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Heterosis for fruit yield and its component traits in brinjal *(Solanum melongena* L.)

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Abstract
A study was conducted to estimate the magnitude of heterosis for fruit yield and its components in brinjal. Forty five F_1 hybrids (generated by line x tester mating design using diverse five lines and nine testers) along with 14 parents and one standard check were evaluated in a randomized block design with two replication at Main Vegetable Research Station Farm, Anand Agricultural University, Anand, Gujarat (India). Appreciable heterosis was found over better and standard parent for all the traits studied in desirable direction. In order of merit, the highest heterobeltiosis was recorded by cross ABSR 2 x GP BRJ-31 (52.52 %) followed by GOB 1 x AB 08-14 (45.31 %) and GOB 1 x GP BRJ-204 (37.78 %), while cross GOB 1 x AB 08-14 ranked first by recording the highest standard heterosis (88.88 %) for fruit yield per plant followed by followed by GOB 1 x GP BRJ-204 (71.42 %) and ABSR 2 x AB 08-14 (70.23 %). The cross GOB 1 x AB 08-14 also recorded significant standard heterosis for fruit girth, fruit weight and total soluble solids. The present study revealed good scope for isolation of pure lines from the progenies of heterotic F_1 hybrids as well as commercial exploitation of heterosis breeding in brinjal.

Keywords: Brinjal, fruit yield, heterobeltiosis, standard heterosis

Introduction
Eggplant (*Solanum melongena* L.), also known as brinjal, is a commercially and nutritionally important solanaceous vegetable crop of India grown extensively throughout the year in all parts of India except at higher altitude. It is widely cultivated in both subtropical and tropical regions of the globe mainly for its immature fruits as vegetables. It is popular among people of all social strata and hence, it is apply referred as "vegetable of masses" (Patel and Sarnaik, 2003) [1]. India is regarded as the primary centre of origin/diversity of brinjal (Genebus, 1963) [2]. Recently, the exploitation of hybrid vigour in vegetable crops considered to be one of the outstanding achievements in vegetable breeding. To know the potentiality of hybrid in particular crop, the magnitude and direction of heterosis is of paramount important. Heterosis response largely depends upon genetic divergence among the parents involved in particular study. In India, wide genetic variability was reported by several workers in vegetables. For the first time, Bailey and Munson (1891) [3] reported artificial hybridization in brinjal. However, none of the hybrids exhibited any heterosis. To obtain high yield per unit area, exploitation of hybrid vigour is one of the good way and particularly in crop like brinjal, where more seeds per fruit are obtained. Therefore, in the present study, an attempt has been made to gather information on the extent of heterosis in L x T crosses to produce promising hybrids/pure lines in brinjal.

Materials and Methods
Five diverse brinjal lines viz., ABSR 2, GOB 1, JBGR 1 KS 224 and GJB 3 and nine testers viz., AB 08-14, GP BRJ-204, AB 15-17, AB 15-22, CHBR 1, GP BRJ-8, GP BRJ-9, GP BRJ-31 and NSR 1 were chosen on the basis of their phenotypic performance and their diverse variation in fruit yield and its contributing traits, and were crossed in a line x tester mating design. The parents along with their F_1 hybrids and one standard check, (GABH 3) were grown in a randomized block design with two replications during Kharif 2016 at Main Vegetable Research Station Farm, Anand Agricultural University, Anand. Each plot consisted of eight plants in a row at 90 x 60 cm inter and intra row spacing. All the recommended package of practices was adopted for raising a successful and healthy crop. The observations were recorded on five randomly selected plants per treatment per replication for 12 characters viz., plant height, number of branches per plant, number of fruits per plant, fruit length, fruit girth, fruit weight, fruit yield per plant, total phenol, ascorbic acid, total soluble sugars, total anthocyanin, total soluble solid except for days to 50 per cent flowering and days to first picking. The observations of both these characters were recorded on plot basis.

Line x tester analysis was carried out by the method suggested by Kempthorne (1957) [4]. Heterosis was worked out over better parent and standard check as per standard procedure.

Results and Discussion

The analysis of variance showed highly significant differences among the genotypes for all the traits suggesting the presence of wide genetic variability in the material used. The differences among parents and hybrids were also found highly significant for all characters suggesting that parents as well as hybrids differed themselves for all the characters. The mean square due to parents vs hybrids contrast was also found highly significant for all the traits except days to first picking and total phenol indicating presence of mean heterosis for these characters (Table 1).

Wide range of variability exists among parents and their F_1 hybrids for different traits under study. Out of the 45 hybrids, the significant desirable heterotic effects over their respective better parent and standard check were noticed in 10 and nine crosses for days to 50 % flowering; eight and 18 crosses for plant height; seven and nine crosses for number of branches per plant; three and seven crosses for number of fruits per plant; three and one crosses for fruit length; 10 and 42 crosses for fruit girth; 14 and 37 for fruit weight; nine and 16 crosses for fruit yield per plant; 13 and five for days to first picking; nine and 17 for total phenol; 14 and 23 for ascorbic acid; 18 and 28 for total soluble sugar; 12 and nine for total anthocynin and 23 and 34 crosses, respectively for total soluble solids (Table 2). The heterobeltiosis and standard heterosis ranged from -40.51 to 52.52 per cent and -39.37 to 88.88 per cent for fruit yield per plant, respectively.

Top three hybrids for different traits with respect to heterosis over better parent and standard check (GABH 3) are presented in Table 3. The highest heterobeltiosis was recorded by cross ABSR 2 x GP BRJ-31 (52.52 %) followed by GOB 1 x AB 08-14 (45.31 %) and GOB 1 x GP BRJ-204 (37.78 %), while cross GOB 1 x AB 08-14 ranked first by recording the highest standard heterosis (88.88 %) for fruit yield per plant followed by followed by GOB 1 x GP BRJ-204 (71.42 %) and ABSR 2 x AB 08-14 (70.23 %). The cross GOB 1 x AB 08-14 also recorded significant standard heterosis for fruit girth, fruit weight and total soluble solids. These results showed that the heterosis for fruit yield per plant was associated with heterosis for its component characters. The findings were in concordance to the reports of Shafeeq *et al*. (2007) [5], Sharma (2010) [6], Kumar *et al*. (2012) [7], Pachiyappan *et al*. (2012) [8] and Vaddoria *et al*. (2015) [9] for heterobeltiosis. Whereas present findings of standard heterosis were in accordance with findings of Shafeeq *et al*. (2007) and partially accordance with findings of Sharma (2010), Dharwad *et al*. (2011) [10] and Vaddoria *et al*. (2015).

The hybrids exhibited desirable heterobeltiosis and economic heterosis for fruit yield per plant and other characters could be further evaluated to exploit the heterosis or utilized in future breeding programme to obtain desirable segregants for the development of superior genotypes.

Table 1: Analysis of variance for yield and its components (Mean sum of squares)

Source	Degree of freedom	DF	PH	NBP	NFP	FL	FG	FW
Replication	1	4.03	2.56	5.86	112.69	3.33	0.03	27.37
Genotypes	59	95.14**	199.67**	28.43**	2094.14**	5.77**	75.21**	2624.66**
Parents	13	115.30**	167.97**	19.45**	1889.10**	5.22**	61.82**	2647.18**
Females	4	81.15**	175.68**	13.98**	2108.85**	9.07**	45.56**	3349.58**
Males	8	102.51**	184.40**	24.23**	1993.65**	3.31**	77.60**	2567.85**
Females vs Males	1	354.14**	5.66	3.09	173.66*	5.17*	0.63	472.15**
Hybrids	44	92.38**	202.04**	31.84**	2217.45**	5.66**	74.88**	2517.00**
Parents vs Hybrids	1	42.89**	682.10**	22.57**	793.42**	21.10**	139.69**	6653.75**
Check vs Hybrids	1	4.32*	46.39	1.66	644.02**	1.81	222.55**	3702.58**
Error	59	8.52	17.09	3.05	43.26	1.06	3.66	58.92

*, ** significant at 5% and 1 % levels of probability, respectively.

FYP	=	Fruit yield per plant (kg)	Tss	=	Total soluble sugar (%)
DP	=	Days to first picking	TA	=	Total anthocyanin (mg/100g)
TP	=	Total phenol (mg/100g)	TSS	=	Total soluble solid (ºBrix)
AA	=	Ascorbic acid (mg/100g)			

Table 1: Contd.

Source	Degree of freedom	FYP	DP	TP	AA	Tss	TA	TSS
Replication	1	0.31	75.25	10.63	0.03	0.01	3.22	0.12
Genotypes	59	6.47**	108.71**	833.39**	5.45**	0.75**	3381.74**	1.04**
Parents	13	2.53**	103.75**	890.44**	4.45**	0.61**	3482.01**	0.24**
Females	4	2.11**	113.25**	1085.95**	4.32**	0.58**	6875.70**	0.27**
Males	8	2.39**	84.63**	765.61**	3.66**	0.59**	2067.55**	0.20**
Females vs Males	1	5.31**	218.75**	1106.98**	11.28**	0.91**	1222.99**	0.43**
Hybrids	44	7.34**	114.15**	851.69**	5.92**	0.75**	3341.29**	1.24**
Parents vs Hybrids	1	5.01**	41.50	21.46	0.82*	2.97**	7239.76**	2.64**
Check vs Hybrids	1	1.42	0.27	91.37**	2.33**	0.30**	987.68**	1.73**
Error	59	0.43	21.73	5.51	0.14	0.02	2.51	0.04

*, ** significant at 5% and 1 % levels of probability, respectively.

FYP	=	Fruit yield per plant (kg)	Tss	=	Total soluble sugar (%)
DP	=	Days to first picking	TA	=	Total anthocyanin (mg/100g)
TP	=	Total phenol (mg/100g)	TSS	=	Total soluble solid (ºBrix)
AA	=	Ascorbic acid (mg/100g)			

Table 2: Magnitude of heterobeltiosis (H1) and standard heterosis (H2) for various characters in brinjal

Sr No.	Characters	Desirable Aspect	Number of Crosses with Significant Heterosis					
			Heterobeltiosis H1 (%)	Standard Heterosis H2 (%)	H_1		H_2	
					+Ve	-Ve	+Ve	-Ve
1	DF	Early	-18.55 to 43.02	-14.29 to 39.05	15	10	8	8
2	PH	High	-16.55 to 24.82	-32.25 to 38.43	16	8	8	3
3	NBP	More	-36.84 to 56.05	-27.04 to 38.35	7	27	9	16
4	NFP	More	-54.08 to 24.86	-57.05 to 69.36	3	30	7	30
5	FL	High	-23.74 to 37.26	-35.42 to 19.55	3	3	1	9
6	FG	High	-39.11 to 44.07	-1.82 to 210.63	10	10	42	0
7	FW	High	-39.79 to 77.57	-33.19 to 195.04	14	19	37	2
8	FYP	High	-40.51 to 52.52	-39.37 to 88.88	9	13	16	6
9	DP	Early	-22.83 to 8.60	-12.30 to 21.39	0	13	6	5
10	TP	Low	-27.42 to 78.86	-31.26 to 61.98	24	9	18	17
11	AA	High	-36.92 to 40.37	-17.20 to 44.96	14	26	23	9
12	Tss	High	-44.17 to 112.30	-38.68 to 59.28	18	15	28	6
13	TA	High	-99.32 to 182.14	-99.79 to 108.96	12	22	9	33
14	TSS	High	-34.59 to 32.29	-18.40 to 47.63	23	10	34	3

DF	=	Days to 50 per cent flowering	FYP	=	Fruit yield per plant (kg)
PH	=	Plant height (cm)	DP	=	Days to first picking
NBP	=	Number of branches per plant	TP	=	Total phenol (mg/100g)
NFP	=	Number of fruits per plant	AA	=	Ascorbic acid (mg/100g)
FL	=	Fruit length (cm)	Tss	=	Total soluble sugar (%)
FG	=	Fruit girth (cm)	TA	=	Total anthocyanin (mg/100g)
FW	=	Fruit weight (g)	TSS	=	Total Soluble Solid (ºBrix)

Table 3: Top three hybrids selected separately on the basis of heterosis over better parent and standard hybrid GABH-3.

Characters	Rank	Most Heterotic Crosses Over			
		Better Parent	Value	Standard Parent	Value
Days to 50 per cent flowering	I	KS 224 x GP BRJ-8	-18.55**	GOB 1 x GP BRJ-8	-14.29**
	II	GOB 1 x GP BRJ-8	-17.43**	KS 224 x GP BRJ-31	-14.29**
	III	ABSR 2 x AB 15-17	-16.36**	GJB 3 x NSR 1	-14.29**
Plant height (cm)	I	GOB 1 x CHBR 1	24.82**	GOB 1 x CHBR 1	38.43**
	II	GOB 1 x AB 08-14	22.16**	GOB 1 x AB 08-14	30.26**
	III	JBGR 1 x GP BRJ-8	19.10**	KS 224 x NSR 1	29.53**
Number of branches per plant	I	GOB 1 x GP BRJ-204	56.05**	GOB 1 x GP BRJ-8	38.35**
	II	GOB 1 x CHBR 1	34.53**	GOB 1 x GP BRJ-204	24.84**
	III	GOB 1 x NSR 1	31.92**	GOB 1 x GP BRJ-31	24.43**
Number of fruits per plant	I	ABSR 2 x GP BRJ-31	24.86**	ABSR 2 x GP BRJ-31	69.36**
	II	GOB 1 x GP BRJ-204	23.24**	ABSR 2 x GP BRJ-8	61.06**
	III	ABSR 2 x GP BRJ-8	18.75**	ABSR 2 x AB 15-22	46.38**
Fruit length (cm)	I	KS 224 x AB 08-14	37.26**	JBGR 1 x NSR 1	19.55*
	II	GOB 1 x AB 15-22	25.40**	JBGR 1 x GP BRJ-9	15.55
	III	KS 224 x AB 15-22	22.78**	JBGR 1 x AB 08-14	15.32
Fruit girth (cm)	I	JBGR 1 x GP BRJ-204	44.07	JBGR 1 x GP BRJ-204	210.63**
	II	KS 224 x AB 08-14	31.91	JBGR 1 x CHBR-1	196.3**
	III	KS 224 x GP BRJ-9	28.64	KS 224 x CHBR-1	177.69**
Fruit weight (g)	I	KS 224 x GP BRJ-204	77.57	GJB 3 x CHBR-1	195.04**
	II	GOB 1 x AB 15-22	74.38	JBGR 1 x AB 08-14	185.71**
	III	GOB 1 x NSR 1	60.14	GJB 3 x AB 08-14	176.24**

Table 3: Contd.

Characters	Rank	Most Heterotic Crosses Over			
		Better Parent	Value	Standard Parent	Value
Fruit yield per plant (kg)	I	ABSR 2 x GP BRJ-31	52.52**	GOB 1 x AB 08-14	88.88**
	II	GOB 1 x AB 08-14	45.31**	GOB 1 x GP BRJ-204	71.42**
	III	GOB 1 x GP BRJ-204	37.78**	ABSR 2 x AB 08-14	70.23**
Days to first picking	I	GJB 1 x NSR 1	-22.83**	ABSR 2 x AB 15-22	-12.30**
	II	KS 224 x GP BRJ-31	-19.42**	KS 224 x GP BRJ-31	-11.23**
	III	ABSR 2 x AB 15-17	-19.14**	ABSR 2 x AB 08-14	-10.70**
Total phenol (mg/100g)	I	ABSR 2 x GP BRJ-31	-27.42**	GJB 3 x GP BRJ-204	-31.26**
	II	ABSR 2 x GP BRJ-9	-27.02**	KS 224 x AB 15-22	-15.51**
	III	GJB 3 x GP BRJ-204	-19.33**	KS 224 x AB 08-14	-14.66**
Ascorbic acid (mg/100g)	I	ABSR 2 x GP BRJ-9	40.37**	GOB 1 x GP BRJ-204	44.96**
	II	ABSR 2 x GP BRJ-31	24.44**	GOB 1 x NSR 1	41.73**
	III	KS 224 x CHBR 1	24.00**	ABSR 2 x GP BRJ-9	40.95**
Total soluble sugar (%)	I	GOB 1 x AB 15-17	112.30**	ABSR 2 x AB 15-17	59.28**
	II	GOB 1 x NSR 1	56.74**	GOB 1 x CHBR-1	52.48**
	III	GOB 1 x GP BRJ-204	49.78**	GOB 1 x NSR 1	51.27**
Total anthocyanin (mg/100g)	I	GJB 3 x GP BRJ-9	182.14	GOB 1 x AB 15-22	108.96**
	II	GJB 3 x GP BRJ-8	95.24	GOB 1 x CHBR-1	61.50**
	III	JBGR 1 x GP BRJ-8	68.92	GOB 1 x GP BRJ-8	50.41**
Total Soluble Solid (ºBrix)	I	GJB 3 x GP BRJ-31	32.29**	GJB 3 x GP BRJ-31	47.63**
	II	JBGR 1 x GP BRJ-31	27.11**	JBGR 1 x NSR 1	47.13**
	III	ABSR 2 x GP BRJ-31	27.00**	KS 224 x NSR 1	47.13**

*, ** significant at 5% and 1 % levels of probability, respectively.

Conclusion

On the basis of above results and discussion, it can be concluded that highest heterobeltiosis was recorded by cross ABSR 2 x GP BRJ-31 followed by GOB 1 x AB 08-14 and GOB 1 x GP BRJ-204, while cross GOB 1 x AB 08-14 ranked first by recording the highest standard heterosis (88.88 %) for fruit yield per plant followed by followed by GOB 1 x GP BRJ-204 (71.42 %) and ABSR 2 x AB 08-14 (70.23 %). The study revealed good scope for isolation of pure lines from the progenies of heterotic F_1 hybrids as well as commercial exploitation of heterosis breeding in brinjal.

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