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Estimation of heterobeltiosis and standard heterosis for fruit yield and its attributes in brinjal (*Solanum melongena* L.)

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Abstract
A diallel analysis was designed aiming towards the identification of best heterotic crosses for fruit yield and its component traits in brinjal (*Solanum melongena* L.). The present study was conducted at Vegetable Research Station, Junagadh Agricultural University, Junagadh during late *kharif* 2016-17 (crossing programme) and late *Kharif* 2017-18 (evaluation programme) in a randomized block design with three replications. Thirty six crosses crosses obtained by crossing 9 x 9 half diallel were evaluated for 6 biometric traits with their parents and check (GJBH-4). The analysis of variance revealed highly significant mean square differences due to genotypes for all the characters indicating that experimental material had sufficient genetic variability for all the characters under investigation. The genotypic variance was further partitioned into variance due to parents, hybrids and parents *Vs* hybrids. The mean square due to parents as well as hybrids was also highly significant for all the characters studied except mean square due to hybrids for average fruit weight suggesting the presence of considerable amount of genetic variability among the parents and the material which was most useful for the study of manifestation of heterosis and genetic parameters involved in the inheritance of different traits studied. Based on study of heterobeltiosis, it was found that number of primary braches per plant, average fruit weight, fruit length and number of fruit per plant were main contributors towards increase in heterotic effects for total fruit yield per plant. Five crosses *viz.*, JBL-10-08-07 x Pant Rituraj, GJB-2 x JBR-15-01, GJB-2 x JBR-15-08, GJLB-4 x JBR-15-08 and JBR-15-08 x JBL-10-08-07 were best heterotic crosses over standard check for fruit yield per plant. These cross combination may utilize for further improvement to develop high yielding genotypes after due testing.

Keywords: Brinjal, diallel, *Solanum melongena*, heterobeltiosis, standard heterosis, fruit yield per plant

Introduction
Brinjal is an annual herbaceous plant with erect or semi-spreading growth habit belonging to Solanaceae family. It is self-compatible and highly self-pollinating crop but in hot & humid climate cross pollination from surrounding plants may occur up to 20% by insects or wind (Grubben, 1977). It has 2n=24 somatic chromosome number.

It is the fourth most important vegetable crop in India and contributes about 8.3 per cent of the total production of vegetables in the country. It is named as “Poor man’s vegetable” because of its low cost of production, ease of culture and availability throughout the year. As fruits are widely used in various culinary preparations *viz*., sliced bhaji, stuffed curry, bertha, chutney, pickles etc., Contrary to the common belief, it is quite high in nutritive value being rich in vitamins and minerals (calcium, magnesium, phosphorus) and fatty acids.

In India total area and production under brinjal is 7.29 lakh ha and 12.61 million tonnes respectively with an average productivity of 18868 kg/ha (Anon., 2017). The area under brinjal in Gujarat is 74.06 thousand ha and production is 14.71 lakh tones with an average productivity of 19848 kg/ha (Anon., 2017). West Bengal is leading in area and production followed by Odisha, Andhra Pradesh & Gujarat with 17478 kg/ha of productivity, Uttar Pradesh has the highest productivity followed by Karnataka and Himachal Pradesh.

Looking to the increasing population of our nation there is an urgent need to satisfy the demand. The incidence of hunger (malnutrition) and poverty in the country is stubbornly high and India is way off the Millennium developmental goal. Moreover, the country is expected to attain the dubious distinction of being the most populous country in the world by 2020’s and its population may stabilize at 1.5 to 1.7 billion by the year 2050- 2070. There are specific genotypes suited for specific preparations apart from the large genetic variation observed with regard to colour, size and shape of fruits. In addition, variation is also noticed for characters like vegetative growth, maturity and presence or absence of spines on leaves, stem and fruit calyx among the indigenous material.

To have such kind of plant profile, we have some different breeding methods. One of such method is exploitation of hybrid vigour through hybridization.

Exploiting hybrid vigour in a single cross hybrid depends on the two parents complementing each other with special reference to desirable characters. However, it is often noticed that all the desirable characters need not to be distributed between only these two parents. Therefore, it might be necessary to involve multiple cross combinations of parents to have wider genetic content and thus broaden the genetic base. Therefore, the exploitation of hybrid vigour in brinjal has been recognized as a practical tool in providing the breeder a means of increasing yield and other economic characters. Most of the local varieties which are grown by farmers in India have not been fully utilized in any genetic improvement programme on scientific line. The development of an effective heterosis breeding programme in brinjal needs to elucidate the genetic nature and magnitude of quantitatively inherited traits and judge the potentiality of parents in hybrid combinations.

The intent of present study is to exploit the heterosis for fruit yield and component traits by using half diallel mating design in brinjal for meet the future challenges.

Materials and methods

The experimental materials comprised of nine promising genotypes of Brinjal (*Solanum melongena L.*). *viz.*, GJB-2, GJLB-4, GOB-1, JBR-15-01, JBW-15-06, JBR-15-08, JBR-15-11, JBL-10-08-07 and Pant rituraj. Which was were used in diallel mating design to prepare thirty six hybrids at Vegetable Research Station, Junagadh Agricultural University, Junagadh during late *kharif* 2016-17 (crossing programme). Thus the experimental material consisted of 46 entries, comprising of nine genotypes, their thirty six hybrids and one check *viz.* GJBH-4. This was evaluated for heterosis analysis in late *Kharif* 2017-18 at same place with single row length of 6 meter, consisting 10 plants in each row with 60 centimeter intra row spacing and 90 centimeter inter row spacing. All the agronomic and plant protection practices were uniformly applied throughout the crop growth period to raise a good crop.

Five competitive plants from each entry excluding border plants were randomly selected to record the observations on fruit length, average fruit weight, fruit girth, number of fruit per plant, number of primary branches and total fruit yield per plant. Analysis of variance technique suggested by [9] was followed to test the difference between genotypes for all the characters under study. Heterosis was estimated in terms of two parameters, *i.e.* heterobeltiosis [3] and standard heterosis [6].

Result and Discussion

The character-wise data of parents and hybrids were subjected to analysis of variance for the experimental design. Analysis of variance for different characters is presented in Table 1. Perusal of data revealed highly significant mean square differences due to genotypes for all the characters indicating that experimental material had sufficient genetic variability for all the characters under investigation. The genotypic variance was further partitioned into variance due to parents, hybrids and parents *Vs* hybrids. The mean square due to parents as well as hybrids was also highly significant for all the characters studied except mean square due to hybrids for average fruit weight.

Mean square due to parents *Vs* hybrids were highly significant for all the traits, indicating that the performance of hybrids as a group was different than that of parents for most of the characters. This revealed the presence of considerable heterosis due to directional dominance. The estimates of heterobeltiosis (HB) was ranged -47.33 (JBR-15-11 x Pant Rituraj) to 33.56 per cent (GOB-1 x JBL-10-08-07) for fruit length, -40.69 (JBR-15-08 x JBL-10-08-07) to 24.51 per cent (GJLB-4 x Pant Rituraj) for average fruit weight, -50.01 (JBR-15-08 x JBL-10-08-07) to 34.34 per cent (JBR-15-08 x JBR-15-11) for fruit girth, -54.56 (JBR-15-11 x Pant Rituraj) to 98.01 per cent (GJLB-4 x JBR-15-08) for number of fruit per plant, -46.97 (JBR-15-11 x Pant Rituraj) to 64.52 per cent (JBR-15-01 x JBL-10-08-07) for number of primary branches per plant and -42.91(JBR-15-11 x Pant Rituraj) to 86.21 per cent(GJLB-4 x JBR-15-08 for total fruit yield per plant (Table 2,3,4 and 5). Several hybrids exhibited significant and desirable (positive) heterobeltiosis in desirable direction for studied characters *i.e.* fruit length (6), fruit girth (4), number of fruit per plant (11), number of primary branches (9) and for total fruit yield per plant (7). While, none of the hybrids registered significant and positive heterobeltiosis for average fruit weight, The heterotic response over better parent was also reported by [2-15].

Improvement in fruit yield in brinjal is one of most important breeding objective of plant breeder. So the superiority of hybrids over best cultivated hybrid is essential for increasing its commercial value. The estimates of standard heterosis (SH) was ranged from -18.88 (JBR-15-11 x Pant Rituraj) to 39.15 per cent (JBL-10-08-07 x Pant Rituraj) for fruit length, -21.49 (JBR-15-08 x Pant Rituraj) to 28.53 per cent (GJLB-4 x Pant Rituraj) for average fruit weight, -7.75 per cent (JBR-15-08 x JBL-10-08-07) to 72.09 per cent (JBR-15-01 x JBR-15-08) for fruit girth, -43.45 (JBW-15-06 x JBL-10-08-07) to 71.05 per cent (GJB-2 x JBR-15-08) for number of fruit per plant, -53.13 (JBW-15-06 x JBR-15-11) to 18.75 per cent **(**GJB-2 x GOB-1) for number of primary branches per plant and -36.74 (JBW-15-06 x JBL-10-08-07) to 60.85 per cent (JBL-10-08-07 x Pant Rituraj) for total fruit yield per plant. Out of 36 hybrids, several hybrids exhibited significant and desirable (positive) heterobeltiosis in desirable direction for studied characters *i.e.* fruit length (25), fruit girth (36), number of fruit per plant (10), number of primary branches (1), and for total fruit yield per plant (7). While, none of the hybrids registered significant and positive heterobeltiosis for average fruit weight. As observed in present investigation, several workers [2-15] had also reported considerable degree of standard heterosis for fruit yield per plant and its component traits.

Conclusion

On the basis of heterosis analysis, five hybrids depicted significant and desirable (positive) heterosis over check (GJBH-4) for total fruit yield per plant *viz.*, JBL-10-08-07 x Pant Rituraj (60.85%), GJB-2 x JBR-15-01 (57.74%), GJB-2 x JBR-15-08 (52.21%), GJLB-4 x JBR-15-08 (52.21%) and JBR-15-08 x JBL-10-08-07 (37.96%). These hybrids also depicted significant and desirable (positive) heterosis over their respective better parent. The high heterotic response of these hybrids was resulted due to positive heterosis of yield attributing character number of fruit per plant and average fruit. The heterotic effect for total fruit yield per plant can be considered as outcome of direct effect of this attributes and indirect effects of the other yield contributing characters like, fruit length, fruit girth and number of primary branches.

Therefore, heterotic effects for total fruit yield per plant could be a result of combinational heterosis. Therefore, these five crosses could be exploited for heterosis breeding programme to boost the fruit yield in brinjal after due testing.

Table 1: Analysis of variance (mean squares) for various characters in brinjal

Source of Variation	d. f.	FL	AFW	FG	TNFP	TNPB	TFYP
Replications	2	0.01	301.23	0.08	13.60	0.37**	127299.00
Treatment	44	22.87**	758.28**	27.25**	100.85**	1.63**	829440.10**
Parents	8	52.77**	1462.03**	55.14**	107.76**	2.79**	995440.60**
Hybrids	35	16.47**	509.16	20.82**	96.52**	1.37**	805338.10**
Parent Vs Hybrid	1	07.45**	3847.36**	29.21**	197.24**	1.49**	345007.30*
Error	88	0.04	379.00	0.13	6.09	0.03	70340.68

*, ** significant at 5 per cent and 1 per cent levels of probability, respectively

FL = Fruit length (cm)	TNFP = Total number of fruit per plant
AFW = Average fruit weight (gm)	TNPB = Total number of primary branches per plant
FG = Fruit girth (cm)	TFYP = Total fruit yield per plant (gm)

Table 2: The estimates of heterosis over BP and SC for different character in brinjal

Sr. no.	Crosses	Fruit length (gm)			Average fruit weight (gm)			Fruit girth (cm)		
		H (%)		SH (%)	H (%)		SH (%)	H (%)		SH (%)
1	GJB-2 x GJLB-4	-0.66		6.05	-15.40		2.16	-21.99	**	24.46**
2	GJB-2 x GOB-1	-2.26		-7.02	-21.89		-5.68	-14.13	**	36.99**
3	GJB-2 x JBR-15-01	-24.08	**	21.39	-18.84		3.09	-2.83	*	55.03**
4	GJB-2 x JBW-15-06	-1.92		-5.22	-10.64		13.17	0.62		62.06**
5	GJB-2 x JBR-15-08	-19.62	**	18.29	-25.83	*	-10.44	-24.39	**	20.62**
6	GJB-2 x JBR-15-11	-17.53	**	25.41	-27.44	*	-12.38	-18.36	**	30.24**
7	GJB-2 x JBL-10-08-07	-19.05	**	23.00	-30.72	**	15.49	-28.05	**	55.08**
8	GJB-2 x Pant Rituraj	-3.72	**	-8.41	-8.17		10.88	-4.06	**	54.59**
9	GJLB-4 x GOB-1	-10.38	**	-1.63	-15.87		-3.02	-14.16	**	33.73**
10	GJLB-4 x JBR-15-01	2.84	*	12.88	-29.28	*	-10.17	2.95		42.08**
11	GJLB-4 x JBW-15-06	3.44	**	13.54	-19.42		2.05	-20.70	**	27.72**
12	GJLB-4 x JBR-15-08	-12.45	**	28.85	-8.07		-5.10	-16.42	**	10.15**
13	GJLB-4 x JBR-15-11	-36.71	**	-3.88	-28.89	*	-21.41	-17.61	**	08.58**
14	GJLB-4 x JBL-10-08-07	-5.33	**	3.90	-25.85	**	23.62	-25.72	**	60.09**
15	GJLB-4 x Pant Rituraj	-11.00	**	-2.32	24.51		28.53	0.43		61.83**
16	GOB-1 x JBR-15-01	-16.80	**	13.85	-12.91		10.63	-10.12	**	37.16**
17	GOB-1 x JBW-15-06	6.64	**	3.05	-1.73		24.46	2.94	*	65.80**
18	GOB-1 x JBR-15-08	-14.22	**	26.24	-23.62		-12.24	-17.06	**	26.57**
19	GOB-1 x JBR-15-11	-44.41	**	15.46	-0.95		13.82	3.50	*	57.94**
20	GOB-1 x JBL-10-08-07	33.56	**	3.85	-39.81	**	0.34	-41.38	**	26.36**
21	GOB-1 x Pant Rituraj	13.97	**	16.61	1.62		16.77	-11.61	**	42.43**
22	JBR-15-01 x JBW-15-06	-18.86	**	16.88	-17.00		5.12	0.96		62.61**
23	JBR-15-01 x JBR-15-08	-46.88	**	21.83	-9.94		14.01	24.05	**	72.09**
24	JBR-15-01 x JBR-15-11	-45.44	**	17.02	-26.88	*	-7.44	-7.23	**	28.69**
25	JBR-15-01 x JBL-10-08-07	-8.60	**	-6.37	-40.52	**	-0.83	-37.71	**	34.27**
26	JBR-15-01 x Pant Rituraj	-18.86	**	16.88	-12.08		11.31	-16.82	**	34.03**
27	JBW-15-06 x JBR-15-08	-7.26	**	36.49	-16.81		5.32	-18.51	**	30.01**
28	JBW-15-06 x JBR-15-11	-36.52	**	-3.46	-14.45		8.30	-6.78	**	48.72**
29	JBW-15-06 x JBL-10-08-07	10.9	**	5.41	-31.71	**	13.85	-31.30	**	48.07**
30	JBW-15-06 x Pant Rituraj	1.56		-3.39	-10.69		13.07	1.45		63.47**
31	JBR-15-08 x JBR-15-11	-30.75	**	5.32	3.39		14.27	34.34	**	62.08**
32	JBR-15-08 x JBL-10-08-07	-15.85	**	23.15	-40.69	**	-1.13	-50.01	**	07.75**
33	JBR-15-08 x Pant Rituraj	-41.1	**	13.90	-19.39		-21.49	-15.80	**	35.68**
34	JBR-15-11 x JBL-10-08-07	-45.68	**	16.54	-29.95	**	16.78	-22.11	**	67.88**
35	JBR-15-11 x Pant Rituraj	-47.33	**	-18.88	13.07		24.42	0.53		61.99**
36	JBL-10-08-07 x Pant Rituraj	-24.39	**	39.15	-35.88	**	6.78	-23.85	**	63.75**
	SE±	0.16		0.16	15.89		15.89	0.29		0.29

Table 3: The estimates of heterosis over BP and SC for different character in brinjal

Sr. no.	Crosses	Number of fruits per plant				Number of primary branches/plant				Total fruit yield per plant(gm)			
		H (%)		SH (%)		H (%)		SH (%)		H (%)		SH (%)	
1	GJB-2 x GJLB-4	7.05		27.53	*	-5.00		-10.94	**	-9.87		27.55	*
2	GJB-2 x GOB-1	11.59		32.94	**	26.67	**	18.75	**	-11.98		24.56	*
3	GJB-2 x JBR-15-01	28.79	**	53.43	**	6.67		0.01		11.46		57.74	**
4	GJB-2 x JBW-15-06	-1.27		17.62		-15.00	**	-20.31	**	-7.54		30.85	**
5	GJB-2 x JBR-15-08	43.58	**	71.05	**	-15.00	**	-20.31	**	7.55		52.21	**
6	GJB-2 x JBR-15-11	17.35		39.80	**	-10.00	*	-15.63	**	-13.58		22.30	
7	GJB-2 x JBL-10-08-07	-35.45	**	-23.10	*	11.67	**	4.69		-38.47	**	-12.92	
8	GJB-2 x Pant Rituraj	-28.69	**	8.92		-22.73	**	-20.31	**	-18.74	*	20.79	
9	GJLB-4 x GOB-1	48.33	**	20.49		-26.42	**	-39.06	**	40.27	**	14.66	
10	GJLB-4 x JBR-15-01	58.51	**	28.75	**	24.44	**	-12.50	**	41.22	**	15.43	
11	GJLB-4 x JBW-15-06	20.67		-1.99		11.11	*	-21.88	**	22.21		-0.11	
12	GJLB-4 x JBR-15-08	98.01	**	65.16	**	10.20	*	-15.63	**	86.21	**	52.21	**
13	GJLB-4 x JBR-15-11	-8.17		5.72		4.44		-26.56	**	-35.20	**	-17.52	
14	GJLB-4 x JBL-10-08-07	-27.11	*	-40.79	**	8.89		-23.44	**	-31.24	**	-28.58	*
15	GJLB-4 x Pant Rituraj	-37.25	**	-4.15		-22.73	**	-20.31	**	-17.94	*	21.97	
16	GOB-1 x JBR-15-01	-10.26		-36.82	**	-3.33		-9.31	*	-14.89		-30.74	**
17	GOB-1 x JBW-15-06	40.92	**	-0.79		-13.33	**	-18.75	**	59.02	**	23.46	
18	GOB-1 x JBR-15-08	43.09	**	19.35		-31.67	**	-35.94	**	28.92	*	4.41	
19	GOB-1 x JBR-15-11	-28.72	**	-17.94		-11.67	**	-17.19	**	-27.13	**	-7.25	
20	GOB-1 x JBL-10-08-07	35.90	*	-4.33		5.00		-1.56		-9.87		-6.39	
21	GOB-1 x Pant Rituraj	-30.73	**	5.81		-36.36	**	-34.38	**	-17.87	*	22.09	
22	JBR-15-01 x JBW-15-06	5.47		-31.46	**	40.91	**	-3.13		-13.99		-30.01	*
23	JBR-15-01 x JBR-15-08	-19.15		-32.56	**	2.04		-21.88	**	-7.12		-24.42	*
24	JBR-15-01 x JBR-15-11	-13.31		-0.20		26.67	**	-40.63	**	-28.76	**	-9.32	
25	JBR-15-01 x JBL-10-08-07	45.83	**	-5.23		64.52	**	-20.31	**	-10.44		-6.98	
26	JBR-15-01 x Pant Rituraj	-31.85	**	4.10		-43.94	**	-42.19	**	-22.76	**	14.82	
27	JBW-15-06 x JBR-15-08	51.68	**	26.52	*	-20.41	**	-39.06	**	64.17	**	32.95	**
28	JBW-15-06 x JBR-15-11	-38.48	**	-29.17	**	-33.33	**	-53.13	**	-39.67	**	-23.21	*
29	JBW-15-06 x JBL-10-08-07	-10.74		-43.45	**	-22.22	**	-45.31	**	-39.09	**	-36.74	**
30	JBW-15-06 x Pant Rituraj	-21.15	**	20.43		-27.27	**	-25.00	**	-8.78		35.59	**
31	JBR-15-08 x JBR-15-11	-37.94	**	-28.56	*	0.01		-29.69	**	-35.99	**	-18.52	
32	JBR-15-08 x JBL-10-08-07	72.16	**	39.84	**	-17.78	**	-42.19	**	32.83	**	37.96	**
33	JBR-15-08 x Pant Rituraj	-23.39	**	17.02		-30.30	**	-28.13	**	-38.54	**	-8.64	
34	JBR-15-11 x JBL-10-08-07	-30.43	**	-20.88		19.35	*	-42.19	**	-29.25	**	-9.94	
35	JBR-15-11 x Pant Rituraj	-54.56	**	-30.60	**	-46.97	**	-45.31	**	-42.91	**	-15.15	
36	JBL-10-08-07 x Pant Rituraj	-1.26		50.81	**	-18.18	**	-15.63	**	8.21		60.85	**
	SE±	2.01		2.01		0.15		0.15		216.54		216.54	

Table 5: Number of hybrids showing significant heterosis and range of heterosis for various characters in brinjal

Character		Fruit length (cm)		Average fruit weight (gm)		Fruit girth (cm)	
		H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)
Range	Minimum value	-47.33	-18.88	-40.40	-21.41	-50.01	7.75
	Maximum value	33.56	39.15	24.51	28.53	34.34	72.09
Significant Cross	Positive crosses	6	25	0	0	4	36
	Negative crosses	26	8	13	0	26	0
	Total crosses	32	33	13	0	30	36
Character		**Number of fruit per plant**		**Number of primary branches**		**Total fruit yield per plant (gm)**	
		H (%)	**SH (%)**	**H (%)**	**SH (%)**	**H (%)**	**SH (%)**
Range	Minimum value	-54.56	-40.79	-46.97	-53.13	-42.91	-36.74
	Maximum value	98.01	71.05	64.52	18.75	86.21	60.85
Significant Cross	Positive crosses	11	10	9	1	7	11
	Negative crosses	13	9	19	31	15	5
	Total crosses	24	19	28	32	22	16

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