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RESEARCH ARTICLE :

Studies on heterosis for yield and yield components in okra (*Abelmoschus esculentus* L.)

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SUMMARY : Okra [*Abelmoschus esculentus* (L.) Moench], being an often cross-pollinated crop, responds well toheterosis breeding. Exploitation of heterosis is primarily dependent on the screening and selection of available germplasm that could be produced by better combinations of important agronomic characters. Six elite, optimally divergent and nearly homozygous lines of okra namely P_1(Arka Abhey), P_2(Pusa-A4), P_3(Arka Anamika), P_4(EC-755647), P_5(EC-755648)and P_6(EC-755654) selected from the germplasm were crossed in all possible combinations including reciprocals during summer 2014. The resultant 30 F_1s along with their 6 parents and one commercial check (Arka Anamika) were evaluated in a Randomized Block Design with two replications during mid *Kharif* (August - October), 2014 at the Adhiparasakthi Horticultural College, Kalavai, Vellore, Tamil Nadu,India. Heterosis over mid parent, better parent and standard check were studied for 10 quantitative characters pertaining to pod yield and its associated characters. For total yield per plant, the crosses as a whole manifested 21.42% and 22.48% average and standard heterosis, respectively. The crosses Arka Abhey x EC-755648 ($P_1 \times P_5$) and EC-755648 x EC-755654 ($P_5 \times P_6$) manifested significantly negative commercial heterosis for days to first flowering (-2.26%) and fruiting nodes (-12.82%), respectively, indicating their earliness. Highest heterobeltiosis of 16.54% for total yield per plant was manifested by the cross EC-755654 x Arka Abhey ($P_6 \times P_1$). The extent of standard heterosis for total yield per plant (22.48%) appears to be sufficient for exploitation of heterosis commercially. The crosses Arka Anamika x EC-755648 ($P_3 \times P_5$) and EC-755647 x EC-755648 ($P_4 \times P_5$) were statistically on par with the standard check in their mean performance and are as promising as that of the standard check (Arka Anamika).

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BACKGROUND AND OBJECTIVES

Cultivated okra [*Abelmoschus esculentus* (L.) Moench] is originated in tropical Africa. It is an introduced vegetable crop in India. Although, it is a multipurpose and multifarious crop, it is extensively grown for its tender pods, which are used as a very popular, tasty and gelatinous vegetable. It is a powerhouse of valuable nutrients. It has huge socio-economic potential for enhancing livelihoods in both rural and urban areas. It offers a possible route to prosperity for small, medium and large-scale producers alike. Okra is the most important vegetable crop in India accounting for 5.5% of the total vegetable cropped area and 3.6% total vegetable production of the country (NHB, 2010). India is one of the largest producers and consumers of okra in the world. Despite its recognized potential and significant area and consumption in the country, it is being neglected because of non-availability of high yielding open-pollinated varieties. Yield plateau seems to have been reached in open-pollinated varieties of okra. To break the yield barriers in existing open-pollinated varieties of okra, a hybridization-based breeding strategy would be desirable. Heterosis breeding has been the most successful approach in increasing the productivity in cross-pollinated vegetable crops. Okra is one often-cross pollinated vegetable crop where the presence of heterosis was demonstrated for the first time by Vijayraghvan and Warier (1946). Since then, heterosis for yield and its components were extensively studied. Several research workers have reported occurrence of heterosis in considerable quantities for fruit yield and its various components (Weerasekara *et al*., 2007 and Jindal *et al*., 2009). The ease in emasculation and very high percentage of fruit setting indicates the possibilities of exploitation of hybrid vigour in okra. The presence of sufficient hybrid vigour is an important prerequisite for successful production of hybrid varieties. Therefore, the heterotic studies can provide the basis for the exploitation of valuable hybrid combinations in the future breeding programmes and their commercial utilization.

RESOURCES AND METHODS

Six elite, optimally divergent and nearly homozygous lines of okra namely P_1 (Arka Abhey), P_2(Pusa-A4), P_3(Arka Anamika), P_4(EC-755647), P_5(EC-755648) and P_6(EC-755654) selected from the germplasm were crossed in all possible combinations including reciprocals during summer 2014. The resultant 30 F_1s along with their 6 parents and one commercial check (Arka Anamika) were evaluated in a Randomized Block Design with two replications during mid *Kharif* (August - October), 2014 at the Adhiparasakthi Horticultural College, Kalavai, Vellore, Tamil Nadu, India. In each replication, each genotype was grown in doublerow plot. Individual plot was of 3.0 m length and 1.2 m in width. An inter-row spacing of 60 cm and an intra-row spacing of 30 cm was maintained. Ten plants per row and 20 plants per plot and genotype were maintained. Recommended package of practices and plant protection measures were carried out to raise a successful crop. Biometric observations were recorded on five plants basis ineach genotype in each replication for plant height (cm.), Number of branches per plant (No's), Days to first flowering (Days), Node at which first flower occurred (No's), Number of fruits per plant (No's), Fruit girth (cm), Fruit length (cm), Individual fruit weight (g). Number of seeds per fruit (No's) and Yield per plant (g). Analysis ofvariance was carried out according to Panse and Sukhatme (1985) to determine the significant differences among genotypes for all the characters.The characters showing significant differences were subjected to heterosis calculation. The direction and degree of heterosis as the difference in F_1s performance over mid parent (relative heterosis), better parent (heterobeltiosis) and commercial check (standard heterosis) were calculated as per the standard formulae. Significance of heterosis and heterobeltiosis and standard heterosis were tested with t-test as suggested by Cochran and Cox (1950) and Wynne *et al*. (1970).

Selection of suitable parents and assessment of degree of heterosis in the resulting crosses forms an important step in the development of new F_1 hybrids. Exploitation of heterosis is primarily dependent on the screening and selection of available germplasm that could be produced by better combinations of important agronomic characters. It is an already established fact that the amount of yield heterosis obtains by hybrids depends largely on the genetic divergence of the populations from which the parental lines have been extracted (Moll *et al*., 1962). It is now a well established fact that heterosis occurs in the hybrids when the most appropriate and compatible combinations of parents are involved. A number of heterotic studies have been made by many workers from India and abroad to establish heterotic patterns among several okra populations and genepools and to maximize their yield for hybrid development. Okra genetic biodiversity is great and the importance of genetic resources has long been emphasized for increasing the genetic base of cultivated okra and in okra breeding programmes (Mohapatra *et al*., 2007; Reddy, 2010 and Singh *et al*., 2007). Previous research efforts have concentrated on crossing okra of diverse origin, which have resulted in the maximization of hybrid vigour. Aseries of heterotic studies have been made by many workers to exploit heterosis from the elite and diverse genotypes selected from the available germplasm of okra (Singh and Syamal, 2006). A vast diversity present in the germplasm is yet to be fully exploited through heterosis breeding.Okra, being an often cross-pollinated crop, responds well to heterosis breeding. Several workers have demonstrated the existence of varying degrees of heterosis for yield and yield associated traits in okra (Dahake and Bangar,2006; Jindal and Ghai, 2005 and Jindal *et al.*,2009). Good results have been achieved in increasing okra yield through the successful exploitation of heterosis for pod yield and other desired traits. Diallel analysis of a fixed set of self and cross pollinated populations provides a basis for preliminary determination of heterotic groups (Gardner and Eberhart, 1966). Diallel mating design has been used extensively by several researchers to generate single crosses and measure heterosis in okra (Bhalekar *et al.*, 2006; Dahake and Bangar, 2006; Jindal and Ghai, 2005; Jindal *et al.*, 2009 and Singh *et al.*, 2009). Heterosis for yield is the result of interaction of simultaneous increase in the expression of heterosis for yield components (Grafius, 1959). Pod yield and several other yield contributing characters lack stability due to strong environmental influence, suggesting the need for breeding for specific environment (Ariyo, 1990). This necessitates evaluating the newly developed F_1 hybrids in the target environment for identifying the highly heterotic and adaptable parental combination for a given environment.

OBSERVATIONS AND ANALYSIS

The attainment of maximum crop yield is an important objective in most breeding programmes and major emphasis in vegetable breeding is on the development of improved varieties. The utilization of the effect of heterosis is very rightly considered to be as one of the most outstanding achievements of vegetable breeders in the 20th century. Vegetable breeders have widely exploited and used heterosis in boosting up yield of many crops. The goal of okra hybrid breeding is to identify and then reliably reproduce superior hybrid genotypes. Virtually all commercial okra hybrids are made from crosses of inbred lines. Knowledge of heterotic groups from which to draw parental germplasm for hybrid combinations is limited. Improvement of complex characters such as, pod yield may be accomplished through the component approach of breeding. This method, in general, assumes strong associations of yield with a number of characters making up yield and simpler inheritance for these component characters.

Analysis of variance:

The analysis of variance (Table 1) indicated significance of mean squares due to genotypes for all characters under study. This can be attributed to the fact that there were clear cut genotypic differences among the parents and their hybrids, which were phenotypically expressed. The mean squares due to parents were highly significant for almost all characters except Node at which first flower occurred under study. The mean squares due to crosses were highly significant for all characters under study. The mean squares due to parents versus crosses, which are a measure of the importance of average heterosis, were highly significant for majority of the characters except Node at which first flower occurred.

Table 1 : Analysis of variance for various characters in tests of diallel crosses

Sr.No.	Character	Mean sum of squares		
		Genotype	Replication	Error
1.	Plant height (cm)	306.554**	0.934	1.739
2.	Number of branches per plant (No's)	0.257**	0.002	0.035
3.	Days to first flowering (Days)	52.206**	0.659	0.689
4.	Node at which first flower occurred (No's)	0.197**	0.245	0.041
5.	Number of fruits per plant (No's)	5.910**	0.085	0.692
6.	Fruit girth (cm)	0.103**	0.010	0.036
7.	Fruit length (cm)	0.951**	0.105	0.291
8.	Individual fruit weight (g)	7.071**	0.753	1.291
9.	Number of seeds per fruit (No's)	1067.649**	5.626	3.611
10.	Yield per plant (g)	1571.766**	221.410	504.484

** indicate significance of value at P=0.01

Heterosis:

Negative heterosis is desirable for days to first flowering because this will help the hybrid to mature earlier. Nine hybrids exhibited negative and significant relative heterosis among the hybrids for number of days taken to first flowering. Significant negative standard heterosis was recorded for the hybrid -2.26% (Arka Abhey x EC-755648) (Table 3). Fifteen hybrids hybrids recorded significant negative values for heterobeltiosis. Similar results are reported by Hosamani *et al.* (2008) and Senthil and Sreeparvathy (2010).

The hybrid 13.57% (EC-755648 x EC-755647) (Table 3) recorded significant and positive standard heterosis for plant height. For relative heterosis and heterobeltiosis recorded significant and positive heterosis (Pusa-A4 x EC-755654) (Table 2) Rewale *et al.* (2003); Singh *et al.* (2004); Hosamani *et al.* (2008) and Kumar *et al.* (2011) revealed similar result for this trait.

Relative and Heterobeltiosis heterosis for number of fruits was positive and significant for nine and five hybrids, respectively. Standard heterosis was positive and significant for 5.99% (Pusa-A4 x EC-755648)(Table 3). Positive heterosis for number of fruits per plant is reported by Rewale *et al.* (2003); Singh *et al.* (2004) and Hosamani *et al.* (2008).

Relative heterosis, heterobeltiosis and standard heterosis ranged from -12.20% to 19.48%, -18.60% to 12.20% and -12.82%to 17.95 % (Table 2), respectively for Node at which first flower occurred. For these traits, four crosses over mid parent, twelve crosses over better

Table 2 : Range of heterosis over three bases for ten traits in okra

Characters	Heterosis	Range (%)
Plant height (cm)	RH	-18.69 to 24.77
	BH	-34.24 to 10.92
	SH	-31.96 to 13.57
Number of branches per plant (No's)	RH	-18.18 to 12.50
	BH	-27.03 to 8.57
	SH	-22.86 to 14.29
Days to first flowering (Days)	RH	-13.54 to 17.92
	BH	-24.40 to 2.02
	SH	-2.26 to 39.70
Node at which first flower occurred (No's)	RH	-12.20 to 19.48
	BH	-18.60 to 12.20
	SH	-12.82 to 17.95
Number of fruits per plant (No's)	RH	-16.39 to 16.96
	BH	-25.15 to 12.67
	SH	-27.54 to 5.99
Fruit girth (cm)	RH	-5.36 to 8.80
	BH	-7.60 to 6.16
	SH	-6.81 to 11.58
Fruit length (cm)	RH	-8.85 to 13.50
	BH	-11.40 to 10.89
	SH	-8.37 to 10.89
Individual fruit weight (g)	RH	-14.65 to 15.29
	BH	-24.08 to 12.93
	SH	-19.00 to 14.87
Number of seeds per fruit (No's)	RH	-37.03 to 36.74
	BH	-52.60 to 8.25
	SH	-6.76 to 111.91
Yield per plant (g)	RH	-18.54 to 21.42

parent and five crosses over commercial check manifested significantly negative heterosis.Singh *et al.* (2004); Hosamani *et al.* (2008); Senthil and Sreeparvathy (2010) and Kumar *et al.* (2011) revealed similar result for this trait.

The fruit weight had a positive and significant heterosis over the mid parent for six hybrids. The crosses (Arka Anamika x EC-755648) had positive significance for fruit weight over heterobeltiosis and standard variety. Singh *et al.* (2004); Hosamani *et al.* (2008); Senthil and Sreeparvathy (2010) and Kumar *et al.* (2011) revealed similar result for this trait.

For the fruit length ten hybrids showed positively significant heterosis over mid parent. Nine hybrids exhibited significant positive heterobeltiosis for this trait. Standard heterosis was positive and significant for

Table 3 : Best four standard heterotic crosses for fruit yield and its component characters in okra

Characters	Heterosis (standard heterosis)
Plant height (cm)	EC-755648xEC-755647 (13.57**)
	EC-755648xArka Anamika (13.03**)
	EC-755648xPusa-A4 (10.83**)
	EC-755648xEC-755654 (6.77**)
Number of branches per plant (No's)	EC-755648xArka Anamika (14.29**)
	EC-755648xEC-755647 (14.29**)
	EC-755648xArka Abhey (8.57*)
	EC-755648xPusa-A4 (8.57*)
Days to first flowering (Days)	Pusa-A4 xArka Anamika (-2.01)
	Arka Abhey xEC-755648 (-2.26)
Node at which first flower occurred (No's)	EC-755648xEC-75565 (-12.82**)
	EC-755648xArka Abhey (-10.26**)
	EC-755648xEC-755647(-10.26**)
	Pusa-A4 xEC-755654 (-7.69*)
Number of fruits per plant (No's)	Arka AnamikaxEC-755648 (9.58**)
	Pusa-A4 xEC-755648 (5.99)
	EC-755647xEC-755648 (2.99)
	EC-755648xEC-755654 (1.80)
Fruit girth (cm)	Arka AnamikaxEC-755648 (11.58**)
	Pusa-A4 xEC-755648 (8.86**)
	EC-755648xEC-755647 (7.84**)
	EC-755647xEC-755648 (6.22**)
Fruit length (cm)	Arka AnamikaxEC-755648 (10.89**)
	EC-755647xEC-755648 (10.12**)
	Arka AnamikaxArka Abhey (5.93**)
	EC-755648xEC-755654 (5.86**)
Individual fruit weight (g)	Arka AnamikaxEC-755648 (14.87**)
	EC-755647xEC-755648 (10.74**)
	Pusa-A4 xEC-755648 (8.72*)
	EC-755648xArka Anamika (7.76*)
Yield per plant (g)	Arka AnamikaxEC-755648 (22.48**)
	EC-755648xArka Anamika (21.6**)
	EC-755647xEC-755648 (20.64**)
	EC-755648xArka Abhey (19.78**)

* and ** indicates significance values at P=0.05 and 0.01, resepctively

10.89% (Arka Anamika x EC-755648) (Table 3). Similar results were presented by Singh and Singh (1979); Poshiya and Shukla (1986); Metwally and Etsamy (1990); Saha and Kabir (2001); Rewale *et al.* (2003); Hosamani *et al.* (2008) and Senthil and Sreeparvathy (2010).

The six hybrids had positive significant heterosis for fruit girth over mid parent. Positively significant standard heterosis over standard variety for fruit girth was observed for nine hybrids. Heterobeltiosis was positively significant for only one hybrid with regard to fruit girth. Similar positive heterosis for this trait is reported by Saha and Kabir (2001); Rewale *et al.* (2003); Singh *et al.* (2004) and Hosamani *et al.* (2008).

Fruit yield is a complex trait. It is the end product of several basic yield components. The standard heterosis is more useful from practical point of view. All the thirty hybrids exhibited significant relative heterosis and of which eight hybrids displayed significant positive standard heterosis for yield per plant. The maximum heterotic expression of 21.42 per cent yield was observed in EC-755654 x Arka Abhey followed by Arka Anamika x EC-755648 (17.93%) and EC-755648 x Arka Anamika (17.24%). Heterobeltiosis was significant and positive for heterobeltiosis was the highest for yield per plant in the hybrid EC-755654 x Arka Abhey (16.54%) followed by Arka Anamika x EC-755648 (13.70%) (Table 2). The hybrids which showed positive and significant estimates for standard heterosis were hybrid Arka Anamika x EC-755648 (22.48%) followed by EC-755648 x Arka Anamika (21.76%) and EC-755647 x EC-755648 (20.64%) (Table 3). These findings are in agreement with those of Rewale *et al.* (2003); Singh *et al.* (2004); Hosamani *et al.* (2008); Senthil and Sreeparvathy (2010) and Kumar *et al.* (2011).

Conclusion :

The results indicated that the phenomenon of heterosis was of a general occurrence for almost all the characters, under study. However, the direction and magnitude of heterosis over three bases varied with characters. On an average, okra displayed heterosis for yield and its component traits studied. Yield components should be considered to increase the yield through selections. In the present study, it was found that among the thirty hybrids, the two hybrids Arka Anamika x EC-755648 and EC-755648x EC-755647 exhibited significant standard heterosis for all the characters and found promising for fruit yield and other traits. Hence, these hybrids need to be on larger scale for their commercial values and can be released for commercial cultivation. These two short listed hybrids may be tested for yield and other quality traits under different agro-climatic conditions for commercial exploitation of hybrid vigour.

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