances, heterosis breeding can be practiced for exploitation of these characters. Parmar *et al.* (2012) suggested that recurrent selection will be advantageous for the characters when their *gca* variance include additive and also a portion of additive and higher order epistatic interactions.

Rai *et al.* (2011) conducted a 5x5 diallel analysis in okra. They reported that fiber yield and dry wood yield were controlled by additive gene effects, plant height was controlled by both additive and dominant effects and the other characters *viz.* branches per plant, days to first flower, basal circumference and vegetable yield by dominant gene effects.

Solankey *et al.* (2012) identified importance of dominance gene action for traits like fruit yield per plant, plant height and number of seeds per fruit. Sharma and Singh (2012) studied combining ability in okra. They identified the best general combiners for plant height, days to 50% flowering, number of branches/plant, average fruit weight, number of fruits/plant, number of seeds/fruit and fruit yield. They also identified good specific combiners for plant height, number of branches/plant, node at which first flower appear, internodal length, fruit length, number of fruits/plant, number of seeds/fruit and fruit yield.

Obiadalla-Ali *et al.* (2013) investigated the combining ability for earliness attributing traits, vegetative traits and yield traits. Their study revealed highly significant mean squares for all the studied characters, showing presence of notable amount of genetic variation among the genotypes under investigation. All the characters studied showed highly significant *gca* and *sca* mean squares. They identified an outstanding general combiner for all characters except fruit weight and also identified a superior cross combination for all characters except number of branches per plant.

Kumar *et al.* (2013) identified good general combiners for improvement of number of days to 50% flowering, fruit girth and fruits per plant. They also identified promising crosses for fruit yield.

Reddy *et al.* (2013a) carried out 8x8 full diallel cross and observed high significant values for both the *gca* and *sca* variances of all the traits implying the role of both additive and non additive gene actions. They also reported that the ratio of *gca* and *sca* variances were less than unity for all the traits except fruit length. This showed prevalence of non-additive gene action in controlling these traits except fruit length which is controlled by additive gene action.

Bhatt *et al.* (2015) conducted a half diallel analysis in okra and reported significant value of *gca* and *sca* mean squares for all traits except fruit length. The ratio of *gca* and *sca* variances obtained in their study implied the predomination of non-additive gene effect for inheritance of all the characters. They identified a genotype and a cross combination which were a good general and specific combiners for fruit yield respectively.

Ram *et al.* (2015) conducted an investigation in okra through 8x8 half diallel analysis and reported presence of over dominance for primary branches per plant, fruit girth and fruit yield per plant. They also reported that over or partial dominance was important for all the traits studied *viz.* plant height, number of primary branches per plant, days to first picking, days to 50% flowering, first fruiting node, fruit length, fruit girth, fruit weight, number of nodes per plant, number of fruits per plant, fruit yield per plant and moisture content.

Verma and Sood (2015) observed significance of non-additive gene action in the expression of plant height, nodes per plant, days to 50% flowering, fruit diameter, fruit length, fruits per plant and mucilage and significance of additive gene action for internodal length, first fruit producing node, days to first picking, average fruit weight and harvest duration. They also suggested the use of population improvement approaches like diallel selective mating or mass selection with concurrent random mating for exploiting both the gene actions and heterosis breeding as the best approach for exploiting non-additive gene action.

Wakode *et al.* (2016) identified best crosses based on mean performance of crosses and *sca* effect and their study revealed superior general combiners of okra for majority of the characters together with yield per plant. In their study mean squares due to *gca, sca* and reciprocal effects were significant for all the characters, indicating substantial genetic variations for all the characters. They also reported the role of non additive gene action in the expression of traits like number of branches, days to first flowering, nodal position for fruit and first picking.

Jupiter and Kandasamy (2017) investigated combining ability effects in okra. In their study they observed greater *sca* variance for all the characters implied significance of non-additive or dominance gene action. They identified outstanding combiner for traits such as number of fruits and fruit yield per plant and also identified best crosses for fruit yield per plant based on mean performance and *sca* effect.

Kumar *et al.* (2017) studied combining ability in okra. They reported predomination of non-additive gene action for plant height, node at which first flower appear, days to first flowering, fruit length, fruit girth and number of fruits per plant and a predomination of additive gene action number of branches. They observed greater dominance variance for characters such as plant height, number of fruit per plant and fruit yield per plant. As this implied the presence of non-additive gene action they suggested heterosis breeding for exploitation of these traits.

Satish *et al.* (2017) analyzed combining ability for yield and its attributing traits in okra. The study revealed the greater influence of non-additive variance for fruit yield per plant and its attributing traits indicating the significance of non-additive gene action in the expression of the characters. They identified superior general combiners for fruit yield per plant and related traits. They also identified a hybrid with high *sca* effects for internodal length, days to 50 per cent flowering, number of branches per plant, fruit girth and fruit yield per plant.

Paul *et al.* (2017) conducted a study in okra to investigate the gene action involved and to identify the superior combiner for fruit yield and yield contributing characters. Significant *gca* and *sca* variances were observed by them for all the characters except for fruit weight and their ratio showed the significance of both additive and non-additive gene action in the inheritance of these traits. They also identified good general combiners and specific combiners for fruit yield per plant and its related traits.

2.2. Heterosis

Hybrids resulting from the crossing of diverse genotypes show increased or decreased vigour. Heterosis is the increased or decreased vigour, yield or function of hybrid (F_1) over its average parental, better parental value or standard check, resulting from the crossing of diverse genotypes. The term positive heterosis is used for increased vigour and negative heterosis for reduction in vigour. Hybrid vigour is used as synonym of heterosis. However, hybrid vigour explains only superiority of the hybrid over the parents but heterosis explains the other conditions of inferiority of hybrid. The first report on hybrid vigour was given by Koelreuter (1766). Shull (1948) described this phenomenon as the stimulus of heterozygosity and coined the term heterosis.

Heterosis can be classified on the basis of types of estimation. Heteosis, when calculated over mid parental value or average of two parents, it is called as average or relative heterosis. Heterobeltiosis obtained when heterosis estimated over better parent. Standard heterosis obtained when heterosis estimated over standard commercial hybrid.

In okra, for the first time, Vijayraghavan and Warrier (1946) observed evidence of hybrid vigour in certain crosses for size, number and weight of fruit. The possibility of exploiting hybrid vigour and heterosis in okra has been proved in various experiments. Heterosis breeding is useful in producing the highest level of transgressive segregates on the basis of best identified parents and their cross combinations (Falconer, 1960).

Highest heterosis for a cross for all the characters studied *viz.* plant height, days to first flowering, number of nodes per plant, fruit length, fruit girth, number of fruits per plant, single fruit weight, number of seeds per fruit, 100 seed weight, crude fiber content, protein content, and yield per plant was reported by Shoba and Mariappan (2006).

Dabandata *et al.* (2010) reported high relative heterosis for all the studied characters including seed number per pod. Kumar and Sreeparvathy (2010) identified hybrid with high standard heterosis for fruit yield per plant and other characters studied except for individual fruit weight and number of branches per plant.

Wammanda *et al.* (2010) reported 23.3% of heterobeltiosis for yield per plant indicating the superiority of hybrid over the best parent.

Rai *et al.* (2011) identified better performing hybrid for early fruiting character through estimates of heterotic effect for ten hybrids.

Reddy *et al.* (2012) investigated heterosis for yield and its components in okra. They identified crosses with negative heterosis for first flowering, 50% flowering and fruiting nodes and suggested that these characters can be exploited for earliness. In their study there were crosses that were on par with standard control.

Das *et al.* (2013) studied heterobeltiosis in okra. They identified good hybrids based on the mean (*per se*) performance, heterosis manifested in them and *sca* effects. Kumar *et al.* (2013) identified crosses with significant standard heterosis for fruit yield.

Kishor *et al.* (2013) estimated heterosis for ten yield and yield attributing characters in okra. They observed significant standard heterosis for yield per plant and heterobeltiosis for number of primary branches, days to first flowering, number of fruits per plant, fruit weight, fruit length, fruit girth and yield per plant.

Lyngdoh *et al.* (2013) assessed the magnitude of heterosis for growth characters. They reported maximum heterobeltiosis for plant height, number of leaves, and internodal length and also standard heterosis for plant height and number of leaves. Negative heterosis over the best parent and the commercial check were also reported by them for internodal length. Reddy *et al.* (2013a) observed negative heterosis for days to 50% flowering, first flowering and fruiting nodes.

Study of Singh *et al.* (2013) revealed significant and positive heterosis over better parent and economic parent. They identified hybrid with high heterosis and *per se* performance over both better parents and standard check for fruit yield per plant.

Nagesh *et al.* (2014) estimated the magnitude of heterosis for fifty four hybrids in okra. In their study appreciable heterosis was found over better parent and commercial check for all the traits studied in desirable direction. They observed maximum positive heterosis over better parent and the commercial check for total yield per hectare.

Arvindbhai (2014) carried out half diallel analysis in okra and estimated heterosis. Heterosis in desirable direction over standard check was observed for stem diameter, internodal length, number of fruits per plant, fruit yield per plant, fruit diameter and fiber content. He also identified crosses that exhibited significant and positive standard heterosis for fruit yield.

Kumar *et al.* (2015) identified hybrid with high standard heterosis for yield. Patel *et al.* (2015) carried out a study to estimate heterosis. They recorded hybrids with high magnitude of heterosis for yield and its attributing characters.

Kumar and Reddy (2016) studied heterotic potential for yield and its components among fifteen hybrids of okra. They identified hybrids with significantly positive mid parental heterosis, better parental heterosis and standard heterosis for marketable yield per plant.

Patel and Patel (2016) reported significant standard heterosis and high mean performance for the trait fruit yield per plant. Solankey *et al.* (2016) reported crosses involving parents that gave better heterosis performance for disease resistance and associated yield traits.

More *et al.* (2017) identified outstanding hybrids for developing high yielding F_1 hybrids of okra with many desirable traits based on their *sca* and heterosis effects. Paul *et al.,* 2017 carried out 11 x 11 diallel excluding reciprocals to estimate the heterobeltiosis and standard heterosis for fruit yield and its attributing traits in okra. They identified crosses with significant heterobeltiosis and standard heterosis for number of fruits per plant. They also identified hybrids with positive and significant heterobeltiosis for total fruit yield per plant.

Shwetha *et al.* (2018) investigated the extent of heterosis for yield and quality parameters. They identified crosses with positive heterosis for yield per plant and yield per hectare over better parent, over the best parent and the commercial checks. They reported crosses with maximum heterobeltiosis and standard heterosis for number of fruits per plant and crosses with heterosis over the commercial checks for average fruit weight. They also reported cross with maximum positive heterosis over better parent and the commercial checks for number of seeds per fruit.

Reddy *et al.* (2018) estimated heterosis for yield and yield related traits *viz.* plant height, , number of branches, days to 50 per cent flowering, inter-nodal length, fruit length, fruit diameter, number of fruits per plant, average fruit weight, fruit yield per plant and fruit yield per hectare. The results of their study revealed standard heterosis for fruit yield per plant, number of fruits per plant, average fruit weight and fruit yield per hectare.

Kerure and Pitchaimuthu (2019) carried out an experiment to study the magnitude of heterosis and to identify potential parents and superior cross combinations. They reported negatively heterotic crosses in okra for 50% flowering and first fruiting node to exploit earliness. They also identified hybrids with significant standard heterosis in any given direction for total yield per plant.

2.2.1. Effect of pest and disease incidence

Kumar and Thania (2006) evaluated 30 hybrids to study heterosis and combining ability for shoot and fruit borer infestation. They identified potential F_1 hybrids with resistance to shoot and fruit borer.

Ameta (2007) investigated 45 F_1 hybrids and identified hybrids with least YVMV incidence. These also showed high *per se* performance, heterobeltiosis and significant SCA effects.

Balakrishnan *et al.* (2011) evaluated okra hybrids and parents for borer resistance. Their evaluation projected a hybrid with higher yield and tolerance to YVMV and borer infestation.

Das *et al.* (2013) evaluated 15 hybrids for heterosis, combining ability and percentage YVMV disease incidence. Their study lead to the revelation of two hybrids with high yield and low percentage YVMV disease index.

Solankey *et al.* (2016) carried out a study to find YVMV disease resistant sources of okra. They found out that YVMV disease pressure was high during rainy season with higher multiplication rate of white flies. In their study crosses involving parents with YVMV tolerance showed higher yield.

Bora *et al.* (2018) conducted evaluation of germplasm and produced hybrids from sected parents. The hybrids were subjected to YVMV resistance test and their study exposed a hybrid with YVMV disease resistance. YVMV resistant hybrid also showed good standard heterosis.

Materials and Methods

3. Materials and Methods

3.1 Experiment-1: Production of F_1 hybrids

3.1.1 MATERIALS

Five promising types of okra namely AE5, AE16, AE18, AE20, and AE30, identified by Prasad (2017) and maintained at Department of Plant Breeding and Genetics along with Salkeerthi were selected as parents in hybridization program. Salkeerthi is a variety released from KAU highly popular in North Kerala for its yellowish green and long fruits.

Table 1. The characteristics of the parents and checks used in half diallel crossing program

Parents and checks	Yield per plant (g)	Fruit colour	Fruit girth (cm)	Fruit weight (g)	Fruit pubescence
AE5	313.34	Yellowish green	8.15	14.56	Prickly
AE16	599.26	Yellowish green	6.09	25.51	Prickly
AE18	329.53	Yellowish green	6.08	15.55	Prickly
AE20	444.28	Green	5.24	19.42	Downy
AE30	499.45	Yellowish green	5.73	19.22	Downy
Salkeerthi	589.16	Yellowish green	6.20	24.88	Downy
Arka Anamika	610.48	Green	6.15	29.19	Downy
Arka Nikita	554.24	Green	6.13	22.13	Downy
Manjima	591.47	Green	5.81	26.54	Downy
Gowreesapattam local	460.37	Green	5.76	20.63	Slightly rough
IC282257	486.04	Green	5.90	20.35	Downy

3.1.2 Hybridization programe

The parental lines were grown in poly bags during Rabi 2018 for carrying out crosses among them in half diallel fashion. The crosses among six parents in half diallel fashion resulted in the development of 15 hybrids. The selection of male and female parental buds was done on the previous day (evening) of their opening. Buds of female parents were emasculated and enclosed with butter paper bags to eliminate chance for out crossing. On the next day, during 8.00 to 10.00 am the pollination was carried out by using pollen grains of preferred male parental lines. The pollinated female flower buds were again enclosed using butter paper bags to eliminate chance of contamination and labeled with the details of male parent and date of pollination using tags. Fully matured fruits were harvested and seeds extracted from them by hands. Extracted seeds were preserved in butter paper bags labeled with the details of cross.

3.2 Experiment-2: Evaluation of F_1 hybrids

3.2.1 MATERIALS

The experimental material included six parents, 15 F_1 hybrids derived from half diallel cross from experiment 1, along with Arka Anamika and Salkeerthi as OPV checks, Manjima and Arka Nikita as F_1 hybrid check and parents of Manjima *viz.* Gowreesapattam local and IC282257. Manjima is the only okra hybrid released by KAU, hence its parents were also included for comparison in the study. These were raised in field in Randomized Block Design for assessing various qualitative and quantitative characters.

3.2.2 METHODOLOGY

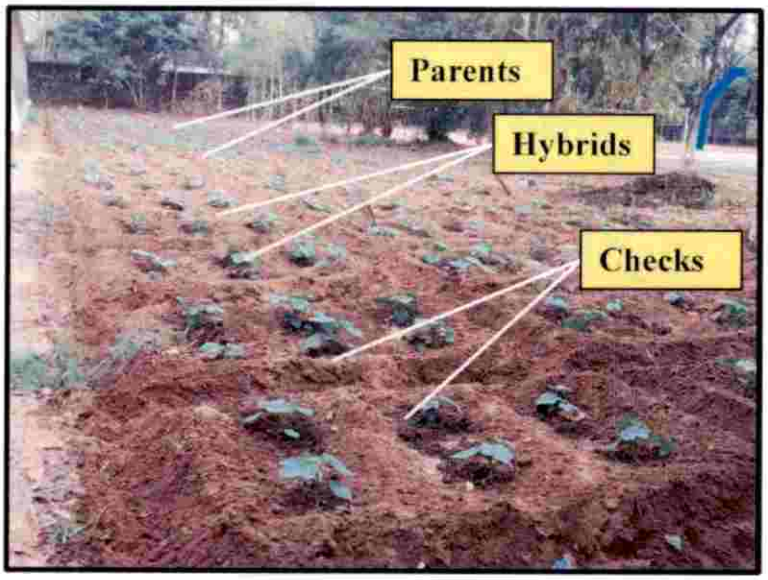
The experiment was conducted at Instructional farm, College of Agriculture, Padannakkad during April-July 2019. The land was prepared after thorough ploughing and levelling. The Seeds were first sown in portray. Transplantation of two weeks old seedlings to the main field were done in an area of 52 X 8 m with a spacing of 60 cm between rows and 30 cm between plants. Seedlings were thinned to one plant per stand two weeks after germination. The experiment was laid out in Randomized block design with 3 replications.

Fertilizers were applied to the plants in the ratio of 1:2:1 (1kg of Urea, 2 kg of Rajphos and 1 kg of Muriate of potash) respectively at 30 DAS (days after sowing). All other cultural practices were done as per package of practices recommendations (KAU, 2016). Acephate was sprayed against various insect pests mainly plant hoppers and jassids. The evaluation of experimental materials for various qualitative and quantitative traits was done and following were the main items of observations made in the field.

Crossing block

Steps of cross pollination

Plate 1. Crossing block and Steps of cross pollination



Field lay out

Field over view

Plate 2. Field lay out and over view

.3 Observations

Observations were recorded for five qualitative, fourteen quantitative traits and two biochemical characters from five randomly selected plants of each treatment per replication including checks.

3.3.1 Qualitative characters

The observations on the following five qualitative characters were taken based on the IPGRI (2000) descriptors and the details are shown below:

3.3.1.1 Colour of fruit

Fruit colour was recorded and grouped into yellowish green-1, green-2, green with red patches-3 and red-4.

3.3.1.2 Fruit shape

Shape of the fruit was recorded and classified into fifteen groups (Fig.1)

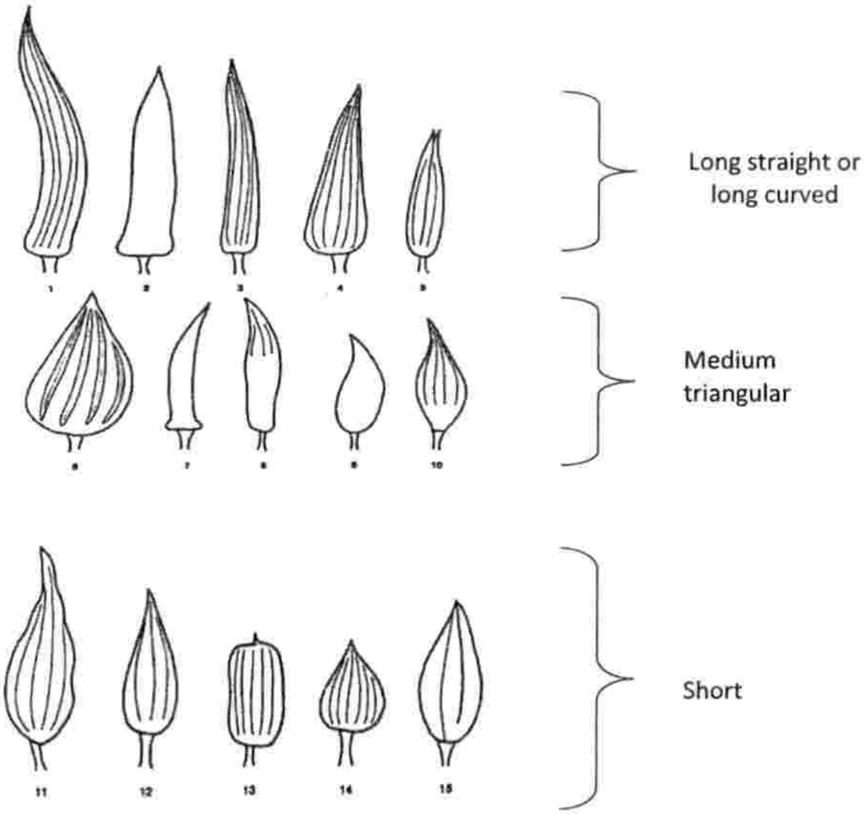


Figure1. Fruit shape of okra as per IPGRI descriptor

3.3.1.3 Position of fruit

Fruit position was recorded and grouped into erect-3, horizontal-5 and pendulous-7.

3.3.1.4 Fruit pubescence

Fruit pubescence was recorded and grouped into downy-3, slightly rough-5 and prickly-7.

3.3.1.5 Ridges per fruit

Ridges per fruit were recorded and grouped into 1, 5 to 7 has 2, 8 to 10 has 3 and more than 10 has 4.

3.3.2 Quantitative Parameters

Observations on fourteen quantitative traits were recorded in five randomly selected plants of each treatment per replication including checks.

3.3.2.1 Plant height (cm)

Plant height was measured from the ground level to the growing tip of the plant at 60 DAS and 90 DAS. Average of plant height at 90 DAS was worked out and expressed in centimeters.

3.3.2.2 Primary branches per plant

The number of primary branches from the main stem in each plant was counted 90 DAS and average was worked out.

3.3.2.3 Internode length (cm)

The distance between the second and third node starting from the basal portion and between the remaining nodes on the main stem of the each plant were recorded 60 DAS and the average was worked out and expressed in centimeters.

3.3.2.4 Days to first flowering

The number of days taken from date of sowing to date on which first flower emerged was recorded as days to first flowering and average was worked out.

3.3.2.5 Days to 50% flowering

The number of days taken from the date of sowing to the day on which 50 percent of the population in a treatment flowered was recorded and average was worked out.

3.3.2.6 Node of fruit set

The node number from the cotyledonous leaves at which first fruit appears was counted in each plant and average was worked out.

3.3.2.7 Number of fruiting node

Number of fruiting nodes in each plant was counted and average worked out.

3.3.2.8 Fruit length (cm)

Fruit length of the tender fruits was measured from the base of the calyx to the tip of the fruit and average was worked out.

3.3.2.9 Fruit girth (cm)

The circumference of the immature pod was taken from the centre of the fruit and then the average was worked out using Vernier Calipers.

3.3.2.10 Fruit weight (g)

Tender fruits of each harvest were weighed and average was worked out and recorded in grams.

3.3.2.11 Number of fruits per plant

The tender fruits harvested from each picking were counted average was worked out.

3.3.2.12 Marketable fruits per plant

The number of good quality edible and tender fruits excluding those infested by pest and diseases from the total number of fruits obtained from all pickings were visually recorded and average was worked out.

3.3.2.13 Yield per plant (g)

Weight of total number of fruits including those infested by pest and diseases obtained from all pickings of each plant were recorded and average was worked out and expressed in grams.

3.3.2.14 Marketable yield per plant (g)

The weight of total number of good quality edible and tender fruits excluding those infested by pest and diseases from all pickings of each plant were recorded and average was worked out and expressed in grams.

3.3.3 Pest and Disease

3.3.3.1 Fruit and shoot borer infestation

The number of plants affected by fruit and shoot borer infestation were visually identified and counted 30 DAS and 60 DAS and percentage of incidence worked out in each genotype.

$$\text{Percentage infestation} = \frac{\text{Number of affected plants}}{\text{Total number of plants}} \times 100$$

3.3.3.2 Yellow vein mosaic infestation

The number of plants affected yellow vein mosaic infestation were visually identified and counted 30 DAS and 60 DAS and percentage of incidence worked out in each genotype.

$$\text{Percentage infestation} = \frac{\text{Number of affected plants}}{\text{Total number of plants}} \times 100$$

3.3.4 Biochemical parameters

3.3.4.1 Fiber content (%)

Two grams of ground material of okra fruit extracted with ether or petroleum ether to remove fat (Initial boiling temperature 35-38°C and final temperature 52°C). After extraction dried material was boiled with 200 ml sulphuric acid for 30 minutes with bumping chips. Then filtered through muslin cloth and washed with boiling water until washings were no longer acidic. Then boiled again with 200ml NaOH for 30 minutes and filtered using muslin cloth and washed using 25 ml of 1.25% boiling H_2SO_4, three portions of 50 ml water and 25 ml alcohol. After that the residue removed and moved to ashing dish (Pre weighed dish). Then the residue dried for two hour at 130±2°C, cooled down in a desicator and weighed. Finally ignited for half an hour at 600±15°C and the weight of ignited sample were taken. Percentage fiber content was calculated (A.O.A.C, 1975).

3.3.4.2 Mucilage content (%)

Fruits of harvestable maturity were cut into small pieces and soaked in water (1:10 v/v) for 6 hours. Then it was filtered through double layer musclin cloth for the residue. The residue was then treated with ethanol in 50:50 v/v. It was washed with acetone (100%) and air dried to get a powder of the mucilage. The percentage yield of extracted mucilage was calculated based on the amount of fresh okra fruits used for the extraction process and the amount of dry mucilage obtained individually depending up on the solvent and expressed as mucilage percentage (%). The percentage yield was calculated from the ratio between weight of dried mucilage obtained and weight of fresh material (Malviya, 2011)

3.4 STATISTICAL ANALYSIS

The data on various observations studied during the course of experiment were subjected to statistical analysis. All qualitative data were converted to binary form based on IPGRI descriptors. For quantitative data, analysis of variance

(ANOVA) for means were done as proposed by Panse and Sukhatme (1967) for randomized block design (RBD)

3.4.1 Analysis of variance for means

Table 2. Analysis of Variance (ANOVA)

Source	d.f	S.S	M.S	E.M.S	F ratio
Replication	(r-1)	Sr	Mr	$\sigma^2e + g\,\sigma^2r$	Mr /Me
Genotype	(g-1)	Sg	Mg	$\sigma^2e + r\,\sigma^2g$	Mg /Me
Parents	(p-1)	Sp	Mp	$\sigma^2e + r\,\sigma^2p$	Mp/Me
Hybrids	(F_1-1)	SF_1	MF_1	$\sigma^2e + r\,\sigma^2F_1$	MF_1/Me
Parent vs. Hybrids	1	SpF_1	MpF_1	$\sigma^2e + r\sigma pF_1$	MpF_1/Me
Error	(r-1) (g-1)	Se	Me	σ^2e	
Total					

Where, p= Number of parents

r= Number of replications

g= Number of genotypes

F_1= Number of hybrids

Mr = Mean square due to replications

Mg= Mean square due to genotypes

Me = Mean square due to error

σ^2e = Expected environment variance

σ^2r = Expected variance due to replications

σ^2g = Expected variance due to genotypes

For the comparison purpose, Standard error (S.E), Critical difference (C.D) and Coefficient of variation (C.V) were worked out

$$S.E.(\pm) = \sqrt{\frac{Me}{r}}$$

$$C.D = \sqrt{2\,x\,\frac{Me}{r}}\ x\ t_{\text{(at error degrees of freedom)}}$$

$$C.\,V\,(\%) = \frac{\sigma}{\bar{x}}\ x\ 100$$

Where, Me = Error mean sum of square

r = Number of replications.

t = Table value of t at error d. f. (at 5% and 1%level of significance)

3.4.2. Estimation of heterosis

Heterosis (in percentage) was estimated over mid parental and better parental values, for all characters by following Rai (1979). Standard heterosis (heterosis over standard variety /check) was also worked out.

Heterosis ovar mid parent = $\frac{(\overline{F_1} - \overline{MP})}{\overline{MP}} \times 100$ (Relative heterosis)

Heterosis over better parent = $\frac{(\overline{F_1} - \overline{BP})}{\overline{BP}} \times 100$ (Heterobeltiosis)

Heterosis over check = $\frac{(\overline{F_1} - \overline{Check})}{\overline{Check}} \times 100$ (Standard heterosis)

Where,

$\overline{MP}$ = Average Mid parental value = $\frac{P1 + P2}{2}$

$\overline{BP}$ = Average Better parental value

$\overline{Fl}$ = Average performance of F_1

$\overline{Check}$ = Average Check Value

Test of Significance:

To test heterosis over mid parent,

S.E. (difference) (M.P) = $\sqrt{\frac{3Me}{2r}}$

To test heterosis over better parent,

S.E. (difference) (B.P) = $\sqrt{\frac{2Me}{r}}$

For testing heterosis over standard check

S.E. (difference) (S.H) = $\sqrt{\frac{2Me}{r}}$

Where,

Me = Error M.S.S

r= number of replications.

Least significant difference (L.S.D):

L.S.D = S.E (difference) x t (at error d.f at 5% and 1 5 level of significance)

Heterois was treated as significant when,

$\overline{F_1}$ - $\overline{MP}$ > LSD

$\overline{F_1}$ - $\overline{BP}$ > L S D

$\overline{F_1}$ - $\overline{SH}$ > L S D

3.4.3. Combining ability analysis

The mean data averaged over replication for all fifteen characters was subjected to combining ability analysis according to Griffing's (1956) model I, method II. Model-I assumes genotypic and replication effects to be constant, the environmental effect to be a random variable and the experimental material to be population about which inferences were to be drawn. It compares the combining ability of the parents when the parents themselves are used as tester and to identify higher yielding combinations. Error is independently distributed with zero mean and variance.

Analysis of variance for combining ability was on the basis of the mathematical model showed below

$Xij = \mu + gi + gj + Sij + \frac{1}{bc} \sum_k \sum_l e_{ijkl}$

Where, i,j = 1,2,……,p

k = 1,2,….,b

l = 1,2,…..,c

P = Number of parents

b = Number of blocks (replications)

c = Number of observations per plot

X_{ij}= Mean of i x jth genotype over k and l

μ = General mean of all hybrids

gi = General combining ability effect of i^{th} parent

gj = General combining ability effect of j^{th} parent

Sij = Specific combining ability effect of the hybrid between i^{th} and j^{th} genotypes

eijkl = Environment effect pertaining to the $ijkl^{th}$ observation

Limitations imposed for the use of this model were

$\sum_i gi = 0$ and $\sum_j \text{Sij} + \text{Sii} = 0$ (for each i)

3.4.3.1. Analysis of variance for combining ability

The analysis of variance for combining ability according to the above mentioned model is as follows

Table 3. ANOVA for combining ability

Source	d.f	S.S	M.S.S	E.M.S
General combining ability	P-1	Sg	Mg	$\sigma^2 e + (P+2) \frac{1}{(P-1)} \sum_i g\text{^}2i$
Specific combining ability	$\frac{P(P-1)}{2}$	Ss	Ms	$\sigma^2 e + \frac{2}{P(P-1)} \Sigma_i \Sigma_j s^2 ij$
Error	$\frac{P(P-1)(P+2)(r-1)}{2}$	Se	Me	$\sigma^2 e$

Where, m = Error degree of freedom

Me= Mean square of error/ number of replication

Mg = Mean squares due to GCA

Ms = Mean squares due to SCA

Sg = Sum of squares due to GCA

$= 1/(P+2)\{\Sigma(Xi+Xij)^2-(4/P) X^2 \ldots\}$

Ss = Sum of squares due to SCA

$= \sum\sum X^2 ij - 1/(P+2)\Sigma (Xi+Xij)^2 + 2/(P+1)(P+2) X^2 \ldots \quad i \leq j$

Where, p = Number of parents

Xi. = Array total involving i^{th} recurrent parent

Xii = Mean value of i^{th} parent

X.. = General total of 'p' parental lines and 'P (P-1)/2' progenies

Xij = Mean value of ij^{th} cross

Me = Error mean square (Me/r)

Every mean square was tested against Me for 'F' test.

3.3.4.2. Estimation of combining ability effects

The general combining ability effects (GCA effect=gi) and specific combining ability effects (SCA effect=Sij) estimated as follows

$\mu = 2 / p(p+1)$ X..

$gi = (1/p+2) \left[\sum(Xi. + Xii) - \frac{2}{P} x.. \right]$

$S_{ij} = X_{ij} - (1/p + 2)(Xi + Xii + Xj + Xjj) + \frac{2}{(n+1)(n+2)} x$

Where,

μ = Population mean

gi = Estimated general combining ability effect of the i^{th} parent

Sij = Estimated specific combining ability effect of the hybrid between i^{th} and j^{th} parents

Xi. + Xii = Total of the i^{th} array + mean value of the parent i

Xj. + Xjj = Total of the of j^{th} array + mean value of parent j

3.3.4.3. Estimation of standard error

The difference between the *gca* and *sca* effects and standard error of estimates were calculated as suggested by Griffing (1956). The standard errors of the estimates were calculated as the square root of the variances of the various estimates as follows:

S. E. (gi) = $\sqrt{\frac{P-1}{P(P+2)} \sigma^{2e}}$

S. E. (Sij) = $\sqrt{\frac{P^{\wedge}2+P+2}{(P+1)(P+2)} \sigma^{2e}}$ $(i \neq j)$

S. E. (gi – gj) = $\sqrt{\frac{2}{P+2} \sigma^{2e}}$ $(i \neq j)$

S. E (Sij - Sik)= $\sqrt{\frac{2(P+1)}{P+2}\sigma^{2e}}$ (i ≠ j. k : j ≠ k)

S. E. (Sij - Skl)= $\sqrt{\frac{2P}{P+2}\sigma^{2e}}$ (i≠j,kl;j≠k,l;k≠l)

Where, p = Number of parent

$\sigma^2 e = \frac{Me}{r}$

Estimation of GCA and SCA ratio

The ratio of additive to non additive variances was obtained using the following formula:

GCA / SCA = $\sum / g^2 i \ \Sigma_i \Sigma_j s^2 ij$

3.3.4.4. Test of significance of difference between two estimates

For the testing of significance of difference between two estimates, critical difference (C.D) were calculated by multiplying standard error of the differences of two estimates and table value of 't' at five and one percent level of probability at error degrees of freedom. The standard error of the difference of two estimates and 't' value were calculated. The standard error of the difference was computed as the square root of the variance of difference between two estimates.

3.3.5 Gene Action

The gene action was determined based on the relative proportion of *gca* variance to *sca* variance for all the traits studied. The greater proportion *gca* variance shows the predomination of additive gene action whereas *sca* variance shows non additive gene action.

Gene action = $\frac{\sigma 2 gca}{\sigma 2\ \text{sca}}$

Results

4. RESULTS

Evaluation of fifteen hybrids obtained from half diallel mating of six parents was done along with their parents and checks for quantitative qualitative and biochemical characters to study heterosis and combining ability. The results of the study "Development of F_1 hybrids in okra" are explained under the following heads.

1. Morphological characterization based on qualitative traits
2. Analysis of variance for experimental design
3. Mean performance of parents and hybrids
4. Incidence of pests and diseases
5. Combining ability analysis
    a) Analysis of variance for combining ability
    b) Estimates of combining ability (*gca* and *sca*) effects
6. Gene action
7. Estimation of heterosis
    a) Relative heterosis (RH)
    b) Heterobeltiosis (HB)
    c) Standard heterosis (SH)

4.1 Morphological characterization based on qualitative traits

Fifteen hybrids, six parents and five checks of okra were evaluated for five qualitative traits as per IPGRI descriptor. The Frequency distribution of 26 okra genotypes for each descriptor state with respect to each trait is given in Table 4. The results obtained are exemplified under following heads.

4.1.1 Colour of fruit

Parents AE5, AE16, AE30, AE18 and Salkeerthi were having yellowish green fruits but AE20 was having green fruit. All the hybrids except AE30 x AE18 were having yellowish green fruits even when the cross involves parent AE20. The hybrid AE30 x AE18 was having green fruit colour even though both parents involved in the

Table 4. Frequency distribution of 26 okra genotypes

Sl.no	Descriptors	Descriptor state	Score code	No. of genotypes	Genotypes
1	Colour of fruit	Yellowish green	1	19	AE16,AE30,AE5,AE18, AE20xAE16, AE16xAE5, AE20xAE5, AE5xSalkeerthi, AE16xAE18, AE16xAE30, AE20xSalkeerthi, AE18xAE5, AE16xSalkeerthi, AE20xAE30, AE20xAE18, AE30xAE5, AE18xSalkeerthi, AE30xSalkeerthi,Salkeerthi
		Green	2	7	AE20,AE30xAE18,Arka Nikita, Arka Anamika, IC282257, Gowreesapattam local, Manjima
		Green with red patches	3	0	Nil
		Red	4	0	Nil
2	Position of fruit	Erect	3	24	AE16, AE30, AE5, AE18,AE20, AE20xAE16, AE16xAE5, AE5xSalkeerthi, AE16xAE18, AE16xAE30, AE20xSalkeerthi, AE18xAE5, AE16xSalkeerthi, AE20xAE30, AE20xAE18, AE30xAE5, AE18xSalkeerthi, AE30xSalkeerthi, AE30xAE18,Arka Nikita, Arka Anamika, IC282257, Gowreesapattam local,Manjimma
		Horizontal	5	2	Salkeerthi,AE20XAE5,
		Pendulous	7	0	Nil
3	Fruit shape		1	17	AE16, AE30, AE18,AE20xAE5, AE16xAE30, AE20xSalkeerthi, AE18xAE5, AE16xSalkeerthi, AE20xAE18, AE30xAE5, AE18xSalkeerthi, AE30xSalkeerthi, AE30xAE18,Arka Nikita, Arka Anamika, Gowreesapattam local,Salkeerthi
			2	2	IC282257,Manjima
			3	2	AE20, AE 20xAE30

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			4	0	Nil
			5	0	Nil
			6	0	Nil
			7	3	AE5, AE16xAE18, AE16xAE5
			8	1	AE5xSalkeerthi
			9	0	Nil
			10	0	Nil
			11	1	AE20xAE16
			12	0	Nil
			13	0	Nil
			14	0	Nil
			15	0	Nil
4	Number of ridges per fruit	None	1	0	Nil
		From 5 to 7	2	26	AE16, AE20, AE30, AE5,AE18, AE20xAE16, AE16xAE5, AE20xAE5, AE5xSalkeerthi, AE16xAE18, AE16xAE30, AE20xSalkeerthi, AE18xAE5, AE16xSalkeerthi, AE20xAE30, AE20xAE18, AE30xAE5, AE18xSalkeerthi, AE30xSalkeerthi, AE30xAE18,Arka Nikita, Arka Anamika, IC282257, Gowreesapattam local, Manjimma,Salkeerthi
		From 8 to 10	3	0	Nil
		More than 10	4	0	Nil
5	Fruit pubescence	Downy	3	16	AE20, AE30, AE16xAE20, AE20xAE5, AE16xAE30, AE20xAE30, AE30xAE5, AE30xSalkeerthi,Salkeerthy, Arka Nikita, Arka Anamika, IC282257, Manjima, AE20xAE18, AE30xAE18, AE20xSalkeerthi
		Slightly rough	5	4	AE5xSalkeerthi, AE16xSalkeerthi, AE18xSalkeerthi, Gowreesapattam local
		Prickly	7	6	AE16, AE5, AE18, AE16xAE5, AE16xAE18, AE18xAE5,

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cross were having yellowish green fruit colour. All checks except Salkeerthi had green fruit colour.

4.1.2. Position of fruit

Parents AE16, AE30, AE5, AE18 and AE20 were having erect fruit position on plant but Salkeerthi was having horizontal fruit position on the plant. All the hybrids except AE20 x AE5 were having erect fruit position on plant even though some crosses involved Salkeerthi as one of the parent. The hybrid AE20 x AE5 was having horizontal fruit position on the plant even though both parents involved in the cross were having erect fruit position. All checks except Salkeerthi had erect fruit position.

4.1.3. Fruit shape

The four parents (AE16, AE30, AE18 and Salkeerthi), ten hybrids (AE20 x AE5, AE16 x AE30, AE20 x Salkeerthi, AE18 x AE5, AE16 x Salkeerthi, AE20 x AE18, AE30 x AE5, AE18 x Salkeerthi, AE30 x Salkeerthi, AE30 x AE18) and three checks (Arka Nikita, Arka Anamika, Gowreesapattam local) were observed with fruit shape score 1. Two checks (IC282257 and Manjima) were observed with fruit shape score 2. One parent (AE20) and one hybrid (AE 20 x AE30) were observed with fruit shape score 3. One parent (AE5) and two hybrids (AE16 x AE18 and AE16 x AE5) were observed with fruit shape score 7. One hybrid (AE20 x AE16) was observed with fruit shape score 11.

4.1.4. Number of ridges per fruit

All the six parents, hybrids and checks had 5-7 ridges per fruit.

4.1.5. Fruit pubescence

The parents AE20, AE30 and Salkeerthi had fruits with downy surface and all the hybrids with them as parents were also observed with fruits of downy surface except AE5 x Salkeerthi, AE16 x Salkeerthi, and AE18 x Salkeerthi. The hybrids AE5 x Salkeerthi, AE16 x Salkeerthi, and AE18 x Salkeerthi had slightly rough fruit surface. The parents AE16, AE5, and AE18 had prickly fruit surface and the crosses among them *viz*. AE16 x AE5, AE16 x AE18, and AE18 x AE5 also had prickly fruit surface. The checks Arka Nikita, Arka Anamika, IC282257, and Manjima had downy fruit surface and Gowreesapattam local had slightly rough fruit surface.

4.2 ANALYSIS OF VARIANCE FOR EXPERIMENTAL DESIGN

The Analysis of variance for all the traits under study showed significant difference among genotypes except for fiber content. All the characters except fiber content observed with significant variance due to parents. Variances due to parent *vs*. hybrids were also found significant for all traits except days to 50% flowering, no. of fruiting nodes, fruit girth and fiber content (Table 5).

4.3 MEAN PERFORMANCE OF PARENTS AND HYBRIDS

The mean performances of parents, hybrids and check for different characters studied except fiber content are presented in Tables 6 to 10. Performance of the hybrids was compared with the checks for different characters. The salient findings for each character are described under the following heads.

4.3.1 Plant height (cm)

There was significant difference between genotypes with respect to plant height (Table 6). The height of parents ranged from 50.45 (AE5) to 60.39 (AE20). Tallest among parents (AE20) was shorter than all the checks. Among hybrids, the tallest was AE30 x AE18 (121.94cm) and the shortest was AE5 x Salkeerthi (74.48 cm). The tallest among the hybrids AE30 x AE18 was taller than checks Arka Nikita (62.90) and IC282257 (119.98) but shorter than the checks Arka Anamika (123.51), Manjima (128.09) and Gowreesapattam local (130.62). The shortest among hybrids, AE5 x Salkeerthi was taller than check Arka Nikita (62.90).

Table 5. ANOVA for the experimental design

Source of variation	d.f.	Plant height (cm)	Primary branches per plant	Internode length (cm)	Days to first flowering	Days to 50% flowering	Node of fruit set
Replications	2	0.32	0.10	1.22	2.08	13.64	1.60
Genotypes	20	1615.45**	1.96 **	30.28**	25.43**	51.15 **	40.14 **
Parents	5	41.21 **	1.42 *	19.14 **	40.38 **	75.96 **	12.86 *
Hybrids	14	557.52**	1.82 **	32.50**	21.14 **	45.80 **	49.36 **
Parents Vs Hybrids	1	24297.62**	6.64 **	55.02 **	10.77 **	2.06	47.45**
Error	40	0.53	0.52	1.18	0.70	5.50	3.74
Total	62	521.47	0.97	10.57	8.72	20.49	15.41

*Significant at 5 per cent level ** Significant at 1 per cent level

Source of Variation	d. f	No. of fruiting nodes	Fruit length (cm)	Fruit girth (cm)	Fruit Weight (cm)	No. of fruits per plant
Replications	2	0.21	2.38	0.98	28.44	70.38
Genotypes	20	63.36 **	73.04 **	122.12**	8949.74 **	5414.92**
Parents	5	113.38**	72.78 **	323.51**	7194.43 **	801.40**
Hybrids	14	47.79 **	74.66 **	58.90**	10157.26 **	2226.33**
Parents Vs. Hybrids	1	31.16	51.70 **	0.08	821.03**	73122.92**
Error	40	10.69	0.78	3.83	11.65	47.39
Total	62	27.34	24.14	41.90	2895.44	1779.59

*Significant at 5 per cent level ** Significant at 1 per cent level

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Table 5. ANOVA for the experimental design

Source of variaton	d.f.	Marketable fruits per plant	Yield per plant (g)	Marketable yield per plant (g)	Mucilage content (%)	Fiber content (%)
Replications	2	8.38**	85.12	2797.63**	13.92	2.51
Genotypes	20	44.64**	36068.43**	29762.90**	2411.80 **	2.79
Parents	5	3.71*	47029.93**	36320.00**	2107.39 **	0.54
Hybrids	14	18.49**	19104.73**	17175.29**	2576.90 **	3.55
Parents Vs Hybrids	1	615.42**	218752.70**	173204.00**	1622.41 **	3.28
Error	40	1.11	231.48	436.57	18.89	2.43
Total	62	15.39	11787.06	9972.84	790.63	2.55

*Significant at 5 per cent level ** Significant at 1 per cent level

4.3.2 Primary branches per plant

There was significant difference between genotypes with respect to primary branches per plant (Table 6). Among parents primary branches per plant ranged from 4.44 (AE30) to 6.22 (AE20). Parent with high number of primary branches (AE20) had more number of primary branches compared to all checks. The hybrid with highest number of primary branches was AE18 x Salkeerthi (7.66) and had more number of primary branches than all the checks. Hybrid with least number of primary branches was AE20 x AE30 (4.55) and had lesser number of primary branches compared to checks IC282257 (5.66), Gowreesapattam local (5.44) and more number of primary branches compared to checks Arka Nikita (2.66) and Arka Anamika (3.55).

4.3.3 Internode length

There was significant difference between genotypes with respect to internode length (Table 6). Among parents the internode length was highest for AE30 (16.84cm) and it was lowest for AE18 (10.82cm). AE 18 showed shorter intenode than the checks Gowreesarapattam local and Manjima and had longer internode compared to checks Arka Nikita, Arka Anamika and IC282257. The hybrid with

Table 6. Mean performances of parents, hybrids and checks for plant height, primary branches per plant and internode length.

Genotypes	Plant height (cm)	Primary branches per plant	Internode length (cm)
AE20xAE16	97.92	5.66	12.38
AE20xAE30	120.45	4.55	8.83
AE20xAE18	117.73	5.55	7.31
AE20xAE5	93.01	6.11	12.74
AE20xSalkeerthi	102.70	5.89	8.54
AE16xAE30	102.40	5.78	9.93
AE16xAE18	95.95	6.77	16.62
AE16xAE5	93.44	6.22	7.36
AE16xSalkeerthi	91.13	6.78	8.55
AE30xAE18	121.94	6.44	12.91
AE30xAE5	93.04	6.66	8.77
AE30xSalkeerthi	121.09	7.33	8.06
AE18xAE5	101.96	5.99	6.64
AE18xSalkeerthi	92.26	7.66	13.78
AE5xSalkeerthi	74.48	5.55	16.39
AE20	60.39	6.22	10.92
AE16	59.28	5.00	14.74
AE30	60.06	4.44	16.84
AE18	58.45	6.11	10.82
AE5	50.45	5.33	11.26
Salkeerthi	58.34	5.77	11.35
Arka Nikita	62.90	2.66	10.15
Arka Anamika	123.51	3.55	8.02
IC282257	119.98	5.66	8.23
Gowreesapattam local	130.62	5.44	11.06
Manjima	128.09	4.55	13.90
Mean	94.57	5.65	10.78
CD(0.05)	1.41	1.11	1.63

longest internode was AE16 x AE18 (16.62cm) and had longer inter node compared to all checks. The hybrid with shortest internode, AE18 x AE5 (6.64 cm) had shorter inter node compared to all checks.

4.3.4. Days to first flowering

Significant difference among treatment means was observed for days to first flowering (Table 7). Among parents early flowering was noticed in AE20 (46.55) which was earlier than checks except Arka Anamika, with which it showed similar mean and late flowering was noticed in AE16 (56.22). Among hybrids, earliest flowering was observed in AE16 x Salkeerthi (47.00) which was earlier compared to all checks except Arka Anamika (46.55). The hybrid AE16 x AE18 recorded longest duration (56.66) for flowering among the hybrids as well as when compared to all checks.

4.3.5. Days to 50% flowering

Significant difference among treatment means was observed for days to 50% flowering (Table 7). Among parents AE20 (63.33) showed earliest 50% flowering and AE16 (76.00) showed delayed 50% flowering. The parent AE20 was also earliest in 50% flowering compared to all checks except Arka Nikita (63.00). The hybrid AE18 x AE5 showed earliest 50% flowering (62.00) among hybrids and also when compared to all checks. Hybrid AE16 x AE18 recorded longest duration (76.33) for 50% flowering among hybrids and also when compared to all checks.

4.3.6. Node of fruit set

Significant difference among treatment means was observed for node of fruit set (Table 8). Among parents, the node of fruit set ranged from 1.77 (AE20 and AE18) to 2.33 (Salkeerthi). The parents with lower most node of fruit set (AE20 and AE18) also had lower most node of fruit set compared to all checks except Gowreesapattam local, with which they showed same mean (1.77). The hybrids AE20 x AE30, AE20 x AE5, and AE20 x Salkeerthi showed uppermost node of fruit

Table 7. Mean performances of parents, hybrids and check for days to first flowering and days to 50% flowering

Genotypes	Days to first flowering	Days to 50% flowering
AE20xAE16	48.00	65.00
AE20xAE30	49.66	71.67
AE20xAE18	49.55	72.67
AE20xAE5	49.11	68.33
AE20xSalkeerthi	47.44	66.33
AE16xAE30	55.67	74.00
AE16xAE18	56.66	76.33
AE16xAE5	49.44	65.67
AE16xSalkeerthi	47.00	67.00
AE30xAE18	49.77	69.33
AE30xAE5	50.33	70.33
AE30xSalkeerthi	49.22	68.00
AE18xAE5	49.55	62.00
AE18xSalkeerthi	50.22	71.33
AE5xSalkeerthi	49.55	64.67
AE20	46.55	63.33
AE16	56.22	76.00
AE30	50.00	73.33
AE18	48.12	65.67
AE5	47.00	65.33
Salkeerthi	47.11	67.00
Arka Nikita	48.33	63.00
Arka Anamika	46.55	67.33
IC282257	48.44	71.67
Gowreesapattam local	47.44	66.33
Manjima	47.44	66.33
Mean	49.25	68.17
C.D(0.05)	1.61	3.76

set (2.77). Lower most nodes of fruit set was shown by hybrids AE20 x AE18, AE16 x AE30, AE16 x AE18, AE16 x AE5, and AE30 x AE18 (1.77) which was lower most compared to all checks except Gowreesapattam local (1.77). The hybrid AE20 x Salkeerthi had uppermost node of fruit set compared to all checks.

4.3.7. Number of fruiting nodes

Significant difference among treatment means was observed for number of fruiting nodes (Table 8). Maximum number of fruiting nodes among the parents was recorded for AE16 (5.44) and it had more number of fruiting nodes than all checks except Arka Nikita and Gowreesapattam local (5.44). Minimum number of fruiting nodes recorded for AE18 (4.00). The maximum number of fruiting nodes was observed for the hybrid AE30 x AE5 (5.44) which also had more number of fruiting nodes compared to all checks except Arka Nikita and Gowreesapattam local (5.44). The hybrid showing minimum number of fruiting nodes was AE16 x AE5 (4.11) and had least number of fruiting nodes compared to all checks.

4.3.8. Fruit length

Significant difference among treatment means was observed for fruit length (Table 8). Maximum fruit length among parents was recorded in AE30 (22.82) and it had longer fruits than all checks. Minimum fruit length recorded for AE20 (8.75). The maximum fruit length observed for the hybrid AE20 x AE18 (22.62) and had longest fruits compared to all checks. The minimum fruit length observed for the hybrid AE20 x AE16 (6.80) and had shortest fruit compared to checks also.

4.3.9. Fruit girth

Significant difference among treatment means was observed for fruit girth (Table 8). Maximum fruit girth among the parents was recorded for AE5 (8.15) and it also had highest fruit girth compared to all checks. Minimum fruit girth recorded for AE20 (5.24). The hybrid AE5 x Salkeerthi had maximum fruit girth (7.35) and it also had highest fruit girth compared to all checks. The minimum fruit girth observed for the hybrid AE16 x Salkeerthi (5.60) which was higher than all checks.

4.3.10. Fruit weight

Significant difference among treatment means was observed for fruit weight (Table 8). Maximum fruit weight among the parents was recorded for AE16 (25.51) which was higher than all checks except Arka Anamika (29.10) and Manjima (26.54). Minimum fruit weight recorded in Salkeerthi (11.43). The maximum fruit weight was observed for the hybrid AE30 x AE5 (28.82) which were higher than all checks except Arka Anamika (29.10). The minimum fruit weight observed for the hybrid AE5 x Salkeerthi (10.52) which was also least compared to all checks.

4.3.11. Number of fruits per plant

Significant difference among treatment means was observed for number of fruits per plant (Table 9). Among the parents maximum number of fruits per plant was recorded for AE30 (26.00) which were higher than all checks except Arka Anamika (27.44). Minimum number of fruits per plant was documented for AE18 (21.11). Maximum number of fruits per plant among the hybrids were recorded by the hybrids AE20 x AE5 and AE16 x AE18 (20.00) but were lesser when compared to all checks. The minimum no. of fruits per plant observed for the hybrid AE5 x Salkeerthi (11.22).

4.3.12. Marketable fruits per plant

Significant difference among treatment means was observed for marketable fruits per plant (Table 9). Among the parents maximum marketable fruits per plant were recorded for AE30 (22.66) which were higher than all checks except Arka Anamika (25.77). Minimum marketable fruits per plant were documented for AE18 (19.55). The maximum marketable fruits per plant were observed for the hybrid AE20 x AE5 (17.78) which were lesser than all checks. The minimum marketable fruits per plant were observed for the hybrid AE5 x Salkeerthi (9.78).

Table 8. Mean performances of parents, hybrids and checks for node of fruit set, number of fruiting nodes, fruit length, fruit girth and fruit weight.

Genotypes	Node of fruit set	No. of fruiting nodes	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
AE20xAE16	2.22	4.44	6.80	6.05	9.94
AE20xAE30	2.77	5.11	12.37	6.09	20.21
AE20xAE18	1.77	4.44	22.62	6.75	24.04
AE20xAE5	2.77	5.33	17.94	6.25	19.93
AE20xSalkeerthi	2.77	4.44	20.42	6.04	25.83
AE16xAE30	1.77	4.89	8.72	6.85	13.84
AE16xAE18	1.77	4.66	9.05	6.61	12.06
AE16xAE5	1.77	4.11	9.54	6.06	14.80
AE16xSalkeerthi	1.89	5.11	12.20	5.60	15.64
AE30xAE18	1.77	5.22	17.27	6.12	14.86
AE30xAE5	1.89	5.44	19.12	6.76	28.82
AE30xSalkeerthi	2.55	4.44	14.72	6.72	20.10
AE18xAE5	1.89	4.55	17.83	6.38	24.12
AE18xSalkeerthi	2.22	5.00	17.02	6.23	21.49
AE5xSalkeerthi	1.89	4.55	8.75	7.35	10.52
AE20	1.77	5.33	14.64	5.24	19.42
AE16	1.89	5.44	19.31	6.10	25.51
AE30	1.89	4.22	22.82	5.73	19.22
AE18	1.77	4.00	12.65	6.08	15.55
AE5	1.89	4.55	9.45	8.15	14.56
Salkeerthi	2.33	4.22	18.90	6.99	11.43
Arka Nikita	4.55	5.44	18.15	6.04	19.18
Arka Anamika	1.89	5.11	13.61	6.13	29.10
IC282257	2.00	4.88	12.97	5.90	20.35
Gowreesapattam local	1.77	5.44	13.25	5.76	20.63
Manjima	2.00	4.77	13.60	5.81	26.54
Mean	2.14	4.79	14.76	6.30	19.35
C.D	0.35	0.52	1.36	0.30	0.64

4.3.13 Yield per plant

Significant difference among treatment means was observed for yield per plant (Table 9). Maximum yield per plant among the parents was recorded for AE16 (599.26) which was higher than all checks except Arka Anamika (599.96). Minimum yield per plant recorded for Salkeerthi (277.45). The maximum yield per plant recorded for hybrid AE30 x AE5 (396.96) which was lesser than all checks. The minimum yield per plant recorded for hybrid AE20 x AE16 (173.50).

4.3.14. Marketable yield per plant

Significant difference among treatment means was observed for marketable yield per plant (Table 9). Maximum marketable yield per plant among the parents were recorded for AE16 (538.98) which was higher than all checks except Arka Anamika (563.95) and Manjima (567.44. Minimum marketable yield per plant were observed for Salkeerthi (254.47). The maximum marketable yield per plant was recorded for the hybrid AE30 x AE5 (361.92) which was lesser than all checks. The minimum marketable yield per plant was observed for the hybrid AE5 x Salkeerthi (98.02).

4.3.15. Mucilage content

Significant difference among treatment means was observed for mucilage content (Table 10). Among the parents maximum mucilage content recorded for Salkeerhi (1.53) which was higher than all checks except Gowreesapattam local (1.94). Minimum mucilage content recorded for AE5 (0.96). The maximum mucilage content was observed for the hybrid AE30 x Salkeerthi (2.00) and it also had more mucilage content than all checks. The minimum mucilage content observed for the hybrid AE18 x AE5 (0.87) which was also lesser than all checks.

4.3.16 Fiber content

Significant difference among treatment means was observed for fiber content (Table 10). Among parents fiber content ranged from 1.89 (AE16) to 0.67 (AE30). Range of fiber content for hybrids was observed between 2.12 (AE16 x

Table 9. Mean performances of parents, hybrids and check for number of fruits per plant, marketable fruits per plant, yield per plant and marketable yield per plant.

Genotypes	No. of fruits per plant	Marketable fruits per plant	Yield per plant (g)	Marketable yield per plant (g)
AE20xAE16	17.44	15.77	173.50	160.33
AE20xAE30	16.99	16.00	343.25	322.98
AE20xAE18	14.55	13.67	274.19	257.27
AE20xAE5	20.00	17.78	373.98	354.71
AE20xSalkeerthi	14.33	13.11	370.71	338.83
AE16xAE30	16.89	15.33	233.43	212.16
AE16xAE18	20.00	17.11	241.24	206.60
AE16xAE5	15.44	14.00	228.85	207.53
AE16xSalkeerthi	18.44	17.44	288.44	273.07
AE30xAE18	16.11	14.77	238.96	219.21
AE30xAE5	13.77	12.55	396.96	361.92
AE30xSalkeerthi	17.55	16.22	352.42	325.74
AE18xAE5	12.66	11.11	314.61	268.42
AE18xSalkeerthi	12.00	11.00	258.84	237.15
AE5xSalkeerthi	11.22	9.78	112.35	98.02
AE20	22.89	21.55	444.28	418.39
AE16	22.77	21.00	599.26	538.98
AE30	26.00	22.66	499.45	435.52
AE18	21.11	19.55	329.53	304.85
AE5	23.22	20.77	313.34	281.76
Salkeerthi	24.22	22.22	277.45	254.47
Arka Nikita	23.66	22.11	454.45	425.38
Arka Anamika	27.44	25.78	599.96	563.95
IC282257	23.44	22.00	486.04	442.71
Gowreesapattam local	22.33	21.00	460.37	432.43
Manjima	22.22	21.33	591.47	567.44
Mean	19.27	17.70	364.69	335.87
C.D (0.05)	1.19	1.71	31.03	36.97

Table 10. Mean performance of parents, hybrids and checks for mucilage content and fiber content.

Genotypes	Mucilage content (%)	Fiber content (%)
AE20xAE16	1.53	1.40
AE20xAE30	1.09	2.11
AE20xAE18	1.02	1.42
AE20xAE5	1.06	1.20
AE20xSalkeerthi	0.99	5.56
AE16xAE30	0.87	1.88
AE16xAE18	1.07	2.12
AE16xAE5	0.96	1.57
AE16xSalkeerthi	0.97	2.01
AE30xAE18	1.17	1.44
AE30xAE5	1.03	1.44
AE30xSalkeerthi	2.00	1.03
AE18xAE5	0.87	1.49
AE18xSalkeerthi	1.24	1.06
AE5xSalkeerthi	0.98	1.68
AE20	1.50	1.46
AE16	1.38	1.89
AE30	0.97	0.67
AE18	1.07	1.23
AE5	0.96	1.09
Salkeerthi	1.53	1.59
Arka Nikita	1.09	2.08
Arka Anamika	1.24	1.82
IC282257	1.20	1.21
Gowreesapattam local	1.94	2.03
Manjima	1.14	1.90
Mean	1.20	1.68
C.D(0.05)	0.07	

x AE18) to 1.03 (AE30 x Salkeerthi). Fiber content for checks observed between 1.21(IC282257) to 2.08 (Arka Nikita).

4.4. Incidence of pest and disease

4.4.1. Fruit and shoot borer infestation

The incidence of fruit and shoot borer on different genotypes was recorded and percentage calculated. The results are presented in Table 11. Maximum incidence of 33.3% was recorded on check Manjima followed by 27.77% on 2 hybrids (AE20 x AE16 and AE18 x AE5) and 22.22% on 2 parents (AE20, AE18) and 4 hybrids (AE20 x AE5, AE16 x 18, AE16 x AE3O, and AE16 x Salkeerthi). Minimum incidence of 5.55% was found in one parent (AE16) 2 hybrids (AE16 x AE5, AE18 x Salkeerthi) and one check (Arka Nikita). No infestation was noticed in check Arka Anamika.

4.4.2. Yellow vein mosaic infestation

The yellow vein mosaic infestation on different genotypes was recorded and percentage calculated. The results are presented in Table 11. Maximum incidence of 44.44% was documented in the hybrid AE20 x AE16 followed by 38.88% in 2 parents (AE20 and Salkeerthi) and 2 hybrids (AE16 x AE30 and AE20 x Salkeerthi). Minimum incidence of 5.55% was observed in 4 hybrids (AE20 x Salkeerthi, AE18 x AE5, AE30 x AE5 and AE18 x Salkeerthi). No incidence was recorded in the checks used in the study.

4.5. Estimation of combining ability (*gca* and *sca*) effects

The *gca* (general combining ability) effects and *sca* (specific combining ability) effects were assessed for six parents and 15 hybrids by following 6 x 6 half diallel mating design. The *gca* and *sca* estimates for all characters are presented in Tables 12 and 13 respectively and the detailed results are presented below.

Table 11. Incidence of pest and disease

Genotypes	Fruit and shoot borer (%)	YVMV (%)
AE16	5.55	27.77
AE20	22.22	38.88
AE30	11.11	27.77
AE5	16.66	33.33
AE18	22.22	22.22
Salkeerthi	11.11	38.88
AE20xAE16	27.77	44.44
AE16xAE5	5.55	22.22
AE20xAE5	22.22	22.22
AE5xSalkeerthi	16.66	27.77
AE16xAE18	22.22	27.77
AE16xAE30	22.22	38.88
AE20xSalkeerthi	11.11	5.55
AE18xAE5	27.77	5.55
AE16xSalkeerthi	22.22	11.11
AE20xAE30	16.66	11.11
AE20xAE18	11.11	16.66
AE30xAE5	11.11	5.55
AE18xSalkeerthi	5.55	5.55
AE30xSalkeerthi	16.66	16.66
AE30xAE18	11.11	22.22
Arka Nikita	5.55	0.00
Arka Anamika	0.00	0.00
IC282257	16.66	0.00
Gowreesapattam local	16.66	0.00
Manjima	33.33	0.00

YVMV Infestation

Shoot borer attack

Fruit borer attack

Plate 3. Incidence of YVMV and Fruit and Shoot borer

4.5.1 Plant height

The estimation of *gca* effect of parents showed that three parental lines *viz.* AE20, AE30, and AE 18 showed significant positive *gca* effect for the character implying that they were good combiners for the trait plant height. The *gca* effect of the parents ranged between -8.17 (AE5) and 7.11 (AE30)

Magnitude of *sca* effect for plant height revealed that the hybrid AE30 x Salkeerthi (28.08) had the maximum value followed by AE30 x AE18 (22.88), AE20 x AE18 (21.98), AE20 x AE30 (20.66) and AE18 x AE5 (18.17) and AE16 x AE5 (15.57). The *sca* effect of hybrids ranged between -3.26 (AE5 x Salkeerthi) and 28.08 (AE30 x Salkeerthi).

4.5.2 Primary branches per plant

Two parents *viz.* Salkeerthi (0.35) and AE18 (0.34) exhibited significant positive *gca* effect for primary branches per plant and one parent (AE30, -0.29) exhibited significant negative *gca* effect. The parental *gca* effects ranged between -0.29 (AE30) and 0.35 (Salkeerthi).

Three hybrids *viz.* AE30 x Salkeerthi (1.27), AE30 x AE5 (1.05) and AE18 x Salkeerthi (0.98) exhibited significant positive *sca* effect. Significant negative *sca* effect was shown by one hybrid. Hybrids *sca* effects ranged between -0.93 (AE20 x AE30) and 1.27 (AE30 x Salkeerthi).

4.5.3. Internode length

Estimates of *gca* effect showed that two parents *viz.* -0.82 (AE20) and -0.47 (AE5) had significant negative *gca* effect and two *viz.* AE16 (0.76) and AE30 (0.49) exhibited significant positive *gca* effect. The parental *gca* effect varied between -0.82 (AE20) and 0.76 (AE16).

Nine hybrids *viz.* AE 18 x AE 5 (-4.14), AE 16 x AE 5 (-4.10), AE 30 x Salkeerthi (-3.58), AE 16 x Salkeerthi (-3.36), AE 20 x AE 18 (-3.12), AE 16 x AE 30 (-2.50), AE 30 x AE 5 (-2.43), AE 20 x AE 30 (-2.01), and AE 20 x Salkeerthi (-1.78) exhibited significant negative *sca* effects for internode length and six hybrids exhibited significant positive *sca* effect for internode length. The *sca* effect for hybrids ranged between -4.14 (AE18 x AE5) and 5.71 (AE5 x Salkeerthi).

4.5.4. Days to first flowering

Three parents *viz.* AE20 (-1.48), Salkeerthi (-1.38) and AE5 (-0.84) showed significant negative *gca* effect for days to first flowering and two parents showed significant positive *gca* effects. The *gca* effects ranged between -1.48 (AE20) to AE16 (2.56).

Four hybrids *viz.* AE16 x Salkeerthi (-4.00), AE20 x AE16 (-2.90), AE16 x AE5 (-2.09) and AE30 x AE18 (-1.19) showed significant negative *sca* effect for days to first flowering and five hybrids showed significant positive *sca* effect. The *sca* effects of hybrids varied between -4.00 (AE16 x Salkeerthi) to 3.88 (AE16 x AE18).

4.5.5 Days to 50% flowering

Three parents *viz.* AE5 (-2.43), AE20 (-1.30) and Salkeerthi (-1.22) showed significant negative *gca* effect for days to 50% flowering and two parents showed significant positive *gca* effect. The *gca* effects ranged between -2.43 (AE5) to 2.36 (AE16 and AE30)

Four hybrids *viz.* AE20 x AE16 (-4.77), AE18 x AE5 (-4.54), AE16 x AE5 (-2.99), and AE16 x Salkeerthi (-2.87) exhibited significant negative *sca* effect and three hybrids exhibited significant positive *sca* effect. The *sca* effects of hybrids ranged between -4.77 (AE20 x AE16) and 5.01 (AE20 x AE18 and AE16x AE18).

4.5.6. Node of fruit set

Among parents *viz.* AE18 (-1.81) and AE16 (-1.52) exhibited significant negative *gca* effect and two exhibited significant positive *gca* effect. The *gca* effects ranged between -1.81 (AE18) and 1.95 (Salkeerthi).

Three hybrids *viz.* AE5 x Salkeerthi (-3.13), AE20 x AE18 (-2.86) and AE16 x Salkeerthi (-2.15) exhibited significant negative *sca* effect and four hybrids exhibited significant positive *sca* effect. The *sca* effects for hybrids ranged between -3.13 (AE5 x Salkeerthi) and 5.88 (AE20 x AE5).

4.5.7. Number of fruiting nodes

Only one parent *viz.* AE20 (1.57) showed exhibited significant positive *gca* effect and two exhibited significant negative *gca* effect. The *gca* effects ranged between -1.62 (AE 18) and 1.57 (AE 20).

Hybrids AE30 x AE5 (6.66), AE30 x AE18 (5.95), AE18 x Salkeerthi (5.70) and AE20 x AE5 (4.45) exhibited significant positive *sca* effect. Two hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -7.34 (AE 16 x AE 5) and 6.66 (AE 30 x AE 5).

4.5.8. Fruit length

Four parents showed significant positive *gca* effect *viz.* AE30 (1.72), Salkeerthi (0.87), AE20 (0.67), and AE18 (0.63) and two exhibited significant negative *gca* effect. The *gca* effects ranged between -2.39 (AE 16) and 1.72 (AE 30).

Hybrids AE20 x AE18 (6.45), AE30 x AE5 (4.02), AE20 x Salkeerthi (4.02), AE20 x AE5 (3.90), and AE18 x AE5 (3.83) exhibited significant positive *sca* effect. Eight hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between-6.35 (AE 20 x AE 16) and 6.45 (AE 20 x AE 18).

4.5.9. Fruit girth

Among parents, AE5 (5.48) and Salkeerthi (1.51) exhibited significant positive *gca* effect and three exhibited significant negative *gca* effect. The *gca* effects ranged between -3.81 (AE20) and 5.48 (AE5).

Hybrids AE20 x AE18 (8.05), AE16 x AE30 (7.24), AE16 x AE18 (4.46), AE30 x Salkeerthi (2.71), AE5 x Salkeerthi (2.63), and AE20 x AE16 (2.12) exhibited significant positive *sca* effect. Five hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -7.73 (AE16 x Salkeerthi) and 8.05 (AE20 x AE18).

4.5.10 Fruit weight

Two parents *viz.* AE20 (14.36) and AE30 (11.20) exhibited significant positive *gca* effect and two exhibited significant negative *gca* effect. The *gca* effects ranged between -13.57 (Salkeerthi) and 14.36 (AE 20).

`Hybrids AE30 x AE5 (95.09), AE20 x Salkeerthi (75.66), AE18 x AE5 (58.84), AE18 x Salkeerthi (46.16), AE20 x AE18 (43.70), AE30 x Salkeerthi (21.48) exhibited significant positive *sca* effect. Seven hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -84.31 (AE20 x AE16) and 95.09 (AE30 x AE5).

4.5.11 Number of fruits per plant

Three parents, AE16 (9.86), AE30 (9.30), and AE20 (4.03) exhibited significant positive *gca* effect and three exhibited significant negative *gca* effect. The *gca* effects ranged between -10.42 (AE18) and 9.86 (AE16).

Hybrids AE20 x AE5 (24.04) and AE16 x AE18 (20.72) exhibited significant positive *sca* effect. Twelve hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -54.86 (AE5 x Salkeerthi) and 24.04 (AE20 x AE5) .

4.5.12 Marketable fruits per plant

Among parents, AE16 (0.90), AE30 (0.72) and AE20 (0.62) exhibited significant positive *gca* effect and two exhibited significant negative *gca* effect. The *gca* effects ranged between -0.96 (AE 5 and AE 18) and 0.90 (AE16).

Hybrid AE20 x AE5 (1.77) exhibited significant positive *sca* effect. Eleven hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -5.30 (AE 5 x Salkeerthi) and 1.77 (AE20 x AE5).

4.5.13 Yield per plant

Three parents exhibited significant positive *gca* effect *viz.* AE30 (42.78), AE20 (25.31) and AE16 (17.79). Three exhibited significant negative *gca* effect. The *gca* effects ranged between -35.50 (Salkeerthi) and 42.78 (AE30).

Five hybrids *viz.* AE20 x Salkeerthi (63.51), AE30 x AE5 (57.83), AE20 x AE5 (52.32), AE18 x AE5 (47.60) and AE30 x Salkeerthi (27.76) exhibited significant positive *sca* effect. Eight hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -186.99 (AE20 x AE 16) and 63.51 (AE20 x Salkeerthi).

4.5.14 Marketable yield per plant

Three parents exhibited significant positive *gca* effect *viz.* AE30 (35.88), AE20 (30.62) and AE16 (13.96). Three exhibited significant negative *gca* effect. The *gca* effects ranged between -30.53 (Salkeerthi) and 35.88 (AE30).

Five hybrids *viz.* AE30 x AE5 (58.09), AE20 x AE5 (56.15), AE20 x Salkeerthi (49.32), AE30 x Salkeerthi (30.97), AE18 x AE5 (28.93) exhibited significant positive *sca* effect. Eight hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -173.67 (AE 20 x AE16) and 58.09 (AE30 x AE5).

4.5.15 Mucilage content

Among parents two showed significant positive *gca* effect *viz.* Salkeerthi (14.36) and AE20 (7.53). Two exhibited significant negative *gca* effect. The *gca* effects ranged between -15.85 (AE5) and 14.36 (Salkeerthi).

Hybrid AE30 x Salkeerthi (70.19), AE20 x AE16 (29.19) and AE30 x AE18 (8.15) exhibited significant positive *sca* effect. Six hybrids exhibited significant negative *sca* effect. The *sca* effects of hybrids ranged between -38.81 (AE20 xSalkeerthi) and 70.19 (AE30 x Salkeerthi).

4.6. Gene action

Analysis of variance for combining ability showed that the magnitude of *sca* variance was greater than *gca* variance for all the traits studied (Table 14). The ratio of *gca* to *sca* (*gca*/*sca*) was found to be lesser than unity for all the traits indicating the prevalence of non additive or dominance gene action.

4.7 Estimation of heterosis

The characters except fiber content were subjected to half diallel analysis for estimating per cent increase or decrease of F_1 value over mid parental value (RH), better parental value (HB), and standard hybrid value (SH) for various characters as magnitude of heterosis and the results are presented in Tables 15 to 20. The summary of the results for each character are presented below.

4.7.1. Plant height

All the fifteen hybrids showed significant positive heterosis for plant height over better parent, mid parent, and standard check (Table 15). Relative heterosis ranged between 36.91 (AE5 x Salkeerthi) and 105.78 (AE30 x AE18). Heterobeltiosis ranged between 27.66 (AE5 x Salkeerthi) and 103.02 (AE30 x AE18). Standard heterosis ranged between 18.41(AE5 x Salkeerthi) and 93.88 (AE30 x AE18).

4.7.2. Primary branches per plant

Among 15 hybrids, eight hybrids exhibited significant positive relative heterosis for primary branches per plant (Table 15). The value of relative heterosis varied between -14.57 (AE20 x AE30) and 43.54 (AE30 x Salkeerthi). Heterobeltiosis ranged between -26.80 (AE20 x AE30) and 26.96 (AE30 x Salkeerthi). Among 15 hybrids, three exhibited significant positive heterobeltiosis and one hybrid exhibited significant negative heterobeltiosis. Standard heterosis ranged between 70.96 (AE20 x AE30) and 187.61 (AE18 x Salkeerthi). All the 15 hybrids have shown significant positive standard heterosis.

4.7.3. Internode length

Three of the 15 hybrids exhibited significant positive relative heterosis and nine exhibited significant negative relative heterosis (Table 15). Magnitude of relative heterosis for internode length ranged from -43.37 (AE16 x AE5) to 44.93 (AE5 x Salkeerthi). Two hybrids exhibited significant positive heterobeltiosis and eleven hybrids exhibited significant negative heterobeltiosis. The magnitude of heterobeltiosis varied from -52.13 (AE30 x Salkeerthi) to 44.38 (AE5 x Salkeerthi).

Table 12. General combining ability effects of six parents

Parents	Plant height	Primary branches per plant	Internode length	Days to first flowering	Days to 50% flowering	Node of fruit set	No. of fruiting nodes	Fruit length
AE20	3.80** (H)	-0.22 (L)	-0.82** (H)	-1.48** (H)	-1.31 ** (H)	1.80** (L)	1.57* (H)	0.67** (H)
AE16	-2.85** (L)	-0.09 (L)	0.76** (L)	2.56** (L)	2.36 ** (L)	-1.52** (H)	1.16 (L)	-2.39** (L)
AE30	7.11** (H)	-0.29* (L)	0.49* (L)	0.74** (L)	2.36 ** (L)	0.14 (L)	0.46 (L)	1.72** (H)
AE18	3.08** (H)	0.34* (H)	0.08 (L)	0.41* (L)	0.24 (L)	-1.81** (H)	-1.62* (L)	0.63** (H)
AE5	-8.17** (L)	-0.09 (L)	-0.48* (H)	-0.84** (H)	-2.43** (H)	-0.55 (L)	-0.09 (L)	-1.50** (L)
Salkeerthi	-2.98** (L)	0.35* (H)	-0.03 (L)	-1.38** (H)	-1.22 ** (H)	1.95** (L)	-1.48* (L)	0.87** (H)

*Significant at 5 per cent level ** Significant at 1 per cent level

H- Stands for significant *gca* effect in desirable direction

L- Stands for non-significant *gca* effects in favorable direction, significant and non-significant *gca* effects in unfavorable direction

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Table 12. General combining ability effects of six parents

Parents	Fruit girth	Fruit weight	No. of fruits per plant	Marketable fruits per plant	Yield per plant	Marketable yield per plant	Mucilage content
AE20	-3.81** (L)	14.36 ** (H)	4.03 ** (H)	0.62** (H)	25.31** (H)	30.62** (H)	7.53 ** (H)
AE16	-1.69** (L)	-12.50 ** (L)	9.86 ** (H)	0.90** (H)	17.79** (H)	13.96** (H)	1.03 (L)
AE30	-0.90* (L)	11.20 ** (H)	9.30 ** (H)	0.72** (H)	42.78** (H)	35.88** (H)	0.19 (L)
AE18	-0.59 (L)	0.49 (L)	-10.42 ** (L)	-0.96** (L)	-29.35** (L)	-28.45** (L)	-7.26 ** (L)
AE5	5.48** (H)	0.02 (L)	-7.91 ** (L)	-0.96** (L)	-21.03** (L)	-21.48** (L)	-15.85 ** (L)
Salkeerthi	1.51** (H)	-13.57 ** (L)	-4.86 ** (L)	-0.31 (L)	-35.50** (L)	-30.53** (L)	14.36 ** (H)

*Significant at 5 per cent level ** Significant at 1 per cent level

H- Stands for significant *gca* effect in desirable direction

L- Stands for non-significant *gca* effects in favorable direction, significant and non-significant *gca* effects in unfavorable direction

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Table 13 Specific combining ability effects of fifteen F_1 hybrids

Hybrids	Plant height	Primary branches per plant	Internode length	Days to first flowering	Days to 50% flowering	Node of fruit set	No. of fruiting nodes	Fruit length
AE20 xAE16	8.08**	-0.02	1.27*	-2.90**	-4.77 **	1.32	-5.70**	-6.35**
AE20 xAE30	20.66**	-0.93*	-2.01**	0.59	1.88	5.20**	1.66	-4.89**
AE20 xAE18	21.98**	-0.56	-3.12**	0.81	5.01**	-2.86**	-2.92	6.45**
AE20xAE5	8.49**	0.42	2.87**	1.61**	3.34 **	5.88**	4.45*	3.90**
AE20xSalkeerthi	12.99**	-0.24	-1.78**	0.49	0.13	3.39**	-3.07	4.02**
AE16xAE30	9.25**	0.16	-2.50**	2.55**	0.55	-1.48	-0.13	-5.48**
AE16xAE18	6.84**	0.54	4.60**	3.88**	5.01 **	0.47	-0.28	-4.05**
AE16xAE5	15.57**	0.41	-4.10**	-2.09**	-2.99 *	-0.79	-7.34**	-1.44**
AE16xSalkeerthi	8.07**	0.52	-3.36**	-4.00**	-2.87 *	-2.15*	4.04*	-1.14*
AE30xAE18	22.88**	0.40	1.16*	-1.19**	-1.99	-1.20	5.96**	0.05
AE30xAE5	5.22**	1.05**	-2.43**	0.62	1.67	-1.32	6.66**	4.02**
AE30xSalkeerthi	28.08**	1.27**	-3.58**	0.05	-1.87	2.82**	-1.96	-2.73**
AE18xAE5	18.17**	-0.24	-4.14**	0.17	-4.54 **	0.62	-0.12	3.83**
AE18xSalkeerthi	3.29**	0.98*	2.55**	1.38**	3.59 **	1.46	5.70**	0.67
AE5xSalkeerthi	-3.26**	-0.70	5.72**	1.96**	-0.41	-3.13**	-0.27	-5.47**

* Significant at 5% level ** Significant at 1% level

Table 13. Specific combining ability effects of fifteen F_1 hybrids

Hybrids	Fruit girth	Fruit weight	No. of fruits per plant	Marketab le fruits per plant	Yield per plant	Marketable yield per plant	Mucilage content
AE20 xAE16	2.12*	-84.31 **	-19.30**	-2.10**	-186.99**	-173.67**	29.19**
AE20 xAE30	1.69	-5.32 **	-23.20**	-1.69**	-42.23**	-32.95**	-13.98**
AE20xAE18	8.05**	43.70 **	-27.88**	-2.34**	-39.16**	-34.32**	-14.18**
AE20 xAE5	-3.02**	3.07	24.04**	1.77**	52.32**	56.15**	-0.94
AE20 xSalkeerthi	-1.18	75.66 **	-35.67**	-3.55**	63.51**	49.32**	-38.81**
AE16xAE30	7.24**	-42.16 **	-30.10**	-2.63**	-144.52**	-127.11**	-29.48**
AE16xAE18	4.46**	-49.21**	20.72**	0.82	-64.56**	-68.34**	-2.68
AE16xAE5	-7.04**	-21.40 **	-27.32**	-2.29**	-85.29**	-74.38**	-4.44
AE16xSalkeerthi	-7.73**	0.65	-0.40	0.50	-11.23	0.21	-33.98**
AE30xAE18	-1.23	-44.91 **	-17.62**	-1.33*	-91.85**	-77.65**	8.15**
AE30xAE5	-0.84	95.09 **	-43.46**	-3.55**	57.83**	58.09**	3.06
AE30xSalkeerthi	2.71**	21.48 **	-8.74*	-0.54	27.76**	30.97**	70.19**
AE18xAE5	-5.02**	58.84 **	-34.84**	-3.32**	47.60**	28.93**	-5.48*
AE18xSalkeerthi	-2.50*	46.16 **	-44.56**	-4.08***	6.31	6.71	1.65
AE5xSalkeerthi	2.63*	-63.10 **	-54.86**	-5.30**	-148.50**	-139.40**	-16.44**

* Significant at 5% level ** Significant at 1% level

Table 14. Analysis of variance for combining ability of different characters

Characters	GCA	SCA	Error	$\sigma^2 gca$	$\sigma^2 sca$	$\sigma^2 gca/\sigma^2 sca$
Plant height	253.03**	633.64**	0.18	31.61	633.46	0.050
Primary branches per plant	0.61**	0.67**	0.17	0.06	0.50	0.12
Internode length	2.777**	12.53**	0.39	0.30	12.14	0.02
Days to first flowering	19.35**	4.85**	0.23	2.39	4.62	0.52
Days to 50% flowering	32.50**	11.90**	1.83	3.83	10.07	0.38
Node of fruit set	20.71**	10.94**	1.25	2.43	9.69	0.25
No. of fruiting nodes	14.15**	23.44**	3.56	1.32	19.89	0.07
Fruit length	20.00**	25.80**	0.26	2.47	25.54	0.10
Fruit girth	81.43**	27.13**	1.28	10.02	25.85	0.39
Fruit weight	1075.58**	3615.14**	3.88	133.96	3615.26	0.04
No. of fruits per plant	631.60**	2196.10**	15.80	76.98	2180.30	0.04
Marketable fruits per plant	5.85**	17.89**	0.37	0.68	17.52	0.04
Yield per plant	8562.08**	13176.38**	77.16	1060.62	13099.23	0.08
Marketable yield per plant	7396.35**	10762.51**	145.52	906.35	10616.98	0.08
Mucilage content	908.64**	769.03**	6.30	112.79	762.73	0.15

*Significant at 5 per cent level ** Significant at 1 per cent level

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from -52.13 (AE30 x Salkeerthi) to 44.38 (AE5 x Salkeerthi). Standard heterosis varied between -34.60 (AE18 x AE5) and 63.66 (AE16 x AE18). Six hybrids exhibited significant positive standard heterosis and four hybrids exhibited significant negative standard heterosis.

4.7.4. Days to first flowering

Nine hybrids exhibited significant positive relative heterosis for days to first flowering and three hybrids exhibited significant negative heterosis (Table 16). Relative heterosis ranged from -9.03 (AE16 x Salkeerthi) to 8.63 (AE16 x AE18). Heterobeltiosis ranged from -16.40(AE16 x Salkeerthi) to 5.19(AE5 x Salkeerthi). Five hybrids exhibited significant positive heterobeltiosis and three hybrids exhibited significant negative heterobeltiosis. Standard heterosis ranged between -2.76 (AE16 x Salkeerthi) and 17.24 (AE16 x AE18) and two hybrids exhibited significant negative standard heterosis.

4.7.5 Days to 50% flowering

Four hybrids exhibited significant positive relative heterosis for days to 50% flowering and four hybrids exhibited negative relative heterosis (Table 16). Relative heterosis ranged between -7.08 (AE16 x AE5) and 12.66 (AE20 x AE18). Heterobeltiosis ranged between -14.47 (AE20 x AE16) and 10.66 (AE20 x AE18). Two hybrids exhibited significant positive heterobeltiosis and five hybrids exhibited significant negative heterobeltiosis. Standard heterosis varied between -1.59 (AE18 x AE5) and 21.16 (AE16 x AE18) and one hybrid showed significant negative standard heterosis.

4.7.6 Node of fruit set

Relative heterosis for node of fruit set ranged from -10.51 (AE16 x Salkeerthi and AE5 x Salkeerthi) to 51.55 (AE20 x AE30 and AE20 x AE5). Five hybrids showed significant positive relative heterosis. Heterobeltiosis ranged between -19.03 (AE16 x Salkeerthi and AE5 x Salkeerthi) and 47.00 (AE20 x AE30 and AE20 x

Table 15. Heterosis (%) for plant height, primary branches per plant and internode length

Genotypes	Plant height			Primary branches per plant			internode length		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
AE20xAE16	63.65 **	62.15 **	55.68**	0.98	-8.95	112.64**	-3.48	-15.99 *	21.96*
AE20xAE30	100.01**	99.47 **	91.51**	-14.57	-26.80 **	70.96**	-36.37 **	-47.56 **	-13.00
AE20xAE18	98.14 **	94.97 **	87.19**	-9.95	-10.77	108.39**	-32.75 **	-33.06 **	-28.00**
AE20xAE5	67.82 **	54.02 **	47.87**	5.74	-1.82	129.29**	14.89 *	13.14	25.51**
AE20xSalkeerthi	73.00 **	70.07 **	63.28**	-1.83	-5.36	121.03**	-23.30 **	-24.76 **	-15.89
AE16xAE30	71.61 **	70.49 **	62.81**	22.43 *	15.61	116.90**	-37.12 **	-41.04 **	-2.20
AE16xAE18	63.01 **	61.87 **	52.56**	22.01 *	10.92	154.32**	30.02 **	12.73 *	63.66**
AE16xAE5	70.31 **	57.63 **	48.56**	20.46 *	16.70	133.54**	-43.37 **	-50.05 **	-27.48**
AE16xSalkeerthi	54.96 **	53.74 **	44.89**	25.84 **	17.38	154.44**	-34.43 **	-41.97 **	-15.76
AE30xAE18	105.78 **	103.02**	93.88**	22.12 *	5.46	141.80**	-6.69	-23.37 **	27.12**
AE30xAE5	68.38 **	54.91 **	47.93**	36.40 **	25.02 *	150.19**	-37.62 **	-47.95 **	-13.66
AE30xSalkeerthi	104.54 **	101.61**	92.53**	43.54 **	26.96 *	175.22**	-42.80 **	-52.13 **	-20.58*
AE18xAE5	87.25 **	74.44 **	62.11**	4.81	-1.86	125.03**	-39.86 **	-41.05 **	-34.60**
AE18xSalkeerthi	57.99 **	57.84 **	46.69**	28.96 **	25.44 *	187.61**	24.28 **	21.38 **	35.69**
AE5xSalkeerthi	36.91 **	27.66 **	18.41**	0.03	-3.81	108.51**	44.93 **	44.38 **	61.39**

RH- Stands for Relative heterosis HB- Stands for Heterobeltiosis

SH - Stands for Standard heterosis

*Significant at 5% level ** Significant at 1% level

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AE5). Four hybrids exhibited significant positive heterobeltiosis and two hybrids exhibited significant negative heterobeltiosis. Standard heterosis varied between -61.03 (AE20 x AE18, AE16 x AE30, AE16 x AE18, AE16 x AE5, and AE30 x AE18) and -39.05 (AE20 x AE30, AE20 x AE5, and AE20 x Salkeerthi). All the 15 hybrids exhibited significant negative standard heterosis (Table 16).

4.7.7. Number of fruiting nodes

Three hybrids exhibited significant positive relative heterosis and two hybrids exhibited significant negative relative heterosis. The relative heterosis varied between -17.72 (AE16 x AE5) and 26.98 (AE30 x AE18). Heterobeltiosis ranged between -24.45 (AE16 x AE5) and 23.62 (AE30 x AE18). Among 15 hybrids, three hybrids exhibited significant positive heterobeltiosis and six hybrids exhibited significant negative heterobeltiosis. Standard heterosis varied from -24.45 (AE16 x AE5) to -2.02 (AE20 x AE5). Nine hybrids exhibited significant negative standard heterosis (Table 17).

4.7.8. Fruit length

Five hybrids exhibited significant positive relative heterosis and eight hybrids exhibited significant negative relative heterosis. Relative heterosis ranged between -59.96 (AE20 x AE16) and 65.75 (AE20 x AE18). Four hybrids exhibited significant positive heterobeltiosis and 11 hybrids exhibited significant negative heterobeltiosis. Heterobeltiosis ranged between -64.80 (AE20 x AE16) and 54.49 (AE20 x AE18). Standard heterosis ranged between -62.56 (AE20 x AE16) and 24.59 (AE20 x AE18). Among 15 hybrids, two hybrids exhibited significant positive standard heterosis and eight hybrids exhibited significant negative standard heterosis for fruit length (Table 17).

4.7.9. Fruit girth

Relative heterosis for fruit girth ranged between –14.88 (AE16 x AE5) and 19.25 (AE20 x AE18). Five hybrids exhibited significant positive relative heterosis and five

Table 16. Heterosis (%) for days to first flowering, days to 50% flowering and node of fruit set

Genotypes	Days to first flowering			Days to 50% flowering			Node of fruit set		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
AE20xAE16	-6.59 **	-14.62**	-0.69	-6.70**	-14.47 **	3.17	21.31 **	17.67 *	-51.21**
AE20xAE30	2.88 *	-0.67	2.76	4.88	-2.27	13.76**	51.55 **	47.00 **	-39.05**
AE20xAE18	4.69 **	3.00 *	2.52	12.66 **	10.66 **	15.34**	0.00	0.00	-61.03**
AE20xAE5	4.98 **	4.49 **	1.61	6.22 *	4.59	8.47**	51.55 **	47.00 **	-39.05**
AE20xAESalkeerthi	1.30	0.71	-1.84**	1.79	-1.00	5.29	35.17 **	19.03 **	-39.05**
AE16xAE30	4.82 **	-0.98	15.18**	-0.89	-2.63	17.46**	-6.01	-6.01	-61.03**
AE16xAE18	8.63 **	0.79	17.24**	7.76 **	0.44	21.16**	-3.10	-6.01	-61.03**
AE16xAE5	-4.20 **	-12.05**	2.30	-7.08 **	-13.60 **	4.23	-6.01	-6.01	-61.03**
AE16xSalkeerthi	-9.03 **	-16.40**	-2.76*	-6.29 **	-11.84 **	6.35*	-10.51	-19.03 **	-58.53**
AE30xAE18	1.47	-0.45	2.99*	-0.24	-5.45 *	10.05**	-3.10	-6.01	-61.03**
AE30xAE5	3.78 **	0.67	4.14**	1.44	-4.09	11.64**	0.00	0.00	-58.53**
AE30xSalkeerthi	1.38	-1.55	1.84	-3.09	-7.27 **	7.94*	20.95 **	9.44	-43.96**
AE18xAE5	4.21 **	3.01 *	2.53	-5.34 *	-5.58	-1.59**	3.10	0.00	-58.53**
AE18xSalkeerthi	5.49 **	4.39 **	3.91**	7.54 **	6.47 *	13.23**	8.20	-4.72	-51.21**
AE5xSalkeerthi	5.31 **	5.19 **	2.52	-2.27	-3.48	2.65	-10.51	-19.03 **	-58.23**

RH- Stands for Relative heterosis HB- Stands for Heterobeltiosis

SH - Stands for Standard heterosis

*Significant at 5% level ** Significant at 1% level

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hybrids showed significant negative relative heterosis. Heterobeltiosis ranged between -25.60 (AE16 x AE5) and 12.41 (AE16 x AE30). Among 15 hybrids, four hybrids exhibited significant positive heterobeltiosis and eight hybrids exhibited significant negative heterobeltiosis. Standard heterosis varied from -7.34 (AE16 x Salkeerthi) to 21.69 (AE5 x Salkeerthi). Seven hybrids exhibited significant positive standard heterosis and one hybrid exhibited significant negative standard heterosis (Table 17).

4.7.10. Fruit weight

Eight hybrids recorded significant positive relative heterosis and seven recorded significant negative relative heterosis (Table18). Relative heterosis ranged between -55.75 (AE20 x AE16) and 70.61 (AE30 x AE5). Among 15 hybrids, seven hybrids exhibited significant positive heterobeltiosis and seven hybrids exhibited significant negative heterobeltiosis. Heterobeltiosis ranged between -61.03 (AE20 x AE16) and 55.08 (AE18 x AE5). Eight hybrids exhibited significant positive standard heterosis and seven hybrids exhibited significant negative standard heterosis. Standard heterosis ranged between -48.17 (AE20 x AE16) and 50.27 (AE30 x AE5).

4.7.11. Number of fruits per plant

All the fifteen hybrids showed significant negative relative heterosis, heterobeltiosis and standard heterosis for number of fruits per plant (Table18). Relative heterosis ranged from -52.71 (AE5 x Salkeerthi) to -8.86 (AE16 x AE18). Heterobeltiosis ranged from -53.69 (AE5 x Salkeerthi) to -12.19 (AE16 x AE18). Standard heterosis ranged from -52.60 (AE5 x Salkeerthi) to -15.50 (AE20 x AE5 and AE16 x AE18).

4.7.12. Marketable fruits per plant

All the fifteen hybrids exhibited significant negative relative heterosis, heterobeltiosis and standard heterosis for marketable fruits per plant (Table18). Relative heterosis varied from -54.52 (AE5 x Salkeerthi) to -15.62 (AE16 x AE18).Heterobeltiosis varied from -56.00 (AE5 x Salkeerthi) to -17.52 (AE20 x

Table 17. Heterosis (%) for number of fruiting nodes, fruit length and fruit girth

Genotypes	Number of fruiting nodes			Fruit length			Fruit girth		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
AE20xAE16	-17.55**	-18.38**	-18.38**	-59.96**	-64.80 **	-62.56**	6.70 **	-0.77	0.17
AE20xAE30	6.95	-4.19	-6.13	-33.97**	-45.81 **	-31.88**	10.94 **	6.22 *	0.77
AE20xAE18	-4.79	-16.70**	-18.38**	65.75 **	54.49 **	24.59**	19.25 **	11.01 **	11.81**
AE20xAE5	7.89	0.00	-2.02	48.92 **	22.54 **	-1.18	-6.62 **	-23.27**	3.53
AE20xSalkeerthi	-7.02	-16.70**	-18.38**	21.73 **	8.01 *	12.47**	-1.28	-13.63**	0.00
AE16xAE30	1.17	-10.17 *	-10.17*	-58.60**	-61.79 **	-51.96**	15.90 **	12.41 **	13.47**
AE16xAE18	-1.17	-14.28**	-14.28**	-43.35**	-53.12 **	-50.13**	8.48 **	8.37 **	9.38**
AE16xAE5	-17.72**	-24.45**	-24.45**	-33.64**	-50.58 **	-47.13**	-14.88 **	-25.60**	0.39
AE16xSalkeerthi	5.80	-6.07	-6.07	-36.17**	-36.84 **	-32.81**	-14.49 **	-19.97**	-7.34**
AE30xAE18	26.98 **	23.62 **	-4.11	-2.60	-24.31 **	-4.85	3.56	0.55	1.27
AE30xAE5	24.06 **	19.56 **	0.00	18.47 **	-16.23 **	-5.31	-2.55	-17.01**	11.98**
AE30xSalkeerthi	5.21	5.21	-18.38**	-29.44**	-35.50 **	-18.91**	5.63 *	-3.91	11.26**
AE18xAE5	6.55	0.07	-16.30**	61.33 **	40.95 **	-1.78	-10.40 **	-21.76**	5.57*
AE18xSalkeerthi	21.62 **	18.40 **	-8.15	7.88	-9.96 *	-6.24	-4.72 *	-10.92**	3.15
AE5xSalkeerthi	3.84	0.07	-16.30**	-38.26**	-53.69 **	-51.78**	-2.93	-9.82 **	21.69**

RH- Stands for Relative heterosis HB- Stands for Heterobeltiosis

SH - Stands for Standard heterosis

*Significant at 5% level ** Significant at 1% level

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AE5). Standard heterosis varied from -55.78 (AE5 x Salkeerthi) to -19.60 (AE20 x AE5).

4.7.13. Yield per plant

All the hybrids except AE20 x Salkeerthi exhibited negative relative heterosis of which only eleven hybrids exhibited significant negative relative heterosis (Table 19). Relative heterosis ranged from -66.75 (AE20 x AE16) to 2.73 (AE20x Salkeerthi). All the hybrids except AE18 x AE5 showed significant negative heterobeltiosis. Heterobeltiosis ranged from -71.05 (AE20 x AE16) to -4.53 (AE18 x AE5). All the fifteen hybrids exhibited significant negative standard heterosis. Standard heterosis varied from -75.28 (AE5 x Salkeerthi) to -12.65 (AE30 x AE5).

4.7.14 Marketable yield per plant

Twelve hybrids exhibited negative relative heterosis of which only ten hybrids had significant negative relative heterosis for marketable yield per plant (Table 19). Relative heterosis ranged from -66.51 (AE20 x AE16) to 1.32 (AE20 x AE5). All the hybrids exhibited significant negative heterobeltiosis. Heterobeltiosis ranged from -70.25 (AE20 x AE16) to -11.95 (AE18 x AE5). All the hybrids exhibited significant negative standard heterosis. Standard heterosis varied from -76.96 (AE5 x Salkeerthi) to -14.92 (AE30 x AE5).

4.7.15 Mucilage content

Among fifteen hybrids, four hybrids exhibited significant positive relative heterosis and ten hybrids exhibited significant negative relative heterosis (Table 19). Relative heterosis ranged from -34.87 (AE20 x Salkeerthi) to 60.27 (AE30 x Salkeerthi). Two hybrids exhibited significant positive heterobeltiosis and eleven hybrids exhibited significant negative heterobeltiosis. Heterobeltiosis varied from -36.87 (AE16 x AE30) to 30.94 (AE30 x Salkeerthi). Four hybrids exhibited significant positive standard heterosis. Standard heterosis varied from -20.18 (AE18 x AE5) to 83.79 (AE30 x Salkeerthi).

Table 18. Heterosis (%) for fruit weight, number of fruits per plant and marketable fruits per plant

Genotypes	Fruit weight			No. of fruits per plant			Marketable fruits per plant		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
AE20xAE16	-55.75 **	-61.03**	-48.17**	-23.61 **	-23.80 **	-26.30**	-25.87 **	-26.82 **	-28.66**
AE20xAE30	4.62 **	4.09 **	5.39**	-30.47 **	-34.63 **	-28.19**	-27.64 **	-29.42 **	-27.65**
AE20xAE18	37.49 **	23.81 **	25.36**	-33.84 **	-36.41 **	-38.50**	-33.51 **	-36.59 **	-38.19**
AE20xAE5	17.30 **	2.64	3.93*	-13.26 **	-13.88 **	-15.50**	-16.00 **	-17.52 **	-19.60**
AE20xSalkeerthi	67.47 **	33.03 **	34.69**	-39.16 **	-40.83 **	-39.44**	-40.10 **	-41.00 **	-40.71**
AE16xAE30	-38.11 **	-45.74 **	-27.83**	-30.75 **	-35.04 **	-28.64**	-29.77 **	-32.34 **	-30.65**
AE16xAE18	-41.24 **	-52.71 **	-37.09**	-8.86 **	-12.19 **	-15.50**	-15.62 **	-18.52 **	-22.61**
AE16xAE5	-26.15 **	-41.99 **	-22.84**	-32.85 **	-33.49 **	-34.74**	-32.99 **	-33.35 **	-36.70**
AE16xSalkeerthi	-15.30 **	-38.67 **	-18.43**	-21.52 **	-23.86 **	-22.07**	-19.30 **	-21.51 **	-21.12**
AE30xAE18	-14.50 **	-22.65 **	-22.49**	-31.61 **	-38.04 **	-31.93**	-30.01 **	-34.81 **	-33.18**
AE30xAE5	70.61 **	49.96 **	50.27**	-44.03 **	-47.02 **	-41.79**	-42.21 **	-44.62 **	-43.24**
AE30xSalkeerthi	31.15 **	4.58 **	4.80**	-30.10 **	-32.49 **	-25.83**	-27.72 **	-28.43 **	-26.64**
AE18xAE5	60.18 **	55.08 **	25.78**	-42.86 **	-45.46 **	-46.49**	-44.92 **	-46.53 **	-48.77**
AE18xSalkeerthi	59.31 **	38.19 **	12.08**	-47.07 **	-50.47 **	-49.30**	-47.33 **	-50.50 **	-50.25**
AE5xSalkeerthi	-19.06 **	-27.76 **	-45.14**	-52.71 **	-53.69 **	-52.60**	-54.52 **	-56.00 **	-55.78**

RH- Stands for Relative heterosis HB- Stands for Heterobeltiosis
SH - Stands for Standard heterosis
*Significant at 5% level ** Significant at 1% level

Table 19. Heterosis (%) for yield per plant and marketable yield per plant

Genotypes	Yield per plant			Marketable yield per plant			Mucilage content		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
AE20xAE16	-66.75 **	-71.05 **	-61.82**	-66.51 **	-70.25 **	-62.31**	6.36 **	2.22	40.67**
AE20xAE30	-27.26 **	-31.28 **	-24.47**	-24.35 **	-25.84 **	-24.07**	-11.47 **	-27.11 **	0.31
AE20xAE18	-29.13 **	-38.29 **	-39.67**	-28.86 **	-38.51 **	-39.52**	-20.98 **	-32.22 **	-6.73*
AE20xAE5	-1.27	-15.82 **	-17.71**	1.32	-15.22 **	-16.61**	-13.55 **	-29.11 **	-2.45
AE20xSalkeerthi	2.73	-16.56 **	-18.43**	0.71	-19.01 **	-20.35**	-34.87 **	-35.51 **	-9.48**
AE16xAE30	-57.51 **	-61.05 **	-48.63**	-56.46 **	-60.64 **	-50.12**	-25.78 **	-36.87 **	-19.88**
AE16xAE18	-48.05 **	-59.74 **	-46.92**	-51.03 **	-61.67 **	-51.43**	-13.16 **	-22.89 **	-2.14
AE16xAE5	-49.85 **	-61.81 **	-49.64**	-49.43 **	-61.50 **	-51.21**	-17.78 **	-30.36 **	-11.62**
AE16xSalkeerthi	-34.20 **	-51.87 **	-36.53**	-31.17 **	-49.34 **	-35.80**	-33.41 **	-36.60 **	-11.01**
AE30xAE18	-42.35 **	-52.16 **	-47.42**	-40.78 **	-49.67 **	-48.47**	14.19 **	8.70 *	7.03*
AE30xAE5	-2.32	-20.52 **	-12.65**	0.91	-16.90 **	-14.92**	6.74 *	6.19	-5.50
AE30xSalkeerthi	-9.28 **	-29.44 **	-22.45**	-5.58	-25.21 **	-23.42**	60.27 **	30.94 **	83.79**
AE18xAE5	-2.12	-4.53	-30.77**	-8.49	-11.95 *	-36.90**	-14.43 **	-18.94 **	-20.18**
AE18xSalkeerthi	-14.71 **	-21.45 **	-43.04**	-15.20 **	-22.21 **	-44.25**	-4.48	-18.74 **	14.07**
AE5xSalkeerthi	-61.97 **	-64.14 **	-75.28**	-63.44 **	-65.21 **	-76.96**	-21.55 **	-36.17 **	-10.40**

RH- Stands for Relative heterosis HB- Stands for Heterobeltiosis
SH - Stands for Standard heterosis
*Significant at 5% level ** Significant at 1% level

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Discussion

5. DISCUSSION

The production of okra is less in Kerala, mainly due to lack of location specific high yielding okra cultivars. Efforts have been taken to develop high yielding location specific okra mainly by exploiting hybrid vigour or heterosis. Kerala Agricultural University has developed a high yielding hybrid that is suitable for southern Kerala conditions. Hence it is important to develop hybrids that are suitable to Northern Kerala conditions.

The present investigation was conducted at Instructional farm, College of Agriculture, Padannakkad during April-July 2019 to develop F_1 hybrids of okra and to evaluate them for heterosis and combing ability. The experiment was carried out in randomized block design with twenty six genotypes in three replications. The experimental material included 6 parents *viz.* AE5, AE16, AE18, AE20, AE30 and Salkeerthi and 15 F_1 hybrids. Arka Nikita was used as check for the estimation of standard heterosis. The mean performances of hybrids were compared with that of mean performances Arka Anamika and Salkeerthi (OPV checks), Manjima and Arka Nikita (F_1 hybrid checks) and parents of Manjima. In this chapter, an attempt has been made to discuss the salient experimental findings.

5.1. Morphological characterization based on qualitative traits

Characterization plays an important role in the assessment of genetic diversity. In the present study, qualitative traits of six parents, fifteen hybrids and 5 checks were subjected to morphological characterization based on IPGRI descriptors. Five qualitative traits namely colour of fruit, position of fruit, fruit shape, ridges per fruit and fruit pubescence were studied. The results of characterization for each character are discussed below:

5.1.1. Colour of fruit

Observation recorded for fruit colour in 26 genotypes indicated that yellowish green was the fruit colour of all parents and hybrids except AE20 and AE30 x AE18. AE 20 had green fruit colour but all crosses involving AE20 showed yellowish green fruit colour. The hybrid AE30 x AE18 showed green fruit colour but the parents involved in the cross showed yellowish green colour. Both these observations are indication of recessive nature of the character "green fruit colour" which needs to be further confirmed by selfing of green fruited types. All the five checks, AE20 and AE30 x AE18 were observed with green fruit colour. Yellowish or light green coloured fruits are mostly preferred in market by consumers (Prasad, 2017) and in the present study most of the genotypes observed with the desirable attractive light green fruits. Similar results are also reported by Ahiakpa (2012).

5.1.2. Position of fruit

Position of the fruit on main stem showed two distinct variations: erect and horizontal. Among the 26 genotypes studied only Salkeerthi and AE20 x AE5 were observed with horizontal fruit position and all other genotypes had erect fruit position. Erect fruit position in all hybrids, including hybrids with Salkeerthi as one of the parent showed dominant nature of the character. There was no genotype showing fruits with pendulous type or drooping position. Similar results were reported by Prasad (2017), Ahiakpa (2012) and Demelie *et al* (2016). *Abelmoshus esculentus* species is characterized by fruits that are erect on the main stem (Bisht *et al.,* 1995). Hence in the present study all the hybrids developed except AE20 x AE5 and all the parents except Salkeerthi were observed with the *Abelmoshus esculentus* species character.

5.1.3. Fruit shape

In okra there is a wide variation in fruit shape. In the present study among 26 genotypes studied most of them belonged to class 1. This finding was in line with the finding of Prasad (2017). All the hybrids except AE20 x AE30, AE16 x AE18, AE16 x AE5, AE5 x Salkeerthi and AE20 x AE16 belonged to class 1. All the parents except AE5 and AE20 belonged to class 1 and this may be reason behind the expression of class 1 fruit shape by majority of crosses. Some of the crosses

Green fruit colour

Yellowish green fruit colour

Erect fruit position

Horizontal fruit position

Plate 4. Fruit colour and Fruit position

involving AE5 and AE20 belonged to class 1 and this indicates the dominant nature of the character. All checks except IC282257 and Manjima belonged to class 1. The parent AE5 and AE20 belonged to class 7 and class 3 respectively. The hybrids AE16 x AE18 and AE16 x AE5 belonged to class 7, AE 20 x AE30 belonged to class 3 and AE20 x AE16 belonged to class 11. The checks IC282257 and Manjima belonged to class 2. In the present study class 4, 5, 6, 9, 10, 12, 13, 14 and 15 were absent which was similar to the findings of Prasad (2017) and Sekyere *et al.*(2011).

5.1.4. Ridges per fruit

Number of ridges may directly relate to the seed yield. Hence more number of ridges higher will be the seed yield (Prasad, 2017). All the parents, hybrids, and checks in the present study showed ridges ranging from five to seven. In commercial cultivation generally five edged medium fruits are preferred (Bisht *et al.,* 1995). So in the present study 5 edged fruits considered as desirable.

5.1.5 Fruit pubescence

The parents AE20, AE30 and Salkeerthi and all the checks had downy fruit pubescence. All the hybrids with AE20 and or AE30 as parents showed downy fruit pubescence even though other parents with prickly fruit pubescence (AE16, AE5 and AE18) were involved in some of the crosses. But majority crosses involving Salkeerthi showed slightly rough nature even though Salkeerthi was downy. This may be indication of recessive nature of downy fruit pubescence. These findings may be indication of decreasing order of dominance for the characters *viz.* slightly rough, downy and prickly respectively. Similar observations were recorded by Bisht *et al.* (1995) and Nwangburuka and Denton (2011). Fruit with downy pubescence is preferred by consumers. Hence in the present study downy fruit pubescence considered as desirable.

5.2 Analysis of variance for experimental design

High significant variations between genotypes, parents and hybrids were recorded for all the characters under study except for fiber content. However, the parents *vs.* hybrids exhibited highly significant mean squares for plant height, primary branches per plant, inter node length, days to first flowering, node of fruit set, fruit length, fruit weight, number of fruits per plant, marketable fruits per plant, yield per plant, marketable yield per plant and mucilage content except for days to 50% flowering, number of fruiting nodes and fruit girth. The significance of parents *vs.* hybrids observed for maximum characters indicated that the basic pre-requisite for the comparison of parents and hybrids for different characters were satisfied. This implied that the selected material was suitable for the study of expression of heterosis and gene effects associated with the inheritance of different traits.

5.3 Mean performance of parents, hybrids and checks

An investigation of mean performance of parents and hybrids for all characters showed significant differences among the six parents and 15 hybrids for all the traits except for fiber content, implied sufficient variability for selection.

A good performing genotype of okra needs tall stature, more number of primary branches, shorter internodes, earliness, lower node of fruit set, higher number of fruiting nodes, increased fruit length, girth, weight, higher number of fruits per plant, higher yield per plant and also reasonable content of fiber and mucilage. Earliness in okra is also a desirable character since it indicates the potential of genotype to give economic yield as early as possible. Hence in this study days to first flowering, days to 50 per cent flowering and first fruit producing nodes are recorded to study earliness of genotypes (Reddy *et al.*, 2013a)

No one of the parents gave consistent good performance for all the characters studied. Same condition was observed by Arvindbhai (2014). Among parents, AE20 showed the best performance for growth and earliness traits with maximum plant height, maximum number of primary branches per plant, lowest internode length, least number of days to first flowering as well as 50% flowering. It was shorter compared to all checks. For primary branches per plant it was good performer compared to all checks. In the case of days to first flowering and days to 50% flowering it was good performer compared to all checks except Arka Anamika. For inter node length AE20 performed well compared to all checks except Manjima and Arka Nikita

AE18 recorded good performance for internode length and node of fruit set. For inter node length AE18 performed well compared to all checks except Manjima and Arka Nikita. In the case of node of fruit set it performed well compared to all checks except Gowreesapattam local.

AE16 had higher number of fruiting nodes and fruit weight which also contributed to its higher yield per plant. It also had least incidence of fruit and shoot borer which contributed to high marketable yield per plant. It was better performer for fruit weight, yield per plant and marketable yield per plant compared to all checks except Arka Anamika. In the case of number of fruiting nodes it performed better compared to all checks except Arka Nikita and Gowreesapattam local.

AE5 had the maximum fruit girth among parents and checks. AE30 recorded highest fruit length among parents and checks. It also recorded highest number of fruits per plant and marketable fruits per plant among parents and all checks except Arka Anamika. Maximum mucilage content was observed in Salkeerthi and it was also higher when compared to all checks except Gowreesapattam local.

There was considerable variability among hybrids for all the traits under study except for fiber content. No one of the hybrids gave persistent good performance for all the traits under study like parents. In terms of growth attributes among the hybrids AE30 x AE18 showed good performance for plant height and node of fruit set. The hybrid AE18 x Salkeerthi gave the best performance for number of primary branches not only among hybrids but also among checks and parents as well. For earliness attributes the hybrid AE18 x AE5 showed the best performance with shortest duration for days to 50% flowering between the hybrids as well as parents and checks. It also had shortest internode length. The hybrid AE16 x Salkeerthi was the earliest for days to first flowering among the hybrids. In terms of yield attributes the hybrid AE30 x AE5 had maximum number of fruiting nodes and fruit weight which also contributed to its maximum yield as well as marketable yield among the hybrids. The hybrid AE20 x AE5 had the highest number of fruits per plant and marketable fruits per plant among the hybrids. Among the hybrids AE20 x AE18 performed well for node of fruit set and fruit length and the hybrid AE5 x Salkeerthi showed higher mean performance for fruit girth. The hybrids AE16 x AE30 and AE18 x AE5 had higher mucilage content among the hybrids. All the hybrids showed lower performance than checks for yield characters.

5.4. Combining ability

Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses (Rashid *et al.,* 2007). Combining ability manifests the breeding potential of parents to produce hybrids. GCA is the average performance of a genotype in a series of hybrid combinations and SCA is those cases in which certain hybrid combinations perform better or poorer than would be expected on the basis of the average performance of the parental inbred lines (Sprague and Tatum, 1942).

The parents with high *gca* and cross combinations with high *sca* can be revealed through combining ability analysis and this knowledge helps in selecting the parents to be included in a hybridization program. The present study uses half diallel method for evaluation of combining abilities.

5.4.1. Analysis of variance for combining ability

Estimates of components of *gca* and *sca* estimates give an idea about general trend of the genetic control of the characters. The *gca* indicate the activity of genes which are largely additive in their effects as well as additive x additive interactions (Griffing, 1956). Specific combining ability is owing to loci with dominance variance (non-additive effects) and all the three types of epistatic interaction components if epistasis was present (additive x dominance and dominance × dominance interactions).

In the present study, both *gca* and *sca* variances were significant for all the characters. This indicated the importance of both additive and non additive variance in the expression of these traits suggesting the use of integrated breeding strategies which can efficiently utilize the additive as well as non additive genetic variability (Reddy *et al.*, 2012). Significance of both the variances have been reported by Sood and Kalia (2001) Rewale *et al.* (2003b) and Laxman *et al.* (2013) for days to first flowering; Sood and Kalia (2001) and Laxman *et al.* (2013) for internodal length; Biju *et al.* (2004) and Reddy *et al.* (2011) for number of fruits per plant; Sood and Kalia (2001) and Singh *et al.* (2009) for plant height; Singh and Sanwal (2010) for fruit yield per plant. But ratio of *gca* variance to *sca* variance was less than unity for all the traits under study. As *sca* variance was more than *gca* variance for all the traits, indicated preponderance of non additive or dominance gene action in the expression of those characters. Identical findings were reported by Reddy *et al.* (2013a) except for fruit girth and number of primary branches. Therefore heterosis breeding can be adopted to exploit non additive gene action for such traits (Verma and Sood, 2015).

5.4.2. Estimation of *gca* and *sca* effect

In okra combining ability effects are considered desirable in positive direction for plant height, number of primary branches per plant, fruit length, fruit girth, fruit weight, total number of fruits per plant, number of marketable fruits per plant, total yield per plant, fiber content, mucilage content and marketable yield per plant. It is desirable in negative direction for internodal length, days to first flowering, days to 50% flowering and first fruiting node.

The *gca* estimates of six parents (Table 21) showed that AE20 was an outstanding general combiner for five traits *viz.* internode length, number of fruiting nodes, fruit weight, and fiber content. AE30 was the best general combiner for plant height, fruit length, number of fruits per plant, and marketable fruits per plant. AE5 was best general combiner for days to first flowering, days to 50% flowering and fruit girth. AE16 was best general combiner for number of fruits per plant and marketable fruits per plant. AE18 was best general combiner for node of fruit set. Salkeerthi was best general combiner for primary branches per plant and mucilage content. None of the parents were good general combiner for all the traits. Similar results reported by Sivakumar *et al.* (1995), Sood and Kalia (2001), Bhalekar *et al.* (2006), Borgaonkar *et al.* (2003), Biju *et al.* (2004), Kumar *et al.* (2005), Srivastava *et al.* (2008) and Singh *et al.* (2009). The parental lines with high *gca* effect can be exploited in a multiple crossing program to isolate desirable lines and these lines could be released as conventional varieties or used as improved parents for F_1 hybrid production.

Relatively higher magnitudes of *sca* effects are due to superior gene combinations. The low *sca* effects observed might be due to unfavorable gene combinations in the parents. The examination of specific combining ability effects of crosses (Table 22) revealed that the hybrid AE30 x AE5 was good specific combiner for number of fruiting nodes, fruit weight and marketable yield per plant. The superior cross combination identified for plant height, primary branches per plant and mucilage content was AE30 x Salkeerthi. The hybrid AE20 x AE5 was identified as good specific combiner for number of fruits per plant and marketable fruits per plant. AE20 x AE18 was identified as superior specific combiner for fruit length and fruit girth. The superior specific combiners for internode length, days to first flowering days to 50% flowering and node of fruit set were identified in the respective hybrids namely AE18 x AE5, AE16 x Salkeerthi, AE20 x AE16 and AE5 x Salkeerthi. The hybrid AE20 x Salkeerthi showed the best specific combining ability for yield per plant. No cross combinations exhibited high significant specific combining ability in desirable direction for all characters studied. Similar findings reported by Singh and Sanwal (2010), Reddy *et al.* (2011), Reddy *et al.* (2013a) and Obiadalla *et al.* (2013). The best specific combiners with highest magnitude of *sca* effect in favorable direction are recommended for heterosis breeding.

5.5. Heterosis

The preeminence of the hybrids in crosses was evaluated over mid-parent, better parent and standard check for all the 16 traits under investigation. The heterotic response of F_1 is an indication of genetic diversity between the parents involved. The actual performance of a hybrid cannot be estimated only based on the relative heterosis and heterobeltiosis because only the hybrid with desirable standard heterosis is said to be commercially worthy. Hence measure of heterosis over standard check (standard heterosis) is better parameter for assessing the practical utility of the hybrid. In the present study the commercial hybrid 'Arka Nikita' used as a standard check. Among the 15 crosses, the crosses that exhibited highly significant heterosis over mid parent, better parent and standard check in the desirable direction are presented in Table 20 and discussed below

In the present study of the 16 characters *viz.* plant height, number of primary branches per plant and internode length largely determines the fruit bearing surface and thus considered as growth attributes. Plant with increased height and more number of primary branches accommodates more number of nodes for given internode length. Shorter distance between nodes accommodates more number of nodes on the main stem leading to higher fruit number. Hence positive heterosis is desirable for plant height and number of primary branches while negative heterosis is desirable for internode length.

The crosses AE30 x AE18, AE30 x Salkeerthi and AE20 x AE30 were identified with highly significant positive relative heterosis, heterobeltiosis and standard heterosis for plant height. For plant height Ahmed *et al.* (1999) reported heterobeltiosis, Chauhan and Singh (2002) reported heterobeltiosis and standard heterosis, and Rewale *et al.* (2003a) reported relative heterosis and heterobeltiosis.

Table 20. Better crosses selected based on heterosis in the desirable direction

Characters	Best crosses for RH	Best crosses for HB	Best crosses for SH
Plant height (cm)	AE30xAE18 AE30xSAL AE20xAE30	AE30xAE18 AE30xSAL AE20xAE30	AE30xAE18 AE30xSAL AE20xAE30
Primary branches per plant	AE30xSAL AE30xAE5 AE18xSAL	AE30xSAL AE18xSAL AE30xAE5	AE18xSAL AE30xSAL AE30xAE5
Inter node length (cm)	AE16xAE5 AE30xSAL AE18xAE5	AE30xSAL AE16xAE5 AE30xAE5	AE18xAE5 AE20xAE18 AE16xAE5
Days to first flowering	AE16xSAL AE20xAE16 AE16xAE5	AE16xSAL AE20xAE16 AE16xAE5	AE16xSAL AE20xSAL
Days to 50% flowering	AE16xAE5 AE20xAE16 AE16xSAL	AE20xAE16 AE16xAE5 AE16xSAL	AE18xAE5
Node of fruit set	AE5xSAL AE16xSAL AE16xAE30	AE5xSAL AE16xSAL	AE16xAE30 AE16xAE18 AE16xAE5 AE20xAE18 AE30xAE18
No. of fruiting nodes	AE30xAE18 AE30xAE5 AE18xSAL	AE30xAE18 AE30xAE5 AE18xSAL	Nil
Fruit length (cm)	AE20xAE18	AE20xAE18	AE20xAE18

	AE18xAE5 AE20xAE5	AE30xSAL AE20xAE5	AE20xSAL
Fruit girth (cm)	AE20xAE18 AE16xAE30 AE20xAE30	AE16xAE30 AE20xAE18 AE16xAE18	AE5xSAL AE16xAE30 AE30xAE5
Fruit weight (g)	AE30xAE5 AE20xSAL AE18xAE5	AE18xAE5 AE30xAE5 AE18xSAL	AE30xAE5 AE20xSAL AE18xAE5 AE20xAE18
No. of fruits per plant	Nil	Nil	Nil
Marketable fruits per plant	Nil	Nil	Nil
Yield per plant (g)	Nil	Nil	Nil
Marketable yield per plant (g)	Nil	Nil	Nil
Mucilage content (%)	AE30xSAL	AE30xSAL	AE30xSAL AE20xAE16

SAL – denotes 'Salkeerthi'

AE30 x Salkeerthi, AE30 x AE5 and AE18 x Salkeerthi showed high significant positive relative heterosis, heterobeltiosis and standard heterosis for primary branches per plant. Desai *et al.* (2007) recorded significant heterobeltiosis and standard heterosis for primary branches per plant and Khatik *et al.* (2012) reported significant relative heterosis for the same character.

For internode length, AE16 x AE5 documented with high significant negative relative heterosis, heterobeltiosis and standard heterosis; AE18 x AE5 exhibited highly significant negative relative heterosis and standard heterosis; AE30 x Salkeerthi showed highly significant negative relative heterosis and heterobeltiosis and AE30 x AE5 showed highly significant negative heterobeltiosis. Hosmani *et al.* (2008) reported negative relative heterosis, heterobeltiosis and standard heterosis for inter node length.

Days to first flowering, days to 50% flowering and node of fruit set are indicators of earliness in okra. Early flowering not only gives early pickings and better returns but also increases the fruiting period of the plant. Hence negative heterosis is considered as desirable for all these three attributes of earliness.

The hybrid AE16 x Salkeerthi showed highly significant negative relative heterosis, heterobeltiosis and standard heterosis for days to flowering; AE20 x AE16 and AE16 x AE5 showed highly significant negative relative heterosis and heterobeltiosis, whereas AE20 x Salkeerthi showed highly significant negative standard heterosis. Identical findings were reported by Reddy *et al.* (2013a).

The hybrids AE16 x AE5, AE20 x AE16 and AE16 x Salkeerthi showed highly significant negative relative heterosis and heterobeltiosis for days to 50% flowering and highly significant negative standard heterosis showed by AE18 x AE5. Negative heterosis for days to 50% flowering was also observed by Weerasekara *et al.* (2007) and Reddy *et al.* (2012).

For node of fruit set, AE5 x Salkeerthi and AE16 x Salkeerthi exhbited high significant negative relative heterosis and heterobeltiosis, AE16 x AE30 showed highly significant negative relative heterosis and standard heterosis, AE16 x AE18, AE16 x AE5, AE20 x AE18, and AE30 x AE18 showed highly significant negative standard heterosis. These findings are in line with that of Weerasekara *et al.* (2007) Jindal *et al.* (2009) Reddy *et al.* (2012) and Singh *et al*. (2012).

Number of fruiting nodes, fruit length, fruit girth, fruit weight and total number of fruits are treated to be directly related with total yield per plant. Hence positive heterosis considered as favorable for all these characters.

AE30 x AE18, AE30 x AE5, and AE18 x Salkeerthi showed highly significant positive relative heterosis and heterobeltiosis for number of fruiting nodes. No one of the hybrids documented with significant positive standard heterosis. Identical findings observed by Desai *et al.* (2007). No one of the crosses exhibited significant standard heterosis in the desirable direction.

For fruit length AE20 x AE18 showed highly significant positive estimates for all the three types of heterosis. AE20 x AE5 showed highly significant positive relative heterosis and heterobeltiosis, AE18 x AE5 exhibited highly significant positive relative heterosis, AE30 x Salkeerthi exhibited highly significant positive heterobeltiosis, and AE20 x Salkeerthi showed highly significant positive standard heterosis. Identical findings were also seen in the study of Chauhan and Singh (2002), Desai *et al.* (2007) and Mehta *et al.* (2007).

The hybrid AE16 x AE30 exhibited high significant positive relative heterosis, heterobeltiosis and standard heterosis for fruit girth. AE20 x AE18 showed highly significant positive relative heterosis and heterobeltiosis. AE20 x AE30 manifested highly significant positive relative heterosis and AE16 x AE18 showed highly significant positive heterobeltiosis. The hybrids showing high significant positive standard heterosis for fruit girth were AE5 x Salkeerthi and AE30 x AE5. Similar results observed by Manivannan *et al.* (2007), Reddy *et al.* (2012) and Obiadalla *et al.* (2013).

The hybrids AE30 x AE5 and AE18 x AE5 manifested high significant positive values for all the three types of heterosis for fruit weight. AE20 x Salkeerthi showed highly significant positive relative and standard heterosis. AE18 x Salkeerthi showed highly significant positive heterobeltiosis and AE20 x AE18 exhibted highly significant positive standard heterosis. These findings were similar to that of Desai *et al.* (2007), Hosamani *et al.* (2008) and Ramya and Kumar (2010).

The hybrid AE30 x Salkeerthi documented with high significant positive heterosis, heterobeltiosis and standard heterosis for mucilage content. AE20 x AE16 showed highly significant positive standard heterosis. This finding was in line with that of Verma and Sood (2015).

None of the cross combinations showed desirable significant positive relative heterosis, heterobeltiosis and standard heterosis for yield attributes *viz.* number of fruits per plant, marketable fruits per plant, yield per plant and marketable yield per plant. Similar results for heterobeltiosis and standard heterosis for yield per plant were also seen in the study of Rewale *et al.* (2003a) and Obiadalla *et al.* (2013) reported undesirable standard heterosis for number of fruits per plant. There were crosses involving both the parents with high general combining ability showing low and negative heterosis for the yield attributes this may be due to lack of complementation of the parental genes or due to unfavorable gene combinations in the parents. Nine of the 15 crosses *viz.* AE20 x AE18, AE20 x AE5, AE20 x Salkeerthi, AE16 x AE18, AE16 x AE5, AE16 x Salkeerthi, AE30 x AE18, AE30 x AE5, and AE30 x Salkeerthi had one poor combiner in the parental combinations (H x L) for the characters number of fruits per plant, marketable fruits per plant, yield per plant and marketable yield per plant. Hence low heterosis of hybrids for these characters may be due to the involvement of one of the parent with low *gca* effect.
Among the 15 crosses, the cosses AE18 x AE5, AE18 x Salkeerthi and AE5 x Salkeerthi involves parents which are low general combiners for number of fruits per plant, marketable fruits per plant, yield per plant and marketable yield per plant.

Hence such combinations with both parents involving low general combiners (L x L) may be the reason for low heterosis shown by these crosses.

Marketable yield per plant in okra is highly influenced by incidence of YVMV and shoot and fruit borer (Reddy *et al.*, 2013a). The incidence of YVMV was observed among all the hybrids. YVMV incidence of 5-12 % was recorded for the hybrids AE20 x Salkeerthi, AE18 x AE5, AE16 x Salkeerthi, AE20 x AE30, AE30 x AE5, and AE18 x Salkeerthi. The seven hybrids *viz.* AE16 x AE5, AE20 x AE5, AE5 x Salkeerthi, AE16 x AE18, AE20 x AE18, AE30 x Salkeerthi, and AE30 x AE18 were recorded with 15-30% YVMV incidence. YVMV incidence of 31-45% observed for the hybrids AE20 x AE16 and AE16 x AE30. Incidence of shoot and fruit borer (> ETL 5%) also recorded for all hybrids. incidence of 5-12% shoot and fruit borer was observed for six hybrids *viz.* AE16 x AE5, AE20 x Salkeerthi, AE20 x AE18, AE30 x AE5, AE18 x Salkeerthi and AE30 x AE18. The nine hybrids *viz.* AE20 x AE16, AE20 x AE5, AE5 x Salkeerthi, AE16 x AE18, AE16 x AE30, AE18 x AE5, AE16 x Salkeerthi, AE20 x AE30 and AE30 x Salkeerthi were recorded with 15-30% incidence of shoot and fruit borer. Hence incidence of YVMV and shoot and fruit borer resulted in the reduction in the number of marketable fruits which inturn resulted in negative heterosis for marketable yield per plant.

5.6. Evaluation of parents

The well performing parents may not be best general combiner. Hence in the present study the parents were evaluated on the bass of both their mean performance and *gca* effects in desirable direction. A perusal of the results on the *gca* effects and mean performance (Table 21), revealed that Salkeerthi was assuring for primary branches per plant and mucilage content. AE18 was best parent for node of fruit set. AE5 was best parent for fruit girth. AE 20 was identified as parent which exhibited superiority for characters *viz.* inter node length, days to first flowering, days to 50% flowering, number of fruiting nodes, fruit weight and yield per plant. AE30 was promising parent for plant height, fruit length, number of fruits per plant, marketable fruits per plant, and marketable yield per plant. Days to first flowering, 50% flowering and node of fruit set are traits contributing to earliness. The parental line AE20 was the high general combiner for all of the three earliness attributes, indicating its potential for exploiting earliness in okra.

The *per se* performance of AE16 was higher for fruit weight, number of fruiting nodes, yield per plant and marketable yield per plant. However it was a poor general combiner for the characters such as number of fruiting nodes, fruit weight, and yield per plant compared to AE20 and marketable yield per plant compared to AE30. High *gca* effects for fruit yield in AE20 and AE30 were associated with good/average *gca* effects for number of fruits per plant and fruit weight (fig 2 to 4). Similar findings have been reported by Biju *et al.* (2004), Bhalekar *et al.* (2006), Reddy *et al.* (2011) and Adiger *et al.* (2013). High *gca* effects are attributed to additive or additive x additive gene effects, which represent the fixable genetic components of variance (Griffng, 1956).

The parental lines with high *gca* effects may be used in a multiple crossing program for isolating desirable lines in okra. The selected lines from such multiple crosses could be released as conventional varieties or used as improved parents for F_1 hybrid production (Reddy *et al.,* 2013a). In the present study AE20 and AE30 are identified as best parents showing good performance for maximum number of characters with high *gca* and *per se* performance. These lines performed well even when they were affected by yellow vein mosaic disease (AE20- 38.88% and AE30- 27.77%) and fruit and shoot borer (AE20-22.22% and AE30- 11.11%). Hence these can be used in further breeding program for higher yield and tolerance to yellow vein mosaic and fruit and shoot borer.

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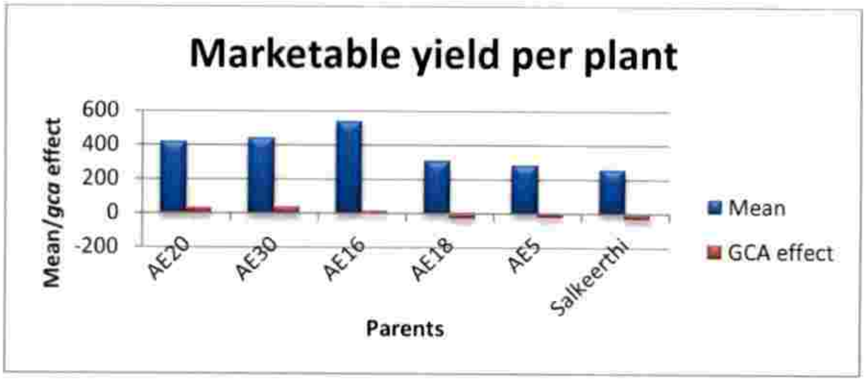

Fig2. Mean and *gca* effects of six parents for marketable yield per plant

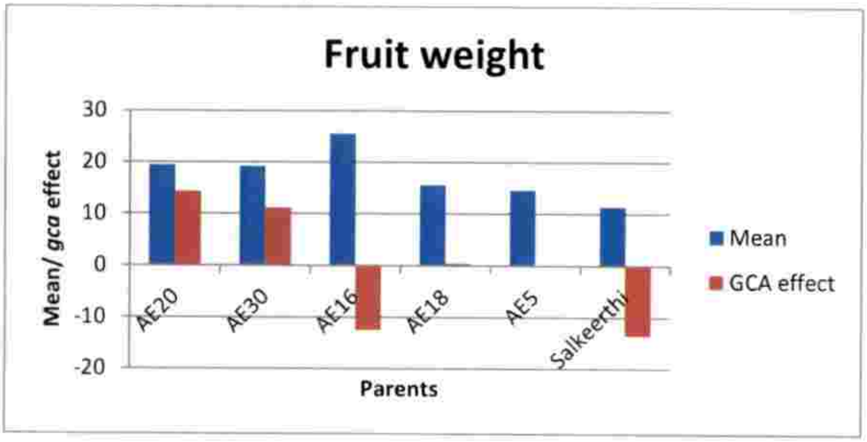

Fig3. Mean and *gca* effects of six parents for fruit weight

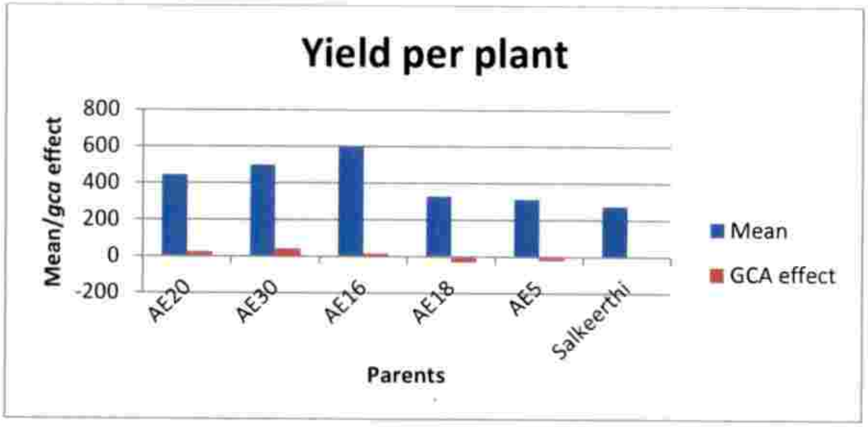

Fig4. Mean and *gca* effects of six parents for yield per plant

Table 21. Better parents selected based on mean performance and *gca* effect

Character	Mean performance	*gca* effect	*gca* effect and mean performance
Plant height (cm)	AE20, AE30, AE16	AE30, AE20,AE18	AE30, AE20
Primary branches per plant	AE20, AE18, Salkeerthi	Salkeerthi , AE18	Salkeerthi, AE18
Inter node length (cm)	AE18, AE20, AE5	AE20, AE5	AE20, AE5
Days to first flowering	AE20, AE5, Salkeerthi	AE20, Salkeerthi, AE5	AE20, Salkeerthi , AE5
Days to 50% flowering	AE20, AE5, AE18	AE5, AE20, Salkeerthi	AE20, AE5
Node of fruit set	AE18, AE20, AE16, AE30, AE5	AE18, AE16	AE18,AE16
No. of fruiting nodes	AE16, AE20, AE5	AE20	AE20
Fruit length (cm)	AE30, AE16, Salkeerthi	AE30, Salkeerthi,AE20	AE30, Salkeerthi
Fruit girth (cm)	AE5, Salkeerthi, AE16, AE18	AE5, Salkeerthi	AE5, Salkeerthi
Fruit weight (g)	AE16, AE20, AE30	AE20, AE30,	AE20, AE30,
No. of fruits per plant	AE30, Salkeerthi, AE5,	AE16, AE30, AE20	AE30
Marketable fruits per plant	AE30, Salkeerthi, AE20,	AE16, AE30, AE20	AE30, AE20
Yield per plant (g)	AE16, AE30, AE20	AE30, AE20, AE16	AE20, AE16, AE30
Marketable yield per plant (g)	AE16, AE30, AE20	AE30, AE20, AE16	AE30, AE20, AE16
Mucilage content (%)	Salkeerthi, AE20, AE16	Salkeerthi, AE20	Salkeerthi, AE20

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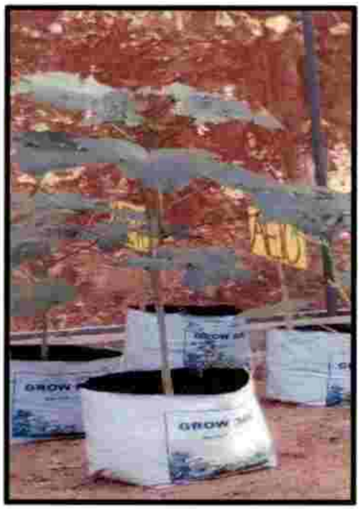
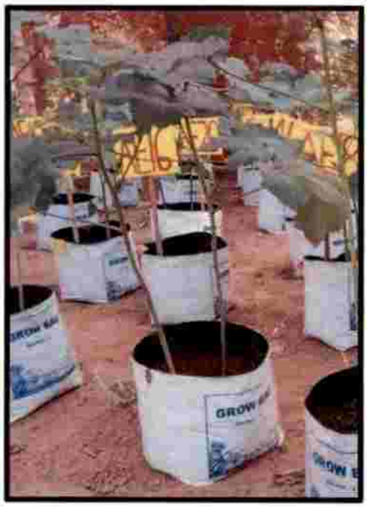


AE 20

Fruit of AE 20



AE 30

Fruit of AE 30

Plate 5. Best parents identified

5.7. Evaluation of hybrids

The basic objective of hybrid development programe is to concentrate the favorable genes from the desirable parents on to a single genetic background. The extent of taking advantage of hybrid vigour mainly focuses on the direction and magnitude of heterosis, biological feasibilities and the nature of gene action involved. Evaluation of hybrid based only on mean performance may not be the appropriate parameter for selection of superior hybrids because hybrids show high heterosis even when the parental means are low and vice versa. A hybrid is commercially worthy only when it exhibits desirable standard heterosis over the best locally adapted variety. The measure of heterosis over standard check (standard heterosis) is better parameter for deciding its practical utility.

Mean performance and standard heterosis estimates still may not be sufficient to decide better hybrid. Specific combining ability is another important parameter that should be considered while selecting superior hybrid. It is used to indicate those situations in which some combination do relatively better or worse than would be expected based on average performance of the genotypes involved. Wakode *et al.* (2016) used mean performance and *sca* effect to select better hybrid and Arvindbhai (2014) used standard heterosis to select better hybrid. Hence in the present study superior hybrids were identified based on mean performance, *sca* effects and standard heterosis. The performance of hybrids for each character as mentioned in the Table 22 is discussed below.

5.7.1 Plant height

Among 15 hybrids, AE30 x AE18, AE30 x Salkeerthi, and AE20 x AE30 were identified as better performers for plant height since they showed high mean performance, significant positive *sca* effect and significant positive standard heterosis. Significant positive *sca* effect was seen in the study of Singh *et al.* (2009) and Sood and Kalia (2001). Significant positive standard heterosis was reported by Arvindbhai (2014) for this character.

5.7.2. Primary branches per plant

The maximum number of primary branches is desirable for higher yield. On the basis of high mean performance coupled with significant positive *sca* effects and significant positive standard heterosis, two hybrids *viz.* AE18 x Salkeerthi and AE30 x Salkeerthi were selected as superior hybrids for number of primary branches. Similar results were also reported for primary branches in okra by Arvindbhai (2014). Significant positive *sca* effect was reported by Wakode *et al.* (2016). Significant positive standard heterosis reported by Joshi *et al.* (1958), Singh *et al.* (1977) and Singh and Singh (1979b).

5.7.3. Internode length

Shorter internodes are required for an ideal okra hybrid. Shorter the distance between nodes higher number of fruiting nodes can be accommodated on the plant (Kerure and Pitchaimuthu, 2019). Hence based on low mean performance coupled with significant negative *sca* effects and significant negative standard heterosis three hybrids *viz.* AE18 x AE5, AE16 x AE5 and AE30 x Salkeerthi were selected as superior performers for shorter internode length. Significant negative *sca* effect was seen in the study of Wakode *et al.* (2016). Significant negative standard heterosis was seen in the study of Ahmed *et al.* (1999), Dhankar and Dhankar (2001) and Rewale *et al.* (2003a), Singh *et al.* (2004), Weerasekara *et al.* (2007) Jindal *et al.* (2009), and Kerure and Pitchaimuthu (2019).

5.7.4. Days to first flowering

Early flowering is a required feature of potential hybrid. Hence based on low mean performance coupled with significant negative *sca* effects and significant negative standard heterosis one hybrid, AE16 x Salkeerthi is identified as superior for days to first flowering. Significant negative *sca* effect was seen in the study of Wakode *et al.* (2016). Significant negative standard heterosis was reported by Rewale *et al.* (2003b) Weerasekara *et al.* (2008) and Reddy *et al.* (2012).

Table 22. Better hybrids selected based on mean performance, *sca* effect and standard heterosis

Character	Mean performance	*sca* effect	Standard heterosis over hybrid	Superior hybrids
Plant height	AE30xAE18 AE30xSAL AE20xAE30 AE20xAE18	AE30xSAL AE30xAE18 AE20xAE18 AE20xAE30	AE30xAE18 AE30xSAL AE20xAE30	AE30xAE18 AE30xSAL AE20xAE30
Primary branches per plant	AE18xSAL AE30xSAL AE16xSAL AE16xAE18	AE30xSAL AE30xAE5 AE18xSAL	AE18xSAL AE30xSAL AE16xSAL	AE18xSAL AE30xSAL
Internode length	AE18xAE5 AE20xAE18 AE16xAE5 AE30xSAL	AE18xAE5 AE16xAE5 AE30xSAL AE16xSAL	AE18xAE5 AE20xAE18 AE16xAE5 AE30xSAL	AE18xAE5 AE16xAE5 AE30xSAL
Days to first flowering	AE16xSAL AE20xSAL AE20xAE16 AE20xAE5	AE16xSAL AE20xAE16 AE16xAE5 AE30xAE18	AE16xSAL AE20xSAL	AE16xSAL AE20xAE16
Days to 50% flowering	AE18xAE5 AE5xSAL AE20xAE16 AE16xAE5	AE20xAE16 AE18xAE5 AE16xAE5 AE16xSAL	AE18xAE5	AE18xAE5
Node of fruit set	AE20xAE18 AE16xAE30 AE16xAE18 AE16xAE5 AE30xAE18	AE5xSAL AE20xAE18 AE16xSAL	AE16xAE30 AE16xAE18 AE16xAE5 AE20xAE18 AE30xAE18	AE20xAE18
No. of fruiting nodes	AE30xAE5 AE20xAE5 AE30xAE18 AE16xSAL	AE30xAE5 AE30xAE18 AE18xSAL AE20xAE5	AE30xAE5	AE30xAE5
Fruit length	AE20xAE18	AE20xAE18	AE20xAE18	AE20xAE18

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	AE20xSAL AE30xAE5 AE20xAE5	AE30xAE5 AE20xSAL AE20xAE5	AE20Xsal	AE20xSAL
Fruit girth	AE5xSAL AE16xAE30 AE30xAE5 AE20xAE18	AE20xAE18 AE16xAE30 AE16xAE18 AE30xSAL	AE5xSAL AE16xAE30 AE30xAE5 AE20xAE18	AE16xAE30 AE20xAE18
Fruit weight	AE30xAE5 AE20xSAL AE18xAE5 AE20xAE18	AE30xAE5 AE20xSAL AE18xAE5 AE18xSAL	AE30xAE5 AE20xSAL AE18xAE5 AE20xAE18	AE30xAE5 AE20xSAL AE18xAE5
No. of fruits per plant	AE20xAE5 AE16xAE18 AE16xSAL AE30xSAL	AE20xAE5 AE16xAE18	AE20xAE5 AE16xAE18 AE16xSAL AE30xSAL	AE20xAE5 AE16xAE18
Marketable fruits per plant	AE20xAE5 AE16xSAL AE16xAE18 AE30xSAL	AE20xAE5	AE20xAE5 AE16xSAL AE16xAE18	AE20xAE5
Yield per plant	AE30xAE5 AE20xAE5 AE20xSAL AE30xSAL	AE20xSAL AE30xAE5 AE20xAE5 AE18xAE5	AE30xAE5 AE20xAE5 AE30xSAL AE20xAE30	AE30xAE5 AE20xAE5
Marketable yield per plant	AE30xAE5 AE20xAE5 AE20xSAL AE30xSAL	AE30xAE5 AE20xAE5 AE20xSAL AE30xSAL	AE30xAE5 AE20xAE5 AE20xSAL AE30xSAL	AE30xAE5 AE20xAE5 AE20xSAL AE3OxSAL
Mucilage content	AE30xSAL AE20xAE16 AE18xSAL AE30xAE18	AE30xSAL AE20xAE16 AE30xAE18	AE30xSAL AE20xAE16 AE18xSAL	AE30xSAL AE20xAE16

SAL- Denotes 'Salkeerthi'

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5.7.5. Days to 50% flowering

Earliness in okra is also determined by the number of days from sowing to 50% full-bloom (Theophilus, 2016). Based on low mean performance coupled with significant negative *sca* effects and significant negative standard heterosis, one hybrids *viz*. AE18 x AE5 is considered as superior for earliness. Significant negative *sca* effect was seen in the study of Reddy *et al.* (2013a). Significant negative standard heterosis was seen in the study of Kerure and Pitchaimuthu (2019).

5.7.6. Node of fruit set

Node of fruit set determines earliness and number of fruiting nodes in okra. Lower node of fruit set is desirable. Based on low mean performance coupled with significant negative *sca* effects and standard heterosis AE20 x AE18 is considered as superior hybrid. Significant negative standard heterosis also reported by Shukla and Gautam (1990), Sood and Sharma (2001) Singh *et al.* (2013) and Kerure and Pitchaimuthu (2019).

5.7.7. Number fruiting nodes

Number of fruiting nodes is a yield determining factor. Depending on high mean performance coupled with significant positive *sca* effects and significant positive standard heterosis, AE30 x AE5 is selected as superior hybrid for the character. No one of the hybrids exhibited significant positive standard heterosis. Hence the hybrid, AE30 x AE5 on par with standard check is considered as promising. Significant positive *sca* effect for this trait was seen in the study of Wakode *et al.* (2016).

5.7.8. Fruit length

Fruit yield is influenced directly or indirectly by fruit length suggesting that these traits are most useful as selection criteria in breeding for yield improvement (Theophilus, 2016). Based on the high mean performance coupled with significant positive *sca* effects and significant positive standard heterosis the hybrids, AE20 x AE18 and AE20 x Salkeerthi are superior. Significant positive *sca* effect was reported by Dabandata *et al.* (2010). Significant positive standard heterosis was seen in the study of Kumar *et al.* (2015), Shwetha *et al.* (2018) and Kerure and Pitchaimuthu (2019).

5.7.9. Fruit girth

Fruit girth contributes to higher fruit yield. Depending on high mean performance coupled with significant positive *sca* effects and significant positive standard heterosis the hybrids, AE16 x AE30 and AE20 x AE18 are considered superior for this trait. Significant positive *sca* effect was seen in the study of Dabandata *et al.* (2010). Significant positive standard heterosis reported by Kerure and Pitchaimuthu (2019), Verma and Sood (2015) and Shwetha *et al.* (2018).

5.7.10. Fruit weight

The fruit weight influence yield and can be used as selection criteria for yield improvement in okra (Theophilus, 2016). Depending on high mean performance coupled with significant positive *sca* effects and standard heterosis for fruit weight the hybrids, AE30 x AE5, AE20 x Salkeerthi and AE18 x AE5 are identified as superior performers for fruit weight. Significant positive *sca* effect was reported by Ashwani *et al.* (2013), Solankey *et al.* (2013), Verma and Sood (2015). Significant positive standard heterosis were reported by Wakode *et al.* (2016), Shwetha *et al.* (2018) and Kerure and Pitchaimuthu (2019).

5.7.11. Number of fruits per plant

The character, number of fruits per plant is a main yield determining character. The hybrids AE20 x AE5 and AE16 x AE18 were selected depending on high mean performance coupled with significant positive *sca* effects and standard heterosis for this character. All hybrids exhibited significant standard heterosis in undesirable direction. Hence hybrids with comparatively less negative standard heterosis identified as better hybrid. Significant negative standard heterosis reported by Dhankar *et al.* (1998). Significant positive *sca* effect was reported by Dabandata *et al.* (2010).

5.7.12. Marketable fruits per plant

Higher number of marketable fruits per plant is a desirable character while selecting superior hybrids. All hybrids showed significant standard heterosis in undesirable direction. Hence hybrids with comparatively less negative standard heterosis identified as better hybrid. Depending on better mean performance coupled with significant positive *sca* effects and standard heterosis, the hybrid AE20 x AE5 selected as superior for the character. Significant positive standard heterosis reported by Reddy *et al.* (2012).

5.7.13. Yield per plant

The trait, yield per plant is the prime concern of a breeder while selecting superior hybrids. All hybrids showed significant standard heterosis in undesirable direction. Hence hybrids with comparatively less negative standard heterosis selected as better hybrid. Depending on the better mean performance coupled with significant positive *sca* effects and standard heterosis, the hybrids AE30 x AE5 and AE20 x AE5 selected as superior hybrids. Significant positive *sca* effect was seen in the study of Reddy *et al.* (2013a) and Wakode *et al.* (2016). Significant positive standard heterosis was seen in the study of Kerure and Pitchaimuthu (2019), Bhatt *et al.* (2016), Patel (2015), Shwetha *et al.* (2018) and Aware *et al.* (2014).

5.7.14. Marketable yield per plant

Marketable yield per plant is the prime important character for superior hybrids. All hybrids showed significant standard heterosis in undesirable direction. Hence hybrids with comparatively less negative standard heterosis selected as better hybrid. Depending on better mean performance coupled with significant positive *sca* effects and standard heterosis the hybrids, AE30 x AE5, AE20 x AE5, AE20 x Salkeerthi, and AE30 x Salkeerthi selected as superior hybrids. Significant positive standard heterosis was seen in the study of Reddy *et al.* (2012).

5.7.15. Mucilage content

Okra mucilage has medicinal value (Gemede *et al.*, 2015). High mucilage content is not favored by the consumers. Hence it is desirable to identify okra lines with moderate mucilage content. Hybrids with high mean performance coupled with significant positive *sca* effects and significant positive standard heterosis *viz.* AE30 x Salkeerthi and AE20 x AE16 are selected as superior for the character. This finding was in line with that of Verma and Sood (2015).

The present investigation projected the crosses AE16 x Salkeerthi and AE18 x AE5 as good performers for earliness attributes *viz.* days to first flowering and days to 50% flowering respectively but they were poor yielders. The better performing hybrids identified in the study are AE30 x AE5, AE20 x AE5, AE20 x Salkeerthi and AE30 x Salkeerthi depending on mean performance and *sca* effects for marketable yield per plant. However these hybrids showed standard heterosis in the unfavorable direction for yield attributes *viz.* number of fruits per plant, marketable fruits per plant, yield per plant and marketable yield per plant. These crosses cannot be used further to exploit heterosis. Among the fifteen crosses these were better performers for marketable yield (fig 5) even when they were affected by yellow vein mosaic disease and shoot and fruit borer. In addition, these hybrids showed good performance for few other yield contributing characters based on per se performance, *sca* effect and standard heterosis. AE30 x Salkeerthi was good performer for plant height, primary branches per plant, internode length and mucilage content. AE30 x AE5 was good performer for fruit weight. AE20 x Salkeerthi was good performer for fruit weight and fruit length. AE20 x AE5 was good performer for yield per plant, marketable fruits per plant and number of fruits per plant. However it showed standard heterosis in the unfavorable direction but it was best among the fifteen for these characters. These crosses can be used in future breeding programs based on association of *gca* and *sca* effect which is discussed below.

AE 20 x AE5

Fruit of AE 20 x AE5

AE 20 x Salkeerthi

AE 20 x Salkeerthi

Plate 6. Outstanding hybrids identified

AE 30 x AE5

Fruit of AE 30 x AE5

AE 30 x Salkeerthi

AE 30 x Salkeerthi

Plate 7. Outstanding hybrids identified

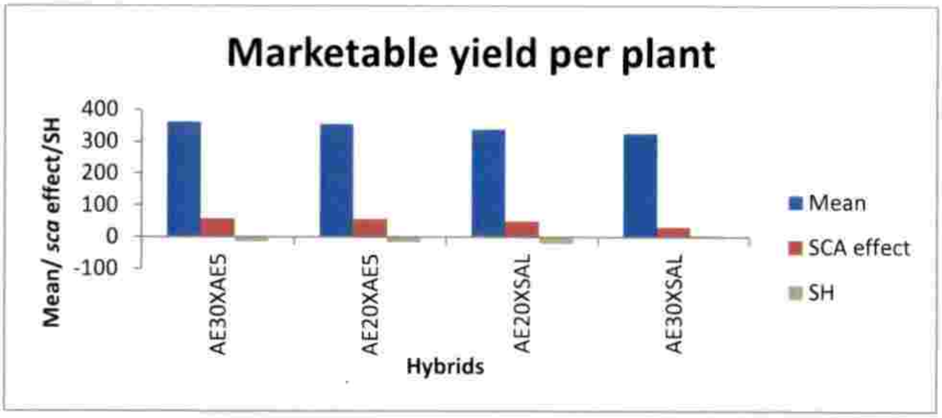

Fig5. Mean, *sca* effects and Standard heterosis (SH) of four superior hybrids for marketable yield per plant

5.8. Associatiofin of *sca* effects of crosses and *gca* effects of parents

Examination of association of *sca* effects of better performing crosses and *gca* effects of parents for each character (Table 23) revealed that the high specific combiners involved high x high, high x low and low x low general combiners as parents indicating that high specific combiners are not only obtained from the combination of high x high general combiners but also obtained from the combination of high x low and low x low general combiners. Thus, high *gca* effects of the parents is not reliable to predict high *sca* effects. High performance of these crosses may be due to additive x additive (high x high), additive x dominance (high x low), or dominance x dominance (low x low) epistatic interactions (Rewale *et al.*, 2003b). Superiority of the cross combinations with high x low, or low x low general combiners as parents may be due to the heterozygous loci of the parents involved in the cross combinations (Kumar *et al.*, 2006). In some of the characters studied, parents with high *gca* effects produced hybrids with low *sca* effects and this may be because of the lack of complementation of the parental genes. On the other hand, parents with low *gca* effects produced hybrids with high *sca* effects and this may be due to complementary gene action.

Table 23. Association of *gca* effects of parents and *sca* effect of better crosses

Characters	Best specific combiners	*gca* staus of parents of high *sca* cross combination	Characters	Best specific combiners	*gca* staus of parents of high *sca* cross combination
Plant height	AE30xSAL AE30xAE18 AE20xAE18 AE20xAE30	HXL HXH HXH HXH	Fruit length	AE20xAE18 AE30xAE5 AE20xSAL AE20xAE5	HXH HXL HXH HXL
Primary branches per plant	AE30xSAL AE30xAE5 AE18xSAL	LXH LXL HXH	Fruit girth	AE20xAE18 AE16xAE30 AE16xAE18 AE30xSAL	LXL LXL LXL LXH
Internode length	AE18xAE5 AE16xAE5 AE30xSAL AE16xSAL	LXH LXH LXL LXL	Fruit weight	AE30xAE5 AE20xSAL AE18xAE5 AE18xSAL	HXL HXL LXL LXL
Days to first flowering	AE16xSAL AE20xAE16 AE16xAE5 AE30xAE18	LXH HXL LXH LXL	No. of fruits per plant	AE20xAE5 AE16xAE18	HXL HXL
Days to 50% flowering	AE20xAE16 AE18xAE5 AE16xAE5 AE16xSAL	HXL LXH LXH LXH	Marketable fruits per plant	AE20xAE5	HXL
Node of fruit set	AE5xSAL AE20xAE18 AE16xSAL	LXL LXH HXL	Yield per plant	AE20xSAL AE30xAE5 AE20xAE5 AE18xAE5	HXL HXL HXL LXL
No. of fruiting nodes	AE30xAE5 AE30xAE18 AE18xSAL AE20xAE5	LXL LXL LXL HXL	Marketable yield per plant	AE30xAE5 AE20xAE5 AE20xSAL AE30xSAL	HXL HXL HXL HXL
			Mucilage content	AE30xSAL AE20xAE16 AE30xAE18	LXH HXL LXL

H- Denotes significant *gca* effect in desirable direction L- Denotes non-significant general combining ability effects in favorable direction, significant and non-significant general combining ability effects in unfavorable direction

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According to Reddy *et al.*, 2013a the *sca* effects do not contribute much to the improvement of self pollinated crops. Okra is a potentially self pollinated crop hence the crosses showing high *sca* along with high *gca*, at least for one parent in the cross combination can be utilized in recombination breeding programs. In the present study, top four crosses *viz.* AE30 x AE5, AE20 x AE5, AE30 x Salkeerthi and AE20 x Salkeerthi were high specific combiners for marketable yield per plant, involved at least one parent with positive significant *gca* effects. Such cross combinations may yield desirable transgressive segregants and can be recommended for future breeding programs for varietal improvement. Selection of superior plants would have to be practiced with great care in the segregating generations as the present study revealed presence of non additive gene action in most of the yield related trait. These crosses may be considered for recombination breeding with single plant selection in the passing generations only after evaluating for the presence of epistatic variance especially for additive x additive and additive x dominance interactions. This additive gene action can be exploited for isolating superior transgressive segregants to develop a high yielding okra variety.

Summary

6. Summary

The present investigation on "Development of F_1 hybrids in okra [*Abelmoschus esculentus* L. Moench] was conducted at the Instructional farm, College of Agriculture, Padannakkad during April-July 2019 to study the heterosis and combining ability.

Materials for the study consisted of six parents *viz.* AE5, AE16, AE18, AE20, AE30 and Salkeerthi and 15 F_1 hybrids produced in half diallel fashion. Arka Anamika and Salkeerthi used as OPV checks and Manjima and Arka Nikita as F_1 hybrid check. Parents of Manjima, Gowreesapattam local and IC282257 also included as checks. The hybrid Arka Nikita used as standard check.

The experiment was laid out in randomized block design with 26 genotypes in three replications. The mean performance, heterosis (Relative heterosis, heterobeltiosis and standard heterosis) and combining ability were studied. The salient findings of the present study are summarized below.

1. Morphological characterisation of all parents, hybrids and checks were done for the characters *viz.* colour of fruit, position of fruit, fruit shape, ridges per fruit and fruit pubescence.
2. Analysis of variance revealed significant differences among the genotypes for fifteen of the sixteen characters studied. There was no variation observed for fiber content.
3. Mean performance of all the genotypes revealed that among parents, AE20 showed the best performance for growth and earliness attributes with maximum plant height, maximum number of primary branches per plant, lowest internode length, least number of days to first flowering as well as days to 50% flowering. AE18 recorded good performance for internode length and node of fruit set. AE16 had higher number of fruiting nodes and fruit weight which also contributed to its higher yield per plant. It also had least incidence of fruit and shoot borer which contributed to high marketable yield per plant.

AE5 had the maximum fruit girth among parents. AE30 recorded with highest fruit length among parents. It also recorded highest number of fruits per plant and marketable fruits per plant among parents. Maximum mucilage content was observed in Salkeerthi.

4. There was considerable variability among hybrids for all the characters studied except for fiber content. In terms of growth attributes among the hybrids AE30 x AE18 showed good performance for plant height and node of fruit set. The hybrid AE18 x Salkeerthi gave the best performance for number of primary branches. For earliness attributes the hybrid AE18 x AE5 showed the best performance with shortest duration for days to 50% flowering among the hybrids. It also had shortest internode length. In terms of yield attributes the hybrid AE30 x AE5 had maximum number of fruiting nodes and fruit weight which also contributed to its maximum yield as well as marketable yield among the hybrids. The hybrid AE20 x AE5 had the highest number of fruits per plant and marketable fruits per plant among the hybrids.
5. In the half diallel analysis both *gca* and *sca* variances were significant for all the characters that were subjected to combining ability analysis. This suggested that both additive and non additive variance were important in the expression of these traits. But ratio of *gca* variance to *sca* variance was less than unity for all the characters studied indicating preponderance of non additive or dominance gene action in the expression of those traits.
6. The general combining ability estimates of six parents revealed that AE20 was an outstanding general combiner for four characters *viz.* internode length, number of fruiting nodes and fruit weight. AE30 was next best general combiner for plant height, fruit length, number of fruits per plant, and marketable fruits per plant.
7. In the present study AE20 and AE30 are identified as best parents showing good performance for maximum number of characters with high *gca* and *per*

se performance. These lines performed well even when they were affected by yellow vein mosaic disease (AE20- 38.88% and AE30- 27.77%), fruit and shoot borer (AE20-22.22% and AE30- 11.11%).

8. The examination of specific combining ability effects of crosses revealed that the hybrid AE30 x AE5 was good specific combiner for number of fruiting nodes, fruit weight and marketable yield per plant. The superior cross combination identified for plant height, primary branches per plant and mucilage content was AE30 x Salkeerthi. The hybrid AE20 x AE5 was identified as good specific combiner for number of fruits per plant and marketable fruits per plant. The superior specific combiners for internode length, days to first flowering and days to 50% flowering were identified in the respective hybrids namely AE18 x AE5, AE16 x Salkeerthi, and AE20 x AE16. The hybrid AE20 x Salkeerthi was showed the best specific combining ability for yield per plant.
9. Three types of heterosis *viz.* relative heterosis, heterobeltiosis and standard heterosis were estimated for each character. Standard heterosis for plant height ranged between 18.41(AE5 x Salkeerthi) and 93.88 (AE30 x AE18). For primary branches per plant standard heterosis ranged between 70.96 (AE20 x AE30) and 187.61 (AE18 x Salkeerthi). Standard heterosis for internode length ranged between -34.60 (AE18 x AE5) and 63.66 (AE16 x AE18).
10. Standard heterosis for earliness character like days to first flowering, days to 50% flowering and node of fruit set ranged between -2.76 (AE16 x Salkeerthi) and 17.24 (AE16 x AE18), -1.59 (AE18 x AE5) and 21.16 (AE16 x AE18) and -61.03 (AE20 x AE18, AE16 x AE30, AE16 x AE18, AE16 x AE5, and AE30 x AE18) and -39.05 (AE20 x AE30, AE20 x AE5, and AE20 x Salkeerthi) respectively.

11. Standard heterosis for fruit traits like fruit length, fruit girth and fruit weight ranged between -62.56 (AE20 x AE16) and 24.59 (AE20 x AE18), -7.34 (AE16 x Salkeerthi) and 21.69 (AE5 x Salkeerthi) and -48.17 (AE20 x AE16) and 50.27 (AE30 x AE5) respectively.
12. Standard heterosis for number of fruiting nodes ranged between -24.45 (AE16 x AE5) and -2.02 (AE20 x AE5). None of the crosses showed desirable significant positive relative heterosis, heterobeltiosis and standard heterosis for yield attributes *viz.* number of fruits per plant, marketable fruits per plant, yield per plant and marketable yield per plant.
13. The present investigation projected four better crosses *viz.* AE30 x AE5, AE20 x AE5, AE20 x Salkeerthi and AE30 x Salkeerthi based on mean performance and *sca* effects. All these four hybrids were good performers for marketable yield even when they were affected by yellow vein mosaic disease and shoot and fruit borer. These hybrids showed non additive gene interaction but negative standard heterosis for yield attributes *viz.* number of fruits per plant, marketable fruits per plant, yield per plant and marketable yield per plant. However some of these hybrids showed significant positive standard heterosis for yield contributing characters. Hence these crosses need to be further evaluated for heterosis and presence of epistatic interaction in additional seasons.

FUTURE LINE OF WORK

- Identified parents can be used in further breeding programme for the improvement of yield components
- Top four crosses identified can be subjected to generation mean analysis to verify the presence of epistatic gene action

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Abstract

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DEVELOPMENT OF F_1 HYBRIDS IN OKRA

[*Abelmoschus esculentus* L. Moench]

by

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ABSTRACT

The project entitled "Development of F_1 hybrids in okra [*Abelmoschus esculentus* L .Moench]" was carried out at the Instructional farm, College of Agriculture, Padannakkad during April-July 2019 to study heterosis and combining ability.

The experiment was carried out in two parts. In part I, six diverse parents *viz.* AE5, AE16, AE18, AE20, AE30 and Salkeerthi were raised in a crossing block. They were crossed in half diallel fashion and 15 F_1 hybrids were produced. In part II, the hybrids were evaluated along with their parents and checks in a randomized block design with 26 genotypes and three replications. Arka Anamika and Salkeerthi were used as OPV checks and Manjima and Arka Nikita as F_1 hybrid checks. Parents of Manjima *viz.* Gowreesapattam local and IC282257 were also included as checks. Half diallel analysis was adopted for combining ability analysis. Relative heterosis, heterobeltiosis and standard heterosis using F_1 hybrid Arka Nikita as standard check were worked out for all the characters.

The estimation of heterosis revealed significant standard heterosis in the hybrids in desirable direction for growth, earliness and fruit traits. Three hybrids AE30 x AE18, AE30 x Salkeerthi and AE20 x AE30 showed highly significant positive standard heterosis for plant height. Three hybrids AE30 x Salkeerthi, AE30 x AE5 and AE18 x Salkeerthi showed highly significant positive standard heterosis for primary branches per plant. Two hybrids AE16 x AE5 and AE18 x AE5 showed highly significant negative standard heterosis for internode length. Two hybridsAE16 x Salkeerthi and AE20 x Salkeerthi showed highly significant negative standard heterosis for days to flowering. One hybrid AE18 x AE5 showed highly significant negative standard heterosis for days to 50% flowering. Five hybrids AE16 x AE30, AE16 x AE18, AE16 x AE5, AE20 x AE18, and AE30 x AE18 showed highly significant negative standard heterosis for node of fruit set. None of the hybrids showed significant positive standard heterosis for number of fruiting nodes. For fruit

length AE20 x AE18 and AE20 x Salkeerthi showed significant positive standard heterosis. Three hybrids AE16 x AE30 AE5 x Salkeerthi and AE30 x AE5 showed significant positive standard heterosis for fruit girth. For fruit weight the hybrids AE30 xAE5, AE18 x AE5, AE20 x Salkeerthi, and AE20 x AE18 showed significant positive standard heterosis. None of the crosses showed significant positive standard heterosis for number of fruits per plant, marketable fruits per plant, marketable fruits per plant and yield per plant. The hybrid AE30 x Salkeerthi showed significant positive standard heterosis for mucilage content.

Analysis of variance for combining ability revealed significant difference among the genotypes for all traits except fiber content, indicating sufficient variability for selection. The *gca* variance/ *sca* variance ratio indicated preponderance of non-additive gene action for all traits. None of the cross combinations exhibited high significant combining ability effects in desirable direction for all characters studied. The association of *sca* effects of outstanding crosses with *gca* effects of parents for each of the characters revealed that the high specific combiners involved high x high, high x low and low x low general combiners as parents.

A combination of mean performance and *gca* effect was used to identify best parents and it revealed AE16, AE30 and AE20 as better performing parents for maximum number of characters. Even though the mean performance of AE16 was higher for fruit weight, number of fruiting nodes, yield per plant and marketable yield per plant, it was a poor general combiner for characters *viz.* number of fruiting nodes, fruit weight, and yield per plant compared to AE20 and marketable yield per plant compared to AE30. High *gca* effects for fruit yield in AE20 and AE30 were associated with good *gca* effects for number of fruits per plant and fruit weight. The parental lines AE20 and AE30 performed well even they were affected by yellow vein mosaic disease and fruit and shoot borer. Hence they can be used in further breeding program for higher yield. The parental line AE20 was the high general combiner for all of the three earliness attributes such as days to first flowering, days to 50% flowering, and node of fruit set, indicating its potential for exploiting earliness in okra.

Promising crosses were identified based on mean performance, *sca* effect and standard heterosis for important growth and yield characters. None of the hybrids exhibited significant standard heterosis in the desirable direction for yield. Hence the hybrids showing lower value of negative standard heterosis were selected. The four better performing crosses identified were AE30 x AE5, AE20 x AE5, AE20 x Salkeerthi and AE30 x Salkeerthi. All these four crosses were good performers for marketable yield even when they were affected by yellow vein mosaic disease and shoot and fruit borer. In addition, these crosses showed good performance for few other yield contributing characters also. The cross AE30 x AE5 performed well for fruit weight, number of fruiting nodes and yield per plant. The cross AE20 x AE5 showed good performance for number of fruits per plant, marketable fruits per plant and yield per plant. AE20 x Salkeerthi was a good performer for fruit weight and fruit length. AE30 x Salkeerthi was good performer for plant height, primary branches per plant, internode length and mucilage content.