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Genetic expression of heterosis for yield and quality traits during different growing seasons in okra (*Abelmoschus esculentus*)

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ABSTRACT

The trial was conducted during summer and rainy seasons of 2006-2008 at the Institute of Agricultural Sciences, BHU, Varanasi. Appreciable heterosis over better parents of 51 F_1'S of okra (*Abelmoschus esculentus* (L.) Moench] was recorded for various horticultural traits and quality traits over both the seasons. It was confounded that rainy seasons was more yield productive seasons than summer. The colour pigment expressed that the reddish green pod colour was dominant over green and purple green pod colour in F_1's crosses due to additive gene effects. The high fruit yield potential and quality attributing traits recorded in the F_1 hybrid Arka Abhay × Arka Anamika has been directly attributed to increased number of fruits/plant during both climatic changes years. Therefore, their parents can be used in breeding programme for development of a new homogenous variety.

Key words: Ascorbic acid content, Fruit colour, Heterosis, Line × tester

India is the largest producer of okra [*Abelmoschus esculentus* (L.) Moench] in the world with total area of 0.43 million hectares and production 4.53 (70% of the total world production) million tonnes green pods, whereas productivity of the crop is 10.5 metric tonnes/ha (FAOSTAT 2009). Among the vegetables, contribution of rainy and summer season cultivated crop okra is 5.4 % in area with 3.5 % share in production. West Bengal is leading state in area and production of okra, while Andhra Pradesh in productivity (Anonymous 2009).

Hence, an attempt has been made to study the 'line × tester' analysis (Kempthorne 1957), to know the heterobeltiosis (heterosis over better parents) for interested traits in okra (Singh *et al.* 1996). Heterosis is a special genetic mechanism wherein the distant genotypes are brought together in a specific pattern to express their ability to make a dramatic shift in the magnitude of a particular trait. The genetical studies revealed that yield and its components is most assessing in nature and magnitude of gene effect is important for increasing the yield potential. Exploitation of heterosis and hybrid vigour has been reported for increase to yield and other yield related traits (Poshiya and Shukla 1986, Thakur *et al.* 1982, Elmaksoud *et al.* 1986). Okra has suffered major cultivation problem in India due to lack of high yielding varieties along with hybrids. Various approaches are being used to overcome this problem one of them considered as hybrid technology for exploitation of heterosis and eco-friendly approaches. Moreover, okra which categorized under often cross-pollinated group showed easy emasculation and high number of seed production in single pollination. It should be kept in mind that due to high chromosome number and polygenic control of major economic traits, 100 % homozygosity in the parents is difficult to achieve (Dhankar and Mishra 2006).

In okra insufficient work has been done in estimating the heterosis effects in different environments. Therefore, the present investigation has been undertaken to estimation of the heterosis over better parents in different seasons for fruit yield and related traits in okra.

MATERIALS AND METHODS

Twenty diverse okra genotypes were received from Indian Institute of Vegetable Research, Varanasi and evaluated at the Vegetable Research Farm, Institute of Agricultural Sciences, BHU, Varanasi during 2006. Crosses were made in

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'line × tester' mating design, using 17 lines as female (IC 128883, VRO 5, VRO 6, AC 108, IC 45806, IC 218877, IC 218844, Arka Abhay, IC 43720, IIVR 342, IC 140906, IIVR 198, EC 305612, IIVR 435, IIVR 401, SA 2 and IC 140934) and 3 testers as male [Arka Anamika (AA), Pusa Sawani (PS) and Parbhani Kranti (PK)]. A total fifty one okra F_1 hybrids were made to study heterosis. These 71 genotypes (51 F_1's + 20 parents) were grown in the vegetable research field of IAS, BHU, Varanasi during two different consecutive seasons (summer and rainy) of 2007 and 2008. The experiments were laid out in randomized complete block design (RCBD) with three replications at the row to row and plant to plant spacing of 45 cm and 15 cm, respectively. All the environmental observation in open field conditions such as rainfall, humidity, temperature and sunshine of both summer and rainy season were recorded till the harvesting date. Observations were recorded in every cropping season for eight characters on 10 randomly selected plants, viz. pod colour, number of fruits/plant, average fruit weight (g), fruit length (cm), fruit diameter (cm), fruit yield/plant (g), number of seeds/fruit and ascorbic acid content (mg/100g). Ascorbic acid was determined by titration method, using 2, 6-dicholoro indophenol solution (AOAC 1990). Pod colour was maintained in Table 1 of each genotype (F_1's and parent). The heterosis of F_1s over the better parent (BPH) and standard parent (SPH) was calculated by following formula:

Per cent heterosis over better parent (BPH) =

$$\frac{\overline{F}_1 ? \overline{BP}}{BP} ? 100$$

Per cent heterosis over standard parent (SPH) =

$$\frac{\overline{F}_1 ? \overline{SP}}{SP} ? 100$$

where, F_1, mean value of F_1's, $\overline{BP}$, better parent value and $\overline{SP}$, standard parent value.

RESULTS AND DISCUSSION

Colour pigments are attractive traits for visualization of diverse okra genotypes which in green colour pod is most preferable for edible purpose. Within 20 genotypes, 17 were in green colour and only three IC 218877, Arka Abhay and

Table 1 Pod color of okra parents and F_1 hybrids

Parents pod color		Hybrids (F_1) pod color					
Lines (Female)							
IC 128883	Green						
VRO 5	Green						
VRO 6	Green						
AC 108	Green	IC 128883 × AA	Green	IC 218877 × PK	Green	IIVR 198 × PS	Green
IC 45806	Green	IC 128883 × PS	Green	IC 218844 × AA	Green	IIVR 198 × PK	Green
IC 218877	Light	IC 128883 × PK	Green	IC 218844 × PS	Green	EC 305612 × AA	Green
IC 218844	Green	VRO 5 × AA	Green	IC 218844 × PK	Green	EC 305612 × PS	Green
Arka Abhay	Purple green	VRO 5 × PS	Green	Arka Abhay × AA	Green	EC 305612 × PK	Green
IC 43720	Green	VRO 5 × PK	Green	Arka Abhay × PS	Green	IIVR 435 × AA	Green
IIVR 342	Reddish green	VRO 6 × AA	Green	Arka Abhay × PK	Green	IIVR 435 × PS	Green
IC 140906	Green	VRO 6 × PS	Green	IC 43720 × AA	Green	IIVR 435 × PK	Green
IIVR 198	Green	VRO 6 × PK	Green	IC 43720 × PS	Green	IIVR 401 × AA	Green
EC 305612	Green	AC 108 × AA	Green	IC 43720 × PK	Green	IIVR 401 × PS	Green
IIVR 435	Green	AC 108 × PS	Green	IIVR 342 × AA	Reddish green	IIVR 401 × PK	Green
IIVR 401	Green	AC 108 × PK	Green	IIVR 342 × PS	Reddish green	SA 2 × AA	Green
SA 2	Green	IC 45806 × AA	Green	IIVR 342 × PK	Reddish green	SA 2 × PS	Green
IC 140934	Green	IC 45806 × PS	Green	IC 140906 × AA	Green	SA 2 × PK	Green
Testers (Male)		IC 45806 × PK	Green	IC 140906 × PS	Green	IC 140934 × AA	Green
Arka Anamika	Green	IC 218877 × AA	Green	IC 140906 × PK	Green	IC 140934 × PS	Green
Pusa Sawani	Green	IC 218877 × PS	Green	IIVR 198 × AA	Green	IC 140934 × PK	Green
Parbhani Kranti	Green						

AA, Arka Anamika; PS, Pusa Sawani; PK, Parbhani Kranti

IIVR 342 had taken light green, purple green and reddish green colour, respectively. The colour of okra genotypes expressed dominant genetic effect on their hybrids. Out of 51 hybrids mostly were green except three IIVR 342 × Arka Anamika, IIVR 342 × Pusa Sawani and IIVR 342 × Parbhani Kranti were reddish green (Table 1). The male parent Arka Anamika and Parbhani Kranti were in green pod colour and Arka Abhay had purple green pod colour but IIVR 342 possesses reddish green pod colour that was dominant over green and purple green pod colour. It was also revealed that the colour of female parent IIVR 342 governed by recessive gene and also found additive gene action. Similar results in pod colour of okra had simple inheritance (multiple alleles) studied by Kalia and Padda (1962). The dominant characters for female parents of okra were studied by many reviewers (Jasin 1967, Nath and Dutta 1970, Bhalekar *et al*. 2004, Udengwu 2008).

Effect of environment revealed that the rainfall, temperature, humidity, sunshine and yield were measured in two years (2007-2008). In present study, most of the genotypes performed better yield traits in rainy season as compared to summer season. Seasonal variation was more effective for yield increment, during the rainy season when the rainfall (45.5), relative humidity (29.7) was high and temperature and sunshine was low, increased the heterosis percent for yield (55.0). Whereas, in summer season, temperature (30.2) and sunshine (9.1) was high but rainfall, relative humidity was low and heterosis percent also reduced for yield (37.8). This may be due to adverse growing condition of okra plants in summer as compared to rainy seasons of both years.

Analysis of variance for various characteristics evaluated in the two environments showed that the differences due to genotypes, parental lines and hybrids were all significant with the exception of male parent fruit diameter and fruit yield in rainy season (Table 2). Table 2, also showed the parents vs hybrids were non-significant for number of fruits/plant and seed number/fruit in summer, fruit length in rainy season, and fruit diameter in both season of rainy and winter seasons. While female vs male was non-significant for number of fruit, fruit yield/plant in summer season, in case of fruit length, it was non-significant in rainy season, fruit diameter was also non-significant in both rainy and summer seasons.

The study of heterosis of 71 genotypes (51 F_1's and 20 parents) for seven variables but selected only three best hybrids according to their highest heterosis expression for each trait across the two environments (summer and rainy) are summarized in Table 3. A large number of hybrids showed superiority over their parents for various characteristics, although no hybrid showed increase of all the characteristics, there were significant differences between mean of hybrids for all measured characteristics.

The highest better and standard parent heterosis for number of fruits was observed in EC 305612 × Pusa Sawani (26.10 and –4.00) during summer season but in rainy season it was highest in IIVR 198 × Parbhani Kranti (67.27 and 12.25). It was also studied within best 3 hybrids that Parbhani Kranti and Pusa Sawani used as male parent for number of fruits/plant in both seasons. The variable fruit number was also reported for better and standard parent heterosis in study of Ahmed *et al.* (1999). For average fruit weight, of the total

Table 2 Analysis of variance (mean squares) for parents and hybrids for 15 characters in okra during both seasons of two years

Source of variation	Season	Replication	Parents	Females	Males	Female vs male	Hybrids (F_1)	Parents vs hybrids	Error
df		2	19	16	2	1	50	1	140
Number of fruits/ plant	Rainy	0.752	7.981**	8.995**	3.103**	1.502*	4.286**	32.337**	0.312
	Summer	2.518	7.503**	8.168**	4.853*	2.176	5.895**	0.405	1.134
Average fruit weight (g)	Rainy	0.212	4.189**	2.421**	11.034**	18.808**	3.269**	43.276**	0.276
	Summer	0.963	2.973**	2.979**	3.368**	0.191	3.644**	16.606**	0.386
Fruit length (cm)	Rainy	0.222	1.110**	1.045**	2.175**	0.023	1.468**	0.058	0.120
	Summer	0.244	1.907**	1.875**	1.083**	4.070**	1.384**	9.423**	0.029
Fruit diameter (cm)	Rainy	0.043	0.027**	0.030**	0.010	0.001	0.032**	0.010	0.009
	Summer	0.017	0.029**	0.029**	0.040*	0.007	0.026**	0.011	0.010
Fruit yield/plant (g)	Rainy	106.272	902.009**	958.048**	112.501	1 584.410**	615.589**	9 309.938**	41.384
	Summer	724.732	1 327.299**	1 425.660**	1 151.311**	105.492	1 300.064**	1 458.938**	150.794
Number of seeds/fruit	Rainy	36.592	284.812**	238.195**	403.254**	793.781**	178.421**	201.969**	16.864
	Summer	116.085	242.523**	241.526**	162.413**	418.688**	171.786**	0.016	19.796
Ascorbic acid (mg/100g)	Rainy	1.331	9.063**	10.000**	2.943*	6.304**	5.597**	3.641*	0.627
	Summer	0.689	9.268**	10.343**	2.590*	5.413**	6.027**	2.379*	0.556

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

Table 3 Heterosis of 'L × T' for seven characters of best three crosses in okra during summer and rainy seasons of two years

Characters	F_1's of Summer season	BPH	SPH	F_1's of Rainy season	BPH	SPH
Number of fruits/plant	EC 305612 × Pusa Sawani	26.10**	–4.00	IIVR 198 × Parbhani Kranti	61.27**	12.25**
	AC 108 × Parbhani Kranti	20.59**	–8.46	IC 140906 × Parbhani Kranti	49.51**	4.06
	VRO 5 × Parbhani Kranti	17.77*	–8.24	IC 43720 × Pusa Sawani	31.75**	–5.15
Average fruit weigh (g)	IC 218844 × Arka Anamika	34.36**	15.65**	IIVR 401x Arka Anamika	36.17**	6.99
	IIVR 401 × Arka Anamika	24.80**	–9.20*	IC 45806 × Arka Anam ika	30.21**	2.31
	IIVR 401 × Pusa Sawani	22.30**	10.32*	Arka Abhay × Arka Anamika	28.40**	10.33**
Fruit length (cm)	IC 218844 × Arka Anamika	23.26**	11.95**	IC 140934 × Pusa Sawani	26.26**	16.82**
	IC 140934 × Pusa Sawani	12.08**	5.33*	IC 218844 × Arka Anamika	23.13**	12.77**
	VRO 5 × Arka Anamika	11.64**	–3.19	EC 305612 × Pusa Sawani	21.79**	18.38**
Fruit diameter (cm)	IIVR 342 × Parbhani Kranti	–18.75**	–13.33*	IC 45806 × Parbhani Kranti	–18.75**	–7.14
	IIVR 435 × Parbhani Kranti	–17.65**	–6.67	IC 43720 × Pusa Sawani	–17.65**	0.00
	AC 108 × Arka Anamika	–11.76	0.00	VRO 5 × Pusa Sawani	–12.50*	0.00
Fruit yield/plant (g)	VRO 5 × Pusa Sawani	37.80**	8.33	Arka Abhay × Arka Anamika	55.00**	11.98*
	AC 108 × Pusa Sawani	36.59**	–6.70	EC 305612 × Arka Anamika	48.20**	7.07
	EC 305612 × Pusa Sawani	35.01**	–7.78	AC 108 × Arka Anamika	37.76**	–0.47
Number of seeds/fruit	Arka Abhay × Arka Anamika	60.20**	–2.71	IC 45806 × Parbhani Kranti	62.18**	1.66
	IC 45806 × Arka Anamika	47.52**	–6.62	IC 218844 × Parbhani Kranti	58.41**	–2.66
	Arka Abhay × Parbhani Kranti	43.88**	–12.63*	Arka Abhay × Arka Anamika	55.19**	–2.80
Ascorbic acid content (mg/100 g)	EC– 305612 × Pusa Sawani	20.97**	–1.81	Arka Abhay × Arka Anamika	21.15**	0.24
	IIVR 401 × Arka Anamika	8.55	–13.59	EC 305612 × Arka Anamika	18.12**	–6.66
	Arka Abhay × Parbhani Krani	8.17	0.55	SA 2 × Pusa Sawani	4.58	–15.14

*Significant at 5%, ** significant at 1%; BPH, better parent heterosis; SPH, standard parent heterosis

hybrids only three crosses showed very high heterosis for better and standard parent, which was found in the cross combination of IC 218844 × Arka Anamika in summer season and IIVR 401 × Arka Anamika in rainy season. IIVR 401 × Arka Anamika was a common hybrid for both (rainy and summer) environments (Table 3). All the best three crosses for fruit weight by introgression of single male parent Arka Anamika, this was an ideal finding that Arka Anamika a good combiner and cross combination IIVR 401 × Arka Anamika a good hybrid for average fruit weight, may be used for development of a hybrid/ variety breeding programme. Similar study of highest heterosis for average fruit weight has been reviewed by Singh *et al*. (2009).

In okra the thin and long podded varieties are preferred for edible as well as for export purposes. The hybrids with positive heterosis are desirable for fruit length but negative heterosis for fruit diameter. Maximum heterosis for fruit length during rainy season was 26.26 % (IC 218844 × Arka Anamika) and 18.38 (VRO 5 × Arka Anamika) over better and standard parent, respectively however, maximum heterosis during summer season was 23.26 % (IC 140934 × Pusa Sawani) and 11.95 % (IC 140934 × Pusa Sawani) over better and standard parent, respectively. Whereas, the fruit diameter is favorable with lowest heterosis in the hybrid IIVR 342 × Parbhani Kranti and IC 45806 × Parbhani Kranti that was found the most promising hybrid for fruit diameter during the rainy and summer season, respectively. The present study revealed that the positive heterosis for fruit length and negative heterosis fruit diameter was support to the earlier findings of Singh (1983), Kumbhani *et al*. (1993), Pawar *et al*. (1999), Singh *et al*. (2009). After a study of environmental variation for fruit length and fruit diameter, rainy season was more favourable with both positive and negative heterosis than summer season.

Fruit yield/plant being a complex trait, is a multiplicative product of several basic components. Maximum heterosis for fruit yield was 37.80 % (VRO 5 × Pusa Sawani) over better parent during summer season but maximum heterosis for rainy season was 55.00 % and 11.98 % in Arka Abhay × Arka Anamika over better and standard parent, respectively. Increased yield in heterotic hybrids of okra has been observed in the present investigation, confirmed by Poshiya and Shukla (1986), Panda and Singh (1999), Nichal *et al*. (2000), Desai *et al*. (2007), Hosamani *et al*. (2008) in their study. The number of seeds/pod is desirable trait for edible fruits of okra (Ahmed *et al.* 1999). Maximum positive and desirable heterosis was 62.18 % (IC 45806 × Parbhani Kranti) over better parent and standard parent (VRO 6) during rainy season, while the maximum positive and desirable better parent heterosis was 60.20 % (Arka Abhay × Arka Anamika) during summer season. Similar results of positive heterosis for number of seeds were observed by Wankhade *et al*.

(1997) and Singh and Syamal (2006).

The positive heterosis is desirable and useful for ascorbic acid content. The maximum heterosis was 20.97 % (EC 305612 × Pusa Sawani) over better parent during summer season but during rainy season it was 21.15 % (Arka Abhay × Arka Anamika) over better parent heterosis. The observations of Pawar *et al*. (1999), Indu Rani *et al*. (2003), Jindal and Ghai (2005), Senthil Kumar *et al*. (2007) explain our finding of high and positive heterosis for ascorbic acid content.

In the present study, the significant of the heterotic performance was highly affected by the genetic background of parental genotypes. The high heterosis among these germplasm for most of the characteristics studied indicates that the considerable potential exist in these materials for developing hybrids. The outstanding hybrids (F_1's) VRO 5 × Pusa Sawani and Arka Abhay × Arka Anamika were good for fruit yield during rainy and summer season, respectively. These hybrids can be developed for breeding programme and also can satisfy the local demand. Okra breeding programme in BHU, Varanasi should aim to produce new F_1 hybrids.

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