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Estimation of Hybrid Vigour for Fruit Yield and Quality Traits of Okra [*Abelmoschus esculentus* (L.) Moench] Through Line x Tester Analysis Carried Over Environments

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A B S T R A C T

Heterosis is one of the greatest practical achievements of plant breeding and has been extensively used in crop improvement in okra. The production of hybrid cultivars with higher fruit yield and quality characters has become increasingly important in recent years due to continuous demand. In the present study, 14 genetically diverse okra parents were crossed in Line x Tester fashion to explore magnitude of heterosis. Pooled analysis of 3 environments data showed that the maximum extent of significant standard heterosis for fruit yield in desired directions was recorded in hybrids from the crosses VIO 47672 x GJO – 3 (33.33 %), IC – 045796 x GJO – 3 (22.83 %), IC – 111493 x GJO – 3 (22.27 %). A pursue of *per se* performance revealed that the hybrid from the cross VIO 47672 x GJO – 3 (E_1: 9.66 t/ha, E_2: 15.58 t/ha, E_3: 5.65 t/ha and pooled: 10.30 t/ha) was found to be performing consistent over environments and in pooled as well. Performance of these hybrids should be further tested for commercial cultivation. Hybrids, VIO 44244 x Arka Anamika (-8.80 %), VIO 44244 x GJO – 3 (-9.48 %) and AOL–09 –17 x GJO– 3 (19.88 %) exhibited significant standard heterosis in desired direction for stalk length, fiber content and shelf life, respectively. Stalk colour is an attractive trait for visualization of diverse okra genotypes in which dark green stalk colour is most preferable for edible purpose. Hybrids from the crosses *viz*, IC – 045796 x GJO – 3, IC – 052273 x GAO – 5, IC – 052273 x Varsha Uphar, VIO 47672 x GJO – 3 and EC – 305623 x GAO – 5 exhibited dark green stalk colour. On the basis of *per se* performance and heterosis analysis for fruit yield per plant hybrid VIO 47672 x GJO – 3 was the best followed by IC – 111493 x GJO – 3, IC – 045796 x GJO – 3 and performance of these hybrids should be further tested for commercial cultivation.

Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) belongs to family Malvaceae, is an important fruit vegetable grown throughout the tropics and warmer parts of the temperate zone (Kumar *et al.,* 2016). Tender okra fruits are used as vegetable in India, Brazil, West Africa and many other countries. Because of high nutritive value and prolonged shelf life, okra captured prominent position among the export oriented vegetable crops and thus act as one of the valuable foreign exchange earner crop (Patel, 2014). Okra is a polyploid, with most observed chromosome number from 2n= 56 to 199 and an often cross pollinated crop. Highly variable cross pollination rate from 0 to 69% has been recorded for *A. esculentus* (Anonymous, 2011; Charrier, 1984). India is a major okra producing country in the world comprising of 72 % of total area under okra (FAOSTAT, 2013). The area under okra cultivation in India is 504 (000 ha) with production of 5709 (000 MT) and productivity of 11.33 MT/ha, containing 5.03 per cent of the total area under vegetable crops and 3.18 per cent of total vegetable production (Anonymous, 2015). Extensive use of local landraces or traditional varieties and limited availability or improved high yielding varieties resulted in stable productivity of okra in India over the years (Reddy *et al.,* 2012). These facts warrant development of high yielding varieties for commercial cultivation. Since, Vijayaraghavan and Warrier (1946) reported heterosis in okra for the first time, hybrid vigour studies have been explored extensively. Several research workers reported the presence of heterosis in desired quantities for fruit yield and its various components (Kishor *et al.*, 2013; Obiadalla *et al.*, 2013; Kumar *et al.,* 2014; Akotkar *et al.*, 2014; Badiger *et al.,* 2014; Patel, 2014; Katagi *et al.,* 2015). The productivity of okra should be increased through hybridization and recombination.

Materials and Methods

The experiment was conducted between September, 2013 and February, 2015 (including crossing programme during September to December, 2013). The experiment consisting 55 genotypes including 14 parents their 40 hybrids and one standard check, was laid out in a Randomized Block Design (RBD) with three replications over three seasons (Table 1) at the Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, situated at coastal region of South Gujarat. Geographically, it is situated at 20°- 37' N latitude and 72°-54' E longitude with an altitude of 11.98 meters above the Mean Sea Level. All recommended horticultural practices along with plant protection measures were followed uniformly and timely.

Fourteen diverse parents (Table 2) based on their divergence values were crossed to produce forty F_1 hybrids. Selfed truthful seeds treated with Thiram 4g/kg of seeds of 14 diverse genotypes were sown in line x tester fashion in a single-row plot of ten plants spaced at 60 x 45 cm in vertisols of Navsari region.

Observations on days to first flowering, internodal length, plant height, number of branches per plant, number of fruits per plant, fruit yield per plant, fruit length, fruit diameter, fruit weight, stalk length, crude fiber content, shelf life at room temperature and stalk colour were recorded in five plant chosen at random in each genotype and in each replication. The crude fiber content from okra fruits was determined by method as described by Thimmaiah (1999). The data pertaining to various traits under study were analyzed as per procedure suggested by Panse and Sukhatme (1967) and Singh and Chaudhary (1977) using following model. Heterosis was estimated as the per cent increase (+) or decrease (-) of F_1 hybrid mean over the standard check (standard heterosis). For practical plant breeding, the estimation of heterosis over standard check is more realistic. These values were calculated using means over replications and tested for significance as follows:

$$\text{Per cent heterosis over Standard check (SC)} = \frac{F1 - SC}{SC} \times 100$$

Where,

F1: Mean performance of F1 hybrid
SC: Mean performance of the standard check

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

S.E. of difference for
Standard check = $[2M_e/r]^{0.5}$

Where,

Me = Error mean square of individual environment

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

Results and Discussion

Analysis of variance

Pooled analysis of variance over three environments (Table 3) revealed highly significant differences for all the traits, which indicated that the genotypes studied, had reacted differentially to the environments. Significant differences for all the traits (except internodal length, fruit length and fruit diameter and fruit weight) existed among parents over environments. The variance due to parents was further partitioned into variance due to females, males and females vs. males. The results followed the same trend as it was for parents. The mean squares due to males and females were highly significant for all traits in individual as well as pooled over environments (except days to first flowering, internodal length, number of branches per plant, fruit yield per plant, fruit length and fruit weight in case of males, while, internodal length, fruit length and fruit weight in the case of females).

The interaction of hybrids x environments were significant for all the traits except fruit length and fruit weight which indicated influence of environment on the expression of various traits.

The average performance of hybrids was different from that of parents in different environments which were evident from the significance of parents' v/s hybrids x environment interaction for various traits. This is in argument with several researchers (Sharma and Singh, 2012; Kishor *et al.*, 2013; Kumar *et al.*, 2014; Das *et al.*, 2013; Badiger *et al.*, 2014).

Per se performance

For any okra hybrid to be acceptable for commercial cultivation, it should possess significant superiority in fruit yield over the existing commercial hybrid. In the present study, the performance of 40 hybrids was compared with the hybrid 'Sonakshi' which is popular in South Gujarat region.

A perusal of mean values of fruit yield per plant (Table 4) revealed that in general the performance of parents and their hybrids were better under E_2. On pooled basis, the hybrid from the cross VIO 47672 x GJO – 3 was found to be the best in respect to fruit yield per plant. High yielding hybrid, in general, had high *per se* performance genotype as one of its parent and this hybrid significantly surpassed its parents as well as the check.

The wide range of *per se* performance of the parents for the traits studied suggest the prevalence of considerable amount of genetic variability which is one of the causes of heterosis. Deviation observed in the *per se* performance of the hybrids compared to that of the parents is also an indication of the manifestation of heterosis in the hybrids.

The above results are in conformity with Badiger *et al.*, (2014). Various environmental parameters *viz;* rainfall, temperature, humidity and sunshine were recorded over three seasons. In the present study, most of the genotypes had better yield traits in rainy season as compared to summer and winter season.

Seasonal variation was more effective for yield increment, during the rainy season when the rainfall and relative humidity was optimum and temperature and sunshine was low, leading to high heterotic values. Whereas, in summer season, temperature and sunshine was high but rainfall, relative humidity was low and heterosis per cent also decreased for yield.

Heterosis values were the lowest in winter season because of low temperature. This may be due to adverse growing conditions of okra plants in summer and winter as compared to rainy seasons.

Estimation of heterosis for yield and yield components

The extent of heterosis of top three crosses over standard check "Sonakshi" estimated for 12 traits in individual environments and on pooled basis is presented in tables 5a and 5b. It can be seen from the results that the top three heterotic crosses for fruit yield exhibited earliness in flowering. Early flowering hybrids with significant and negative heterosis for days to first flowering were IC – 111493 x GJO – 3 (-6.49 %), VIO 47672 x GJO – 3 (-6.37 %) and VIO 47672 x GAO – 5 (-6.04 %). Plant height and internodal length at fully matured stages is one of the important ideotype in okra for higher yield.

VIO 47672 x GJO – 3 (18.28 %), IC – 111493 x GJO – 3 (15.50 %) and IC – 045796 x GJO – 3 (13.79 %) were the top three performer for plant height while in the case of internodal length, top three hybrids were JOL – 08 – 13 x GJO – 3 (-9.93 %),JOL – 08 – 13 x Varsha Uphar (-9.78 %) and IC – 052273 x Arka Anamika (-8.69 %).

The number of branches per plant and number of fruits per plant are major yield attributing components contributing to higher productivity. Component wise examination of the crosses revealed that most of the high yielding crosses manifested high standard heterosis for number of branches per plant and number of fruits per plant which are major yield components.

VIO 47672 x GJO – 3 (20.92 % and 24.15 %), IC – 045796 x GJO – 3 (15.18 % and 13.79 %) and IC – 111493 x GJO – 3 (15.16 % and 15.50 %) were the top three hybrids with significant and positive standard heterosis for number of fruits and plant height, respectively.

The increase in number of branches and plant height ultimately increased number of fruits which in turn resulted in significant increase in yield (Katagi *et al.*, 2015).

Table.1 Details of seasons taken under study

Environment	Seasons
E_1	Summer, 2014 (February to May, 2014)
E_2	Rainy, 2014 (June to September, 2014)
E_3	Winter, 2014 – 15 (November, 2014 to February, 2015)

Table.2 Parental material used for the study

Parent	Source/Origin
Lines	
VIO 44244	AVRDC, Taiwan
IC – 111493	NBPGR, New Delhi, India
JOL – 08 – 13	Junagadh Agricultural University, Junagadh (Gujarat)
EC – 284327	NBPGR, New Delhi, India
IC – 045796	NBPGR, New Delhi, India
IC – 052273	Junagadh Agricultural University, Junagadh (Gujarat)
JOL – 10 – 18	Junagadh Agricultural University, Junagadh (Gujarat)
AOL – 09 – 17	Anand Agricultural University, Anand (Gujarat)
VIO 47672	AVRDC, Taiwan
EC – 305623	NBPGR, New Delhi, India
Testers	
GAO – 5	Anand Agricultural University, Anand (Gujarat)
GJO – 3	Junagadh Agricultural University, Junagadh (Gujarat)
Arka Anamika	IIHR, Bengaluru, India
Varsha Uphar	IIHR, Bengaluru, India
Commercial Check Sonakshi (F_1 ; Company: Nunhems)	

Table.4 *Per se* performance of females, males and hybrids for fruit Yield per plant (g) under individual and pooled over environments

Range	Females				Males				Hybrids			
	E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
Min	EC-305623 (158.90)	IC-052273 (229.30)	JO-08-13 (86.43)	EC-305623 (161.89)	Arka Anamika (180.40)	Varsha Uphar (190.60)	Arka Anamika (89.97)	Varsha Uphar (164.24)	EC-305623 x GAO-5 (153.75)	IC-052273 x GJO-3 (200.36)	IC-052273 x Arka Anamika (75.92)	IC-045796 x Varsha Uphar (163.73)
Max	IC-111493 (214.36)	IC-045796 (306.60)	JOL-10-18 (107.42)	IC-111493 (207.31)	GAO-5 (213.60)	GAO-5 (305.77)	GJO-3 (95.59)	GAO-5 (204.98)	VIO 47672 x GJO-3 (260.90)	VIO 47672 x GJO-3 (420.96)	VIO 47672 x GJO-3 (152.43)	VIO 47672 x GJO-3 (278.01)

Note: E_1, E_2 and E_3 are different environments *viz.*, Summer – 2014, Rainy – 2014 and Winter – 2014 – 15, respectively

Table.3 Analysis of variance (Mean Squares) for yield and yield components in okra over environments (Pooled basis)

Source	d.f.	Characters											
		DFF	IL	NOB	PH	FY	NF	FL	FD	FW	SL	CF	SLD
Environment	2	1629.4**	1558.3**	0.57**	5591.32**	1366434**	5591.3**	780.77**	2.370**	560.293**	0.516**	6.689**	31.08**
Replication/Environment	4	1.55	0.07	0.07	1.85	78.269	1.858	1.117	0.012	0.176	0.035	0.059	0.034
Genotype	53	26.63**	4.34**	0.27**	21.56**	6075.58**	21.560**	2.122**	0.064**	1.614**	0.075**	0.867**	1.61**
Parent	13	19.59**	0.33	0.09**	12.17**	2842.48**	12.177**	0.676	0.015	0.421	0.055*	0.399**	0.68**
Female (F)	9	20.02**	0.36	0.10**	10.35**	2589.78**	10.352**	0.739	0.008	0.487	0.055**	0.518**	0.63**
Male (M)	3	3.970	0.27	0.07	21.70**	4544.40	21.709**	0.204	0.040*	0.109	0.070*	0.024	0.98**
Female vs Male (F vs M)	1	62.60**	4.16**	0.00	0.008	11.07	0.008	1.523	0.000	0.759	0.014	0.451**	0.27**
Parents vs. Hybrids (P vs. H)	1	91.15**	27.5 **	0.34**	36.02**	13753.62**	36.022**	12.655**	0.055**	6.795**	0.253**	6.199**	0.10*
Hybrids	39	27.32**	5.08**	0.32**	24.31**	6956.41**	24.317**	2.337**	0.082**	1.879**	0.077**	0.886**	1.96**
Genotype x Environment	106	11.4**	2.26**	0.04**	8.50**	1880.67**	8.506**	0.679*	0.016**	0.425*	0.037**	0.388**	0.06**
Parents x Environments	26	6.39	0.48	0.02	8.73**	1484.68**	8.736**	0.901*	0.014	0.162	0.028	0.329**	0.06**
Females x Environments	18	7.3	0.48	0.01	5.59**	991.14**	5.596**	1.150*	0.011	0.182	0.024	0.248**	0.06**
Males x Environments	6	4.05	0.35	0.04	15.86**	2963.04**	15.867**	0.399*	0.022	0.096	0.032	0.604**	0.07**
(F vs M) x Environment	2	4.34	0.92	0.07	15.60**	1491.47**	15.603**	0.168	0.022	0.178	0.056	0.236**	0.03
(P vs H) x Environment	2	5.35	12.4**	0.01	8.99*	4480.20**	8.999*	0.192	0.009	2.028**	0.009	0.006	0.22**
Hybrids x Environment	78	13.2 **	2.59**	0.05**	8.41**	1946.02**	8.417**	0.618	0.017**	0.472	0.041**	0.417**	0.05**
Pooled Error	318	5.05	0.56	0.03	2.174	243.61	2.174	0.582	0.011	0.400	0.022	0.036	0.025

Note: DFF: Days to first flowering, IL: Internodal length (cm), NOB: Number of Branches, PH: Plant height (cm), FY: Fruit yield per plant (cm), NF: Number of fruits per plant, FL: Fruit length (cm), FD: Fruit diameter (cm), FW: Fruit weight (g), SL: Stalk length (cm), CF: Crude fibre content (%), SLD: Shelf life (days).

Table.5a Per cent standard heterosis (top three crosses) in different environment and across environments for various characters in okra

Character	E_1	Standard heterosis (%)	E_2	Standard heterosis (%)	E_3	Standard heterosis (%)	Pooled	Standard heterosis (%)
Days to first flowering	VIO 47672 x GJO – 3	-4.4	IC – 111493 x GAO – 5	-11.77**	VIO 47672 x GJO – 3	-5.9*	IC – 111493 x GJO – 3	-6.49*
	IC – 045796 x GAO – 5	-3.5	VIO 47672 x GAO – 5	-11.55**	IC – 111493 x GJO – 3	-5.27*	VIO 47672 x GJO – 3	-6.37*
	IC – 111493 x GJO – 3	-2.75	IC – 111493 x GJO – 3	-11.44**	IC – 045796 x GJO – 3	-5.07	VIO 47672 x GAO – 5	-6.04*
Intermodal length (cm)	AOL – 09 – 17 x Arka Anamika	-19.97**	IC – 052273 x GJO – 3	-12.59	JOL – 08 – 13 x GJO – 3	-13.53**	VIO 44244 x GAO – 5	-9.93*
	EC – 284327 x Arka Anamika	-17.65**	VIO 44244 x GAO - 5	-11.46	JOL – 08 – 13 x Varsha Uphar	-12.52*	JOL – 10 – 18 x Varsha Uphar	-9.78*
	EC – 305623 x GJO – 3	-13.82*	JOL – 10 – 18 x Varsha Uphar	-11.20	IC – 052273 x Arka Anamika	-12.23*	AOL – 09 – 17 x Arka Anamika	-8.69*
Number of branches	VIO 47672 x GJO – 3	34.80**	VIO 47672 x GJO – 3	19.40**	VIO 47672 x GJO – 3	18.18**	VIO 47672 x GJO – 3	24.15**
	IC – 045796 x GAO – 5	28.63**	IC – 045796 x GJO – 3	18.10**	IC – 111493 x GJO – 3	15.91**	IC – 111493 x GJO – 3	19.15**
	IC – 111493 x GJO – 3	24.23**	IC – 111493 x GJO – 3	17.24**	IC – 045796 x GJO – 3	14.09**	IC – 045796 x GAO – 5	19.15**
Plant height (cm)	VIO 47672 x GJO – 3	6.06	VIO 47672 x GJO – 3	25.70**	VIO 47672 x GJO – 3	19.96**	VIO 47672 x GJO – 3	18.28**
	IC – 045796 x GAO – 5	4.29	IC – 045796 x GJO – 3	23.97**	IC – 111493 x GJO – 3	17.73**	IC – 111493 x GJO – 3	15.50**
	IC – 111493 x GJO – 3	3.86	IC – 111493 x GJO – 3	22.28**	IC – 045796 x GJO – 3	16.51**	IC – 045796 x GJO – 3	13.79**
Fruit yield per plant (g)	VIO 47672 x GJO – 3	21.17**	VIO 47672 x GJO – 3	36.60**	VIO 47672 x GJO – 3	48.93**	VIO 47672 x GJO – 3	33.30**
	IC – 045796 x GAO – 5	16.28**	IC – 045796 x GAO – 5	27.56**	IC – 045796 x GAO – 5	45.54**	IC – 045796 x GAO – 5	22.83**
	IC – 111493 x GJO – 3	9.52*	IC – 111493 x GJO – 3	23.45**	IC – 111493 x GJO – 3	40.05**	IC – 111493 x GJO – 3	22.27**
Number of fruits per plant	VIO 47672 x GJO – 3	13.33*	VIO 47672 x GJO – 3	19.40**	VIO 47672 x GJO – 3	28.15**	VIO 47672 x GJO – 3	20.92**
	IC – 045796 x GAO – 5	9.97*	IC – 045796 x GJO – 3	18.10*	IC – 045796 x GJO – 3	24.93**	IC – 045796 x GJO – 3	15.18**
	IC – 111493 x GJO – 3	7.41	IC – 111493 x GJO – 3	17.24*	IC – 111493 x GJO – 3	23.17**	IC – 111493 x GJO – 3	15.16**

Note: E_1, E_2 and E_3 are different environments *viz.*, Summer – 2014, Rainy – 2014 and Winter – 2014 – 15

Table.5b Per cent standard heterosis (top three crosses) in different environment and across environments for various characters in okra

Character	E_1	Standard heterosis (%)	E_2	Standard heterosis (%)	E_3	Standard heterosis (%)	Pooled	Standard heterosis (%)
Fruit length (cm)	VIO 47672 x GJO – 3	11.17*	VIO 47672 x GJO – 3	8.71*	VIO 47672 x GJO – 3	21.35**	VIO 47672 x GJO – 3	12.72**
	IC – 045796 x GAO – 5	9.8	IC – 045796 x GAO – 5	7.91	IC – 045796 x GAO – 5	19.23**	IC – 045796 x GAO – 5	10.22**
	IC – 111493 x GJO – 3	8.18	IC – 111493 x GJO – 3	6.47	IC – 111493 x GJO – 3	17.10**	IC – 111493 x GJO – 3	10.07**
Fruit diameter (cm)	VIO 47672 x GJO – 3	35.40**	VIO 47672 x GJO – 3	9.76*	VIO 47672 x GJO – 3	18.44**	VIO 47672 x GJO – 3	20.74**
	IC – 045796 x GAO – 5	24.90**	IC – 045796 x GAO – 5	9.15	IC – 045796 x GAO – 5	12.77**	IC – 045796 x GAO – 5	14.67**
	IC – 111493 x GJO – 3	24.21**	IC – 111493 x GJO – 3	8.54	IC – 111493 x GJO – 3	12.06**	IC – 111493 x GJO – 3	14.44**
Fruit weight (g)	VIO 47672 x GJO – 3	9.44**	VIO 47672 x GJO – 3	11.07*	VIO 47672 x GJO – 3	18.14**	VIO 47672 x GJO – 3	12.44**
	IC – 045796 x GAO – 5	7.84*	IC – 045796 x GAO – 5	9.71	IC – 045796 x GAO – 5	17.58**	IC – 111493 x GJO – 3	9.96**
	IC – 111493 x GJO – 3	5.34	IC – 111493 x GJO – 3	8.68	IC – 111493 x GJO – 3	14.56*	IC – 045796 x GAO – 5	8.83**
Stalk length (cm)	VIO 44244 x Arka Anamika	-3.13	EC – 284327 x Varsha Uphar	-8.68	VIO 44244 x Arka Anamika	-16.00**	VIO 44244 x Arka Anamika	-8.80*
	IC – 111493 x Varsha Uphar	-3.13	VIO 44244 x Arka Anamika	-6.61	IC – 111493 x GJO – 3	-16.00**	IC – 111493 x GJO – 3	-8.66*
	IC – 111493 x GJO – 3	-2.68	IC – 111493 x GJO – 3	-6.61	EC – 284327 x GJO – 3	-12.80**	IC – 111493 x Varsha Uphar	-4.89
Crude fiber content (%)	VIO 47672 x Arka Anamika	-9.77**	VIO 47672 x Varsha Uphar	-13.25**	IC – 111493 x Varsha Uphar	-18.81**	VIO 44244 x GJO – 3	-9.48**
	VIO 44244 x GJO – 3	-9.56**	IC – 052273 x Varsha Uphar	-10.64**	VIO 44244 x GJO – 3	-18.14**	IC – 045796 x Varsha Uphar	-6.34**
	IC – 111493 x GJO – 3	-7.90*	AOL – 09 – 17 x Arka Anamika	-8.09	IC – 111493 x Arka Anamika	-13.72**	IC – 045796 x Arka Anamika	-6.13**
Shelf life (days)	IC – 111493 x Varsha Uphar	10.80**	JOL – 08 – 13 x GJO – 3	15.95**	JOL – 08 – 13 x GJO – 3	5.75	AOL – 09 – 17 x GJO – 3	19.88**
	JOL – 08 – 13 x GJO – 3	10.51**	IC – 111493 x Varsha Uphar	9.62**	VIO 47672 x Arka Anamika	4.83	JOL – 08 – 13 x GJO – 3	10.58**
	VIO 47672 x Arka Anamika	6.82**	VIO 47672 x Arka Anamika	7.59**	EC – 284327 x GAO – 5	1.61	IC – 111493 x Varsha Uphar	6.43**

Note: E_1, E_2 and E_3 are different environments viz., Summer – 2014, Rainy – 2014 and Winter – 2014 – 15

Table.6 Fruit stalk colour of okra parents and F_1 hybrids

Parents		Stalk colour	Hybrids	Stalk colour	Hybrids	Stalk colour	Hybrids	Stalk colour
Lines	VIO 44244	Light green	VIO 44244 x GAO – 5	Light green	EC – 284327 x Arka Anamika	Light green	AOL – 09 – 17 x GAO – 5	Light green
	IC – 111493	Medium green	VIO 44244 x GJO – 3	Light green	EC – 284327 x Varsha Uphar	Light green	AOL – 09 – 17 x GJO – 3	Medium green
	JOL – 08 – 13	Light green	VIO 44244 x Arka Anamika	Light green	IC – 045796 x GAO – 5	Light green	AOL – 09 – 17 x Arka Anamika	Light green
	EC – 284327	Light green	VIO 44244 x Varsha Uphar	Light green	IC – 045796 x GJO – 3	Dark green	AOL – 09 – 17 x Varsha Uphar	Light green
	IC – 045796	Medium green	IC – 111493 x GAO – 5	Light green	IC – 045796 x Arka Anamika	Light green	VIO 47672 x GAO – 5	Medium green
	IC – 052273	Light green	IC – 111493 x GJO – 3	Medium green	IC – 045796 x Varsha Uphar	Light green	VIO 47672 x GJO – 3	Dark green
	JOL – 10 – 18	Light green	IC – 111493 x Arka Anamika	Medium green	IC – 052273 x GAO – 5	Dark green	VIO 47672 x Arka Anamika	Light green
	AOL – 09 – 17	Light green	IC – 111493 x Varsha Uphar	Light green	IC – 052273 x GJO – 3	Light green	VIO 47672 x Varsha Uphar	Light green
	VIO 47672	Medium green	JOL – 08 – 13 x GAO – 5	Light green	IC – 052273 x Arka Anamika	Light green	EC – 305623 x GAO – 5	Dark green
	EC – 305623	Light green	JOL – 08 – 13 x GJO – 3	Light green	IC – 052273 x Varsha Uphar	Dark green	EC – 305623 x GJO – 3	Light green
Testers	GAO – 5	Dark green	JOL – 08 – 13 x Arka Anamika	Dark green	JOL – 10 – 18 x GAO – 5	Light green	EC – 305623 x Arka Anamika	Light green
	GJO – 3	Dark green	JOL – 08 – 13 x Varsha Uphar	Light green	JOL – 10 – 18 x GJO – 3	Medium green	EC – 305623 x Varsha Uphar	Light green
	Arka Anamika	Dark green	EC – 284327 x GAO – 5	Light green	JOL – 10 – 18 x Arka Anamika	Light green	CHECK (Sonakshi)	Dark green
	Varsha Uphar	Dark green	EC – 284327 x GJO – 3	Medium green	JOL – 10 – 18 x Varsha Uphar	Light green		

VIO 47672 x GJO – 3 (12.72 %, 20.74 % and 12.44 %), IC – 045796 x GAO – 5 (10.22 %, 14.67 % and 8.83 %) and IC – 111493 x GJO – 3 (10.07 %, 14.44 % and 9.96 %) were the top three hybrids for fruit length, fruit diameter and fruit weight, respectively. In the present investigation, the maximum standard heterosis for fruit yield per plant recorded by cross combination VIO 47672 x GJO – 3 (33.33 %) followed by IC – 045796 x GAO – 5 (22.83 %) and IC – 111493 x GJO – 3 (22.27 %).

It is interesting to note that top ranking crosses based on *per se* performance and standard heterosis was the same. The high fruit yield recorded in the hybrid from the VIO 47672 x GJO – 3 cross can be directly attributed to earlier flowering (-6.37%), increased number of branches per plant (24.15%), number of fruits per plant (20.92%), fruit length (12.72%), fruit diameter (20.74%) and fruit weight (12.44%) because they are very closely related yield components. Heterosis for growth parameters is an indication of heterosis for yield as growth and yield parameters are strongly associated. Heterosis is thought to result from the combined action and interaction of allelic and non-allelic factors and is usually closely and positively correlated with heterozygosity (Falconer, 1952). Similar observations were reported earlier in okra by many researchers like Kishor *et al.,* (2013), Obiadalla *et al.,* (2013), Kumar *et al.,* (2014), Akotkar *et al.,* (2014), Badiger *et al.,* (2014) and Katagi *et al.,* (2015).

In okra, the fruit length, fruit diameter and fruit weight are the important yield components. Such high heterotic response would be useful for obtaining higher fruit yield. Both the parents and hybrids exhibited wider variation for fruit weight. Such an increase in fruit weight can be attributed to the conglomeration of favorable genes in the hybrids (Das *et al.,* 2013).

Estimation of heterosis for quality parameters

Very few researchers have studied the heterosis for quality traits in okra. Okra fruits with shorter stalk length and lower crude fibers are considered as good in quality. Cross of VIO 44244 x Arka Anamika (-8.80 %) and IC – 111493 x GJO – 3 (-8.66 %) exhibited heterosis in desired direction for stalk length. Cross combination, VIO 44244 x GJO – 3 (-9.48%) resulted in the lowest significant and negative heterosis for this trait in pooled analysis for crude fiber content (Table 5b).

In present study, negative and significant heterosis for stalk length and crude fiber observed which is in confirmation with the findings of Shobha and Marriappan (2007), Indurani *et al.,* (2003), Kumar *et al.,* (2014) and Flemine Xavier *et al.,* (2016). AOL – 09 – 17 x GJO – 3, JOL – 08 – 13 x GJO – 3 and IC – 111493 x Varsha Uphar are the top three crosses which resulted in significant and positive heterosis over standard check for shelf life. The present findings are in agreement with results reported by Patwary *et al.,* (2013), Narasimhamurthy and Gowda (2013) and Garg *et al.,* (2013) in tomato.

Visual observation of fruit stalk colour

The colour of the fruit and fruit stalk (Table 6) are important quality parameters in okra. Consumers prefer mostly dark green fruit. In the present investigation, three colour shades were observed in fruits of okra *viz.,* Dark Green, Medium Green and Light Green. Among all the parents, lines, IC – 111493, IC – 045796 and VIO 47672 had medium green stalk colour and rest of all had light green stalk colour. Dark green stalk colour is a desirable trait as per the quality point of view. Hybrids *viz;* IC – 045796 x GJO – 3, IC – 052273 x GAO – 5, IC – 052273 x Varsha Uphar, VIO 47672 x GJO – 3 and EC –

305623 x GAO – 5 exhibited dark green stalk colour. Colour of fruit was also reported by Alake and Ariyo (2012) and Solankey *et al.*, (2013). In the present study, the significance of the heterotic performance was highly affected by the genetic background of parental genotypes. The high heterosis among these hybrids for most of the characteristics studied indicates that the considerable potential exist in parents for developing hybrids. The outstanding hybrids (F_1) VIO 47672 x GJO – 3, IC – 045796 x GAO – 5 and IC – 111493 x GJO – 3 were good for fruit yield during all the seasons. These hybrids can be evaluated further to satisfy the local demand.

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