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HETEROSIS STUDIES IN OKRA (*Abelmoschus esculentus* (L.) MOENCH.) FOR GREEN FRUIT YIELD AND QUALITY PARAMETERS OVER THE ENVIRONMENTS

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ABSTRACT

The experiments were conducted comprised of 90 genotypes of okra including 17 parents, 72 hybrids and standard check GJOH-3 were sown at Anand Agricultural University, Anand during K*harif* 2016 (E_1), late *Kharif* 2016 (E_2) and *Rabi* 2016-17 (E_3) to study the magnitude of heterobeltiosis and standard heterosis. Significant differences were observed among parents and hybrids indicating considerable genetic variation among these genotypes. Maximum heterosis over better parent and standard check was observed for green fruit yield per plant, fruit length, internode length, number of fruits per plant, primary branches per plant, total chlorophyll content and crude fiber content. The range of heterobeltiosis and standard heterosis for green fruit yield per plant was -13.45 to 43.91 to % and -22.70 to 27.84 to % over pooled basis respectively. As regards the quality parameters the estimates of heterosis was low to moderate in desired direction. The Hybrids DHOK-153 x Kashi Kranti, JF 108-2 x Kashi Kranti , DHOK-153 x GJO 3, DHOK-153 x Kashi Pragati, JF 108-2 x GAO 5 and AOL 9-2 x Phule Utkarsha were found to be high yielding and heterotic over the environments and pooled basis. These hybrids recorded no incidence of YVMV reation. Hence, these hybrids were identified as potential for commercial cultivation after sufficient evaluation.

Key words : *Heterosis, green gruit, yield, quality parameters, okra.*

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the most important fruit vegetable grown worldwide and in India. Okra provides an important source of nutraceutical such as vitamins, calcium, potassium and minerals. Immature green fruits are mucilaginous, low in calories, antioxidant property okra mucilage and edible fiber which helps to stabilize blood sugar by curbing the rate at which sugar is absorbed from the intestinal tract (1).

Okra is a polyploid, belonging to the family *Malvaceae* with 2n = 8x = 72 or 144 chromosome and a often cross pollinated crop. India is a major okra producing country in the world comprising of 70 per cent of total area under okra. In India, okra is commercially grown in the states of West Bengal, Gujarat, Odisha, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh, Andhra Pradesh and Maharashtra as a *Kharif* as well as summer season crop.

Cultivation of open pollinated varieties, lack of location specific high yielding varieties/hybrids with high degree of resistance to diseases like okra yellow vein mosaic virus are the major reasons of low productivity in India and Gujarat. To exploit the heterosis of potential yield components, knowledge of genetic architecture of fruit yield and its attributes is important in crop improvement. 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 first time demonstrated by (2). Hybrid vigour provides the means to an increase in the crop yield, disease and insect resistance and to combining ability characters, it is one of the important objectives in the plant breeding. Heterosis for yield and yield components has been also reported by several workers, (3, 4, 5).

MATERIALS AND METHODS

The experimental material consisted of 17 parents [8 elite lines *viz.,* AOL 9-2, AOL 12-52, AOL 12-59, AOL 13-96, DHOK-153, KS 404, JF 108-2, GP OK-45 and 9 high yielding released okra varieties as testers *viz.,* GJO-3, Kashi Vibhuti, Kashi Pragati, Kashi Kranti, Phule Utkarsha, Arka Anamika, Pusa Sawani, GO-2 and GAO 5] and their 72 F_1s derived by crossing these parents in a Lines x Testers factorial mating design. The okra hybrid GJOH-3 was used as standard check. The experiments were conducted at the Distant Hybridization farm and Agronomy farm, Anand Agricultural University, Anand during *Kharif,* Late *Kharif* and *Rabi* 2016-17 with three sowing dates [7th July, 2016 (E_1), 7th September, 2016 (E_2) and 9th November, 2016 (E_3)].

Observations were recorded on three phenological trait *viz.,* days to 50% flowering, days to first picking, days to last picking, three growth attributes *viz.,* plant height, number of primary branches per plant, internode length, five yield contributing characters *viz.,* number of fruits per plant, fruit length, fruit girth, fruit weight, and green fruit yield per plant, six fruit quality parameters *viz.,* moisture content, total chlorophyll content, muscilage content, crude fiber content, total carbohydrate content and ash content. The standard protocols were applied for analysis of biochemical quality parameters. The collected data

Table-1 : Analysis of variance (Line x Tester) for green fruit yield and yield contributing and quality characters in okra pooled over environments.

Sources of Variations (d.f.)	Green fruit yield per plant (g)		Days to 50% flowering		Days to first picking		Days to last Picking		Plant height (cm)		No.of Branches per plant		Internode Length (cm)		No. of fruits per plant	
Environments (2)	1308901.94	**	6199.91	**	6374.31	**	39913.42	**	820474.10	**	22.018	**	226.54	**	5482.77	**
Genotypes (88)	4338.58	**	47.19	**	45.26	**	89.77	**	1107.08	**	0.454	**	2.32	**	16.00	**
Parents (16)	1434.17	**	64.58	**	63.36	**	156.02	**	1325.49	**	0.271	**	1.97	**	6.31	**
Crosses (71)	3915.24	**	41.56	**	39.68	**	75.79	**	922.78	**	0.493	**	1.92	**	16.29	**
Parent vs Crosses (1)	80866.52	**	169.20	**	151.31	**	22.60	*	10698.21	**	0.617	**	36.22	**	150.97	**
Genotypes x environments (176)	1426.40	**	1.77		1.83		9.29	**	110.25	**	0.184	**	0.67	**	7.80	**
Error (176)	501.25		2.74		2.59		5.78		38.45		0.037		0.051		2.47	

Sources of Variations (d.f.)	Fruit Length (cm)		Fruit girth (cm)		Fruit weight (g)		Total chlorophyll content (mg/g)		Muscilage content (g/100g)		Crude fiber content (%)		Total carbohydrate content (%)		Ash content (%)	
Environments (2)	852.38	**	84.585	**	214.43	**	0.056	**	1.6535	**	0.304	**	11.542	**	8.037	**
Genotypes (88)	8.54	**	0.822	**	2.46	**	0.014	**	0.3217	**	0.744	**	2.583	**	0.131	**
Parents (16)	4.14	**	0.766	**	1.61	**	0.011	**	0.3105	**	0.438	**	2.417	**	0.121	*
Crosses (71)	9.41	**	0.749	**	2.29	**	0.015	**	0.3232	**	0.793	**	2.466	**	0.136	**
Parent vs Crosses (1)	17.41	**	6.969	**	27.49	**	0.018	**	0.3908	**	2.178	**	13.610	**	0.011	
Genotypes x environments (176)	0.36	**	0.059		1.29	**	0.007	**	0.0027		0.308	**	0.180	**	0.121	**
Error (176)	0.16		0.059		0.44		0.002		0.0047		0.056		0.064		0.063	

*, ** Significant at 5 and 1 per cent levels, respectively E_1 : Kharif 2016, E_2 : Late Kharif 2016 , E_3 : Rabi 2016-17

were subjected to statistical analysis for estimates of heterotic effects as suggested by (6).

RESULTS AND DISCUSSION

The utilization of the heterotic effect for vegetable improvement is considered to be as one of the most outstanding achievements 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 potential parents and then reliably reproduce superior hybrid genotypes. The analysis of variance (L x T) for green fruit yield and other characters is presented in Table-1. The significance of mean sum squares due to parents vs hybrids for all the traits proved that the differences in the performance of parents and hybrids were real and manifested the presence of heterosis for most of the traits studied. The significance of environmental interactions with parents and hybrids indicated the influence of environments in most of the traits.

In respect to *per se* performance of parents, AOL-9-2, AOL 12-52 and DHOK-153 (lines) GO-2, Phule Utkarsha, Kashi Kranti and Kashi Pragati (testers) and hybrids DHOK-153 x Kashi Kranti, JF 108-2 x Kashi Kranti , DHOK-153 x GJO- 3, DHOK-153 x Kashi Pragati, AOL 9-2 x Phule Utkarsha and JF 108-2 x GAO-5 were found to be superior for green fruit yield per plant and for most of the yield contributing and quality characters. The green fruit yield per plant for hybrids ranges from 193.67 to 370.67 g in E_1 , 131.29 to 246.48 g in E_2 , 86.88 to 153.39 in E_3 and 153.90 to 254.52 g on pooled basis.

The range of the heterobeltiosis and standard heterosis of hybrids over the environments and pooled basis were presented in Table-2. The degree and magnitude of various heterotic effects were varied from cross to cross and character to character. Considerable amount of heterobeltiosis and standard heterosis were observed for green fruit yield and most of other related traits studied in the present investigation. The magnitude of heterosis was varied in different environments for the various traits. Heterotic effect over better parent for green fruit yield were observed to the extent of 61.96 per cent during *Kharif* 2016, 56.66 per

Table-2 : Estimates of per cent heterosis over better parent and standard check in okra over the environments and pooled basis.

Character	Range	Mean performance (pooled)	Estimates of Heterosis (%)							
			Over Better Parents				Over standard Check			
			E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
Days to 50% flowering	Minimum	40.33	-5.88	-4.35	-3.77	-3.76	-19.08	-13.24	-11.46	-14.39
	Maximum	51.78	28.18	18.85	16.08	19.89	9.92	11.03	9.55	9.91
Days to first picking	Minimum	46.66	-7.45	-3.55	-4.27	-3.67	-15.89	-12.82	-11.8	-13.4
	Maximum	58.33	22.14	17.02	16.46	16.63	9.27	8.97	8.43	8.25
Days to last Picking	Minimum	89.67	-12.81	-8.04	-6.98	-8.73	-14.34	-7.17	-5.39	-8.70
	Maximum	105.00	5.96	7.04	3.54	3.39	5.59	11.32	8.38	6.78
Plant height (cm)	Minimum	77.11	-31.54	-37.31	-26.41	-32.52	-22.41	-25.23	-15.21	-22.10
	Maximum	134.64	29.54	19.36	35.25	27.58	20.30	11.21	46.87	21.28
No.of Branches per plant	Minimum	1.93	-30.00	-36.73	-26.32	-20.17	-28.-5	-32.61	-23.53	-23.73
	Maximum	3.05	25.81	45.95	21.21	31.37	13.16	22.83	17.65	16.10
Internode Length (cm)	Minimum	3.36	-23.07	-26.05	-21.97	-13.86	-36.82	-29.78	-15.86	-24.49
	Maximum	5.85	85.54	39.11	107.6	67.20	15.41	10.72	46.62	14.01
No. of fruits per plant	Minimum	13.60	-26.89	-25.74	-24.33	-15.38	-36.42	-27.25	-11.60	-23.55
	Maximum	20.14	34.99	45.17	26.67	28.70	8.77	24.19	24.85	13.20
Fruit Length (cm)	Minimum	8.68	-22.7	-10.78	-20.23	-17.55	-22.33	-15.90	-18.88	-17.90
	Maximum	13.36	18.86	34.51	40.00	29.47	28.20	23.24	27.60	26.35
Fruit girth (cm)	Minimum	4.23	-14.97	-17.23	-19.78	-16.67	-15.61	-16.80	-19.07	-17.03
	Maximum	5.65	21.42	23.31	27.27	22.61	13.15	11.59	13.16	10.80
Fruit weight (g)	Minimum	9.68	-10.86	-13.00	-23.03	-9.23	-11.76	-7.98	-30.06	-12.49
	Maximum	12.04	22.69	21.37	27.08	19.13	15.85	23.93	1.36	6.49
Green fruit yield per plant (g)	Minimum	147.60	-24.24	-24.96	-26.60	-13.45	-30.03	-24.93	-31.67	-22.70
	Maximum	254.52	61.96	56.66	56.23	43.91	29.45	34.10	20.35	27.84
Moisture content (%)	Minimum	83.41	-5.60	-2.72	-4.42	-3.51	-5.11	-2.45	-3.03	-2.69
	Maximum	86.87	1.47	1.65	2.21	1.22	1.65	1.48	2.05	1.34
Total chlorophyll content (mg/g)	Minimum	0.427	-43.37	-31.20	-32.56	-23.56	-16.37	-13.16	-19.63	-9.86
	Maximum	0.647	49.38	29.32	32.61	24.52	71.02	47.69	50.47	37.01
Muscilage content(g/100g)	Minimum	1.05	-40.30	-45.89	-42.86	-42.89	-40.92	-45.58	-41.94	-41.94
	Maximum	2.05	23.60	15.26	19.70	19.60	17.62	9.69	13.89	13.80
Crude fiber content (%)	Minimum	3.04	-33.45	-32.87	-36.85	-29.77	-40.22	-36.80	-35.27	-29.80
	Maximum	4.81	33.74	25.83	49.61	30.19	10.16	20.19	13.90	11.18
Total carbohydrate content (%)	Minimum	5.60	-19.27	-22.94	-23.31	-19.32	-25.14	-27.41	-29.06	-24.18
	Maximum	7.87	29.93	15.35	17.88	17.46	13.54	5.91	4.23	6.59
Ash content (%)	Minimum	5.08	-8.91	-20.25	-20.76	-10.52	-9.79	-17.31	-12.38	-70.1
	Maximum	5.82	13.33	7.77	5.92	7.12	11.19	9.48	9.71	6.37

E_1 : Kharif 2016, E_2 : Late Kharif 2016, E_3 : Rabi 2016-17

cent during Late *Kharif* 2016 and 56.23 per cent during *Rabi* 2016. While, heterosis over the check hybrid GJOH-3 was observed to the extent of 29.45, 34.10 and 20.35 per cent during *Kharif* 2016, Late *Kharif* 2016 and *Rabi* 2016, respectively. None of the cross showed consistent performance across the environments for the different characters under investigation, which suggested effect of environmental variation.

On pooled basis the top hybrids exhibiting highest per cent heterosis over the better parent and standard check for differenent characters were AOL 9-2 x Phule Utkarsha for days to 50 % flowering (-3.76, -14.39), for days to first picking (-3.67, -13.04) and number of primary branches per plant (27.44, 16.10). The crosses, AOL 12-59 x Kashi Pragati (3.39, 6.78) for days to last picking, DHOK-153 x GAO -5 (27.58, 21.28) for plant height, AOL 12-52 xGO-2 (-13.86, -24.49) for internode length, DHOK -153 x Kashi Kranti for number of fruits per plant (28.70, 13.20) and green fruit yield per plant (41.64, 27.84), GP OK-45 x GJO 3 (9.93, 26.35) for fruit length, AOL 12-59 x Kashi Pragati (15.92, 10.80) for fruit girth, AOL 12-59 x GAO 5 (7.64, 6.49) for fruit weight, AOL 12-52 x GAO 5 (13.18, 37.01) for total chlorophyll content, GP OK 45 x GO-2 (16.05, 13.80) for mucilage content, AOL12-52 x Phule Utkarsha (17.46, 6.59) for total carbohydrate

Table-3 : Per se performance of heterotic crosses for green fruit yield per plant (g) and singnificant heterosis for other yield contributing characters on the pooled basis.

Promising Crosses	Per se performance Green fruit yield per plant (g)				Heterosis for green fruit yield over		Cross Significant heterosis for other yield contributing characters	
	E_1	E_2	E_3	Pooled	BP	SH	BP	SH
DHOK-153 x Kashi Kranti	370.67	241.27	151.61	254.52	41.64**	27.84**	GFYPP, PBPP, NFPP, FW	GFYPP, INL, NFPP, PBPP, FW, CHLO, MUSC
JF 108-2 x Kashi Kranti	355.33	215.28	142.02	237.54	32.19**	19.31**	GFYPP, PLHT, PBPP, NFPP, FL	GFYPP, DPF, DFP, PBPP, NFPP, FL
DHOK-153 x GJO 3	316.33	246.48	134.23	232.35	40.30**	16.70**	GFYPP, PLHT, PBPP, NFPP, FW, CFIB	GFYPP,DLP, PBPP, INL, CFIB
DHOK-153 x Kashi Pragati	305.67	232.71	140.21	226.20	25.75**	13.61**	GFYPP,NFPP, FG, FW, CFIB	GFYPP,INL, FG, CHLO, CFIB
JF 108-2 x GAO 5	329.33	196.82	140.91	222.35	38.59**	11.68**	GFYPP, PLHT, PBPP, NFPP, FL, FG, FW, CFIB	GFYPP, PLHT, FL, FG, FW, CFIB
AOL 9-2 x Phule Utkarsha	339.67	209.14	117.22	222.01	22.92**	11.51**	GFYPP, DPF, DFP, PLHT, PBPP, NFPP, FW	GFYPP, DPF, DFP, PBPP, INL,
GJOH 3 (SC)	286.33	183.80	127.15	199.09	—	—	—	—

Note : DPF = ... ; DLP = ... ;

1.	GFYPP	:	Green fruit yield per plant (g)	7.	INL	:	Internode length (cm)	13.	CHLO	:	Total chlorophyll content (mg/g)
2.	DPF	:	Days to 50% flowering	8.	FL	:	Fruit length (cm)	14.	MUSC	:	Mucilage content (g/100g)
3.	DFP	:	Days to first picking	9.	FG	:	Fruit girth (cm)	15.	CARB	:	Total carbohydrate content (%)
4.	DLP	:	Days to last picking	10.	NFPP	:	Number of fruits per plant	16.	C FIB	:	Crude fiber content (%)
5.	PLHT	:	Plant height (cm)	11.	FW	:	Fruit weight (cm)	17.	ASH	:	Ash content (%)
6.	PBPP	:	Primary branches per plant	12	MOIS	:	Moisture content (%)				

content DHOK-153 x GJO-3 (-29.77, -29.80) for crude fiber content (%) and KS 404 x GAO 5 (7.12, 6.37) for ash content.

In pooled analysis, for green fruit yield per plant total 30 and 06 hybrids exhibited significant and positive heterobeltiosis and standard heterosis, respectively. Among those, the crosses DHOK-153 x Kashi Kranti (41.64%), DHOK-153 x GJO 3 (40.30%), JF 108-2 x GAO 5 (38.59%), AOL 12-59 x GAO 5 (36.64%), GP OK-45 x Arka Anamika (33.73%), JF 108-2 x Kashi Vibhuti (32.60%), JF 108-2 x Kashi Kranti (32.19%), KS 404 x GAO 5 (28.71%), DHOK-153 x Kashi Pragati (25.75%) and AOL 9-2 x Phule Utkarsha (22.92%) exhibited higher magnitude of heterobeltiosis. Whereas, for standard heterosis, the hybrids DHOK-153 x Kashi Kranti (27.84 %), JF 108-2 x Kashi Kranti (19.31%), DHOK-153 x GJO 3 (16.70%) DHOK-153 x Kashi Pragati (13.61%), JF 108-2 x GAO 5 (11.68%) and AOL 9-2 x Phule Utkarsha (11.51%) depicted high heterotic effects in pooled over the environments.

A perusal of *per se* performance and heterotic effects of promising 06 hybrids based on standard heterosis were presented in Table-3. The hybrid DHOK-153 x Kashi Kranti ranked first followed by JF 108-2 x Kashi Kranti, DHOK-153 x GJO- 3, DHOK-153 x Kashi Pragati, AOL 9-2 x Phule Utkarsha and JF 108-2 x GAO for all the approaches, and found promising for commercial exploitation after its critical evaluation. These hybrids also exhibit heterotic effects in desired direction for major yield contributing characters viz; number of primary branches per plant, number of fruits per plant, fruit weight, fruit length, fruit girth and internode length, across the environments as well as pooled over the environments. The heterotic effects for green fruit yield was because of direct and indirect effects of various yield contributing characters. The score of per cent disease incidence (PDI) for yellow vein mosaic virus for these hybrids was zero i.e. no incidence reaction for YVMV.

As regards the quality parameters the estimates of heterosis for total chlorophyll content and crude fiber

content were moderate to high in desired direction. For muscilage content, carbohydrate content and ash content there was no significant difference among the parents and hybrids, hence the estimates of heterobeltiosis and standard heterosis were lowest in desired direction.

However, appreciable amount of heterobeltiosis and standard heterosis in desirable direction for yield and yield contributing characters was also reported by (3, 4, 5, 6).

The adaptation of recurrent selection by inter mating of the most desirable segregants followed by selection is suggested for development of open pollinated varieties in okra to utilize the additive and non additive genetic variances observed in the inheritance of the various traits. Multiple crosses and biparental mating might also prove to be effective alternative approaches. However, heterosis breeding programme is suggested for the improvement of fruit yield and majority of the traits, since non additive variance was observed to be predominant.

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