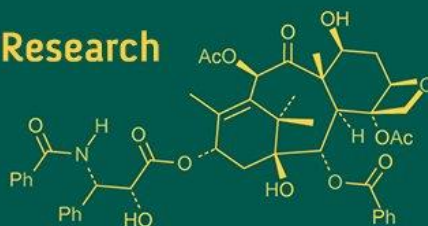


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Heterosis and combining ability study in brinjal (*Solanum melongena* L.)

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Abstract

A field experiment was carried out with a view to estimate, heterosis, combining ability and gene effects in brinjal (*Solanum melongena* L.). The present investigation was carried out using seven parental lines, their resulted 21 half-diallel crosses and one standard check GJBH 4. The experiment was evaluated in randomized block design with three replications during *rabi* 2021-22 at Horticulture Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The analysis of variance (mean sum of square) revealed significant differences for the genotypes, parents, hybrids and parents vs. hybrids were present among most of the characters, which supported sufficient amount of heterosis was present in crosses for fruit yield per plant and its attributing characters. The parent DOLI 5 was recorded maximum mean performance for fruit yield per plant. The cross PLR 1 x JBCL-16-12 was best heterotic cross over mid parent, better parent and standard check (GJBH 4) for fruit yield per plant. The result of analysis of variance for combining ability revealed that mean sum of squares due to general and specific combining ability were found highly significant for all the characters. The ratio ($\sigma^2_{GCA}/\sigma^2_{SCA}$) of variances for various characters revealed importance of non-additive type of gene action in the expression of fruit yield per plant and its related traits except fruit girth. Among the parents, ISD-006, DOLI 5 and GRB 7 were good general combiners for fruit yield per plant and its contributing traits. The hybrid on the basis of *sca* effects for fruit yield per plant were PLR 1 x JBCL-16-12, GRB 7 x GJB 3 and ISD-006 x DOLI 5. The cross PLR 1 x JBCL-16-12 was identified as potential for fruit yield per plant and suggested to further evaluation for generation advancement in future breeding programme to isolate good transgressive segregants for fruit yield per plant.

Keywords: Brinjal, diallel, heterosis, combining ability, *gca* & *sca* effect, F_1 hybrids

Introduction

Brinjal or eggplant (*Solanum melongena* L.) is an important commercial vegetable crop of India and having chromosome number $2n = 2x = 24$. It is often cross-pollinated crop belonging to the family solanaceae. Eggplant grown throughout the year which is a common and popular vegetable crop in the subtropics and tropics mainly for its immature fruits as vegetables. India considered as the primary centre of origin of brinjal (Vavilov, 1935) ^[18].

Brinjal is usually self-pollinated but the extent of cross-pollination has been reported as high as 29% and hence it is classified as often cross-pollinated or facultative cross-pollinated. The cultivars of brinjal display a wide range of fruit shapes and colours. A number of cultivars are grown throughout the country depending upon the yield and consumers' preference about colour, size and shape. 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 as well as rich in vitamins, minerals (calcium, magnesium, phosphorus) and fatty acids.

Knowledge and information regarding genetic architecture (combining ability and gene action) of a crop is necessary for development of such type of varieties and hybrids. In heterosis breeding programme, it is better to study and evaluate available useful promising diverse potential lines in their hybrid combinations for yield and attributing characters.

The concept of heterosis is proved to be most essential genetic tool for improving yield of crop plants. The prime objective of heterosis breeding is to identify the specific cross combination capable of producing the maximum heterotic effect in the F_1 generation.

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In hybridization programme, selection of suitable type of parents is a crucial step for a breeder. Combining ability analysis is a powerful tool to identify good as well as poor combiners and selection of a suitable parental material. It also elucidates the nature of gene action involved in the inheritance of the particular character.

Materials and Methods

The experimental material consisted of seven parental lines viz., JBCL-16-12, JNB-110, ISD-006, Doli 5, GRB 7, PLR 1, GJB 3 and their 21 half-diallel crosses along with check GJBH 4. The seeds of 21 F_1 hybrids were produced during summer 2021 at College farm, College of Horticultural, S. D. Agricultural University, Jagudan by hand emasculation and pollination technique. The seeds of parental lines were maintained through selfing. A set of 29 genotypes comprising of seven parents (including check GJBH 4) and their 21 F_1 hybrids were sown in Randomized Block Design (RBD) with three replications during *rabi* 2021-22. Each hybrid and parents represented single rows of 6-meter length spaced at 60 cm between rows and 60 cm between plants. The experimental area fertigated as per recommendation. Other recommended agronomic practices and plant protection measures were adopted for raising a healthy seedling during nursery bed and experimental crop afterwards. The observations were recorded both as visual assessment for days to flower initiation, days to flowering and days to maturity. while measurement on five randomly selected and tagged plants of each genotype in each replication for The observations on number of primary branches per plant, number of fruits per plant, fruit length (cm), fruit girth (cm), plant height (cm), fruit weight (g), fruit volume (cm^3) and fruit yield per plant (kg) were measured from five randomly selected and tagged plant of each genotype of each replication. The replications-wise mean values of each genotype for twelve characters were subjected to statistical analysis as per the procedure of Randomized Block Design (RBD) as suggested by Panse and Sukhatme (1985) [10]. The analysis of variance (ANOVA) was carried out as per the method suggested by Snedecor and Cochran (1967) [15] and reviewed by Panse and Sukhatme (1985) [10]. Heterosis was estimated as percent increase or decrease in the mean value of F_1 hybrid over the mid parent *i.e.*, relative heterosis (Turner, 1953) [16], better parent, *i.e.*, heterobeltiosis (Fonesca and Patterson, 1968) [5] and over standard check *i.e.*, standard heterosis Meredith and Bridge (1972) [9] for each character. The mean value of 28 genotypes (seven parents and their twenty-one F_1 hybrids) were subjected for combining ability analysis was carried out according to the procedure given by Griffing (1956) [6] as per Method-II (in which parents and a set of F_1 's without reciprocals are included) and Model-I [which assumes that the genotypes and block effects are constant (fixed) but environmental effect is variable].

Results and Discussion

The analysis of variance for all the characters studied is presented in Table 1. The results revealed significant differences due to genotypes for all the characters. This supports that the mean squares due to genotypes, parents and hybrids (F_1) were highly significant for all the characters revealing the existence of potential variability in the parental material used in the present study. The mean squares due to parents vs. hybrids were highly significant for

number of primary branches per plant, number of fruits per plant, plant height, fruit weight, fruit volume and fruit yield per plant at 1%. Whereas, mean squares due to parents vs. hybrids significant only 5% for days to flower initiation and fruit length. Mean squares due to parents vs. hybrids was also significant for all the characters except days to flowering, number of flowers per cluster and fruit girth which indicated F_1 's had heterotic effects for these characters.

A perusal of mean value of parents shown that none of the parental genotypes was superior for all the characters under study. Considering the primary breeding objectives, *i.e.*, high yielding, earliness and quality parameters, the mean performance of parents revealed that the parent DOLI 5 was showed better mean performance for fruit length (cm) and fruit weight (g). While the parent JNB-110 was found superior for number of primary branches and number of fruit per plant.

In case of F_1 hybrids none of the cross combination was found superior for all the characters under investigation. The top F_1 hybrid PLR 1 x JBCL-16-12 was recorded maximum fruit yield per plant (kg) and revealed better mean performance for days to maturity, number of fruits per plant and fruit weight (g), respectively. The cross combination ISD-006 x DOLI 5 showed better mean performance for number of fruits per plant and fruit weight (g), respectively. Whereas, the crosses PLR 1 x DOLI 5 was exhibited its superiority for number of fruits per plant, fruit weight (g) and fruit volume (cm^3). The correspondence range of yield and attributes were also reported earlier by Shitap *et al.* (2017) [12], Bhatt *et al.* (2019) [2], Varma *et al.* (2020) [17] and Singh *et al.* (2021) [13]. However, the range may slightly be varying as it merely depends on genotype potential and environmental fluctuation.

Considering the importance of fruit yield per plant in the present investigation, out of 21 F_1 hybrids, only one hybrids manifested significant and positive estimates of relative heterosis, heterobeltiosis and standard heterosis (check GJBH 4), respectively. For fruit yield per plant a wide range of heterosis over mid parent, better parent and standard check were recorded *i.e.*-57.04 (JBCL-16-12 x DOLI 5) to 71.63 percent (PLR 1 x JBCL-16-12) for relative heterosis, -67.08 (GJB 3 x DOLI 5) to 64.69 percent (PLR 1 x JBCL-16-12) for heterobeltiosis and -64.87 (GJB 3 x JNB-110) to 12.50 (PLR 1 x JBCL-16-12) for standard heterosis over check GJBH 4 (Table 2). The low to high estimates of relative heterosis, heterobeltiosis and standard heterosis for fruit yield per plant are also reported earlier by Shitap and Patel (2017) [12], Bhatt *et al.* (2019) [2] and Singh *et al.* (2021) [13].

Based on comparative study of best heterotic hybrids (Table 3), for fruit yield per plant over mid parent, better parent and standard check, revealed that these hybrids also expressed significant and positive heterosis over standard check for various component characters viz., number of flowers per cluster, fruit weight, fruit volume, number of fruit per plant.

The analyses of variance for combining ability for twelve characters are furnished in Table 4. The results revealed that mean sum of squares due to general and specific combining ability were found highly significant for all the characters viz., days to flower initiation, days to flowering, days to maturity, number of flowers per cluster, number of primary branches per plant, number of fruits per plant, fruit length, fruit girth, plant height, fruit weight, fruit volume and fruit

yield per plant indicating both additive and non-additive gene actions were important for inheritance of these traits. The ratio ($\sigma^2_{GCA}/\sigma^2_{SCA}$) of variances for various characters revealed importance of non-additive type of gene action in the expression of yield and component characters. The predominant role of non-additive gene action in the inheritance of fruit yield per plant and contributing characters in brinjal was in accordance with the results those reported by several workers in different characters viz., fruit yield per plant by Makani *et al.* (2016) [8], Dubey *et al.* (2014) [4], Ansari and Singh (2014) [11], Desai *et al.* (2017) [3], Kachouli *et al.* (2019) [7] and Siva *et al.* (2020) [14]. Preponderance of additive gene action was reported for fruit girth by Makani *et al.* (2016) [8] and Patel *et al.* (2017) [12]. Based on the estimates of general combining ability effects, the parents were classified as good, average and poor general combiners for different characters based on the value of *gca* effects (Table 5). The *gca* effects of parents explicated that none of the parents was consistently good general combiner for all the characters under investigation. Best general combiner for various characters were PLR 1 and GJB 3 for days to flower initiation, days to flowering and days to maturity respectively; GRB 7 and JNB-110 for

number of flowers per cluster; PLR 1, GJB 3 and DOLI 5 for number of primary branches per plant; PLR 1 and JBCL-16-12 for number of fruits per plant; GJB 3, JNB-110 and DOLI 5 for fruit length; GJB 3 for fruit girth; PLR 1, JBCL-16-12, ISD-006 and JNB-110 for plant height; PLR 1, GJB 3 and DOLI 5 for fruit weight; PLR 1, GJB 3 and DOLI 5 for fruit volume and DOLI 5, JNB-110 and GRB 7 for fruit yield per plant.

The crosses on the basis of *sca* effects for various characters are presented in Table 6. A perusal of data implied that none of the crosses had high-ranking *sca* effects for all the characters. The data revealed that the high ranking *sca* for most of the characters were accompanied by high ranking mean performance, which proving predominant role of non-additive gene effects in expression of fruit yield per plant and component characters. The crosses PLR 1 x JBCL-16-12, GRB 7 x GJB 3 and ISD-006 x DOLI 5 for fruit yield per plant recorded the highest *sca* effects which involved average x average; good x poor; good x good for green fruit yield per plant. Furthermore, these crosses also exhibited a positive significant *sca* effects for other contributing characters viz. days to maturity, number of fruits per plant and fruit weight (g), respectively.

Table 1: Analysis of variance (mean sum of square) for experimental design of twelve characters in brinjal

Source of Variation	d.f.	Days to flower initiation		Days to flowering		Days to maturity		Number of flowers per cluster		Number of primary branches per plant		Number of fruits per plant	
Replications	2	0.25		13.26		7.45		0.04		0.15		0.04	
Genotypes (G)	28	14.28	**	31.33	**	31.80	**	0.57	**	2.89	**	3.72	**
Parents (P)	6	20.54	**	17.01	**	21.12	**	1.38	**	3.86	**	3.66	**
Hybrids (H)	20	12.90	**	38.11	**	35.88	**	0.38	**	2.82	**	3.53	**
Parents vs. Hybrids	1	18.63	*	4.94		40.96		0.02		0.75	**	11.48	**
Check vs. Hybrids	1	0.04		8.08		4.93		0.12	*	0.77	**	0.03	
Error	56	3.13		5.15		10.29		0.02		0.10		0.12	

Table 2: Analysis of variance (mean sum of square) for experimental design of twelve characters in brinjal

Source of Variation	d.f.	Fruit length		Fruit girth		Plant height		Fruit weight		Fruit volume		Fruit yield per plant	
Replications	2	0.04		0.91		12.24		5.21		30.00		0.001	
Genotypes (G)	28	14.43	**	36.40	**	315.90	**	4360.35	**	3275.8	**	1.55	**
Parents (P)	6	23.92	**	76.36	**	304.64	**	1033.52	**	817.51	**	2.11	**
Hybrids (H)	20	12.73	**	27.94	**	319.67	**	5133.22	**	4089.2	**	1.08	**
Parents vs. Hybrids	1	2.80	*	0.29		147.87	**	13204.45	**	4976.6	**	6.48	**
Check vs. Hybrids	1	3.00	*	1.94		475.94	**	19.89		56.11		2.57	**
Error	56	0.46		1.98		3.98		77.73		40.77		0.04	

* $p \leq 0.05$ (5%); ** $p \leq 0.01$ (1%).

Table 3: F₁ hybrids depicted significant heterotic effects for various characters in brinjal

Characters	Range		
	Over mid parent	Over better parent	Over standard check (GJBH 4)
Days to flower initiation	-5.24 to 15.06	-1.83 to 20.06	-10.25 to 6.49
Days to flowering	-10.5 to 16.27	-8.39 to 18.75	-6.17 to 18.03
Days to maturity	-7.35 to 13.74	-4.38 to 15.56	-4.55 to 13.74
No. of flowers/cluster	-29.16 to 37.88	-38.28 to 33.63	-14.41 to 45.34
No. of primary branches per plant	-36.34 to 52.09	-42.28 to 31.37	-40.44 to 12.95
No. of fruits per plant	-19.87 to 14.30	-21.82 to 13.22	-12.97 to 11.33
Fruit length	-45.99 to 69.5	-59.8 to 62.65	-41.78 to 28.53
Fruit girth	-21.97 to 30.07	-35.74 to 29.65	-24.11 to 35.86
Plant height	-16.92 to 50.41	-29.20 to 32.98	-44.1 to 21.04
Fruit weight	-32.65 to 122.23	-43.34 to 117.06	-41.57 to 75.25
Fruit volume	-28.45 to 78.85	-36.27 to 68.68	-29.00 to 79.93
Fruit yield per plant	-57.04 to 71.63	-67.08 to 64.69	-64.87 to 12.50

Table 4: Comparative study of heterotic crosses in brinjal for fruit yield per plant with other characters

Hybrid	Fruit yield per plant (kg)	Standard heterosis (%)	sca effect	Useful and significant standard heterosis for other characters
PLR 1 x JBCL-16-12	3.22	12.50	1.41**	FPP,FW,FV
ISD-006 x DOLI 5	3.04	2.71	0.59**	FPC,FPP,FW, FV

* $p \leq 0.05$, ** $p \leq 0.01$. FW: Fruit weight FPC: Number of flowers per cluster

FV: Fruit volume FPP: Number of fruits per plant

Table 5: Analysis of variance components (mean sum of square) for combining ability of twelve characters in brinjal

Source of variation	d.f.	Days to flower initiation		Days to flowering		Days to maturity		Number of flowers per cluster		Number of primary branches per plant		Number of fruits per plant	
GCA	6	10.60	**	15.38	**	21.77	**	0.39	**	1.07	**	1.25	**
SCA	21	3.31	**	9.40	**	7.83	**	0.13	**	0.96	**	1.29	**
Error	54	1.07		1.72		3.41		0.008		0.03		0.04	
σ^2_{GCA}		1.05		1.51		2.03		0.04		0.11		0.13	
σ^2_{SCA}		2.24		7.68		4.42		0.13		0.93		1.25	
$\sigma^2_{GCA/\sigma^2_{SCA}}$		0.47		0.19		0.46		0.32		0.12		0.10	

Table 6: Estimation of general combining ability effect associated with each parent for twelve characters in brinjal

Parents	Days to flower initiation		Days to flowering		Days to maturity		Number of flowers per cluster		Number of primary branches per plant		Number of fruits per plant	
PLR 1	-1.47	**G	-1.99	**G	-2.03	**G	-0.07	* P	0.46	**G	0.27	** G
GRB 7	-1.57	**G	-1.61	**G	-2.28	**G	0.44	**G	0.01	A	-0.17	** P
GJB 3	0.48	P	0.83	* P	0.81	A	-0.07	* P	0.12	* G	-0.67	** P
JBCL-16-12	-0.00	A	0.02	A	0.52	A	-0.04	A	0.01	A	0.52	** G
ISD-006	0.75	* P	0.34	A	0.84	A	-0.22	**P	-0.67	**P	-0.10	A
JNB-110	0.91	**P	1.12	**P	1.86	**P	0.06	* G	-0.11	A	0.09	A
DOLI 5	0.91	**P	1.29	**P	0.28	A	-0.09	**P	0.16	**G	0.06	A
S.E. (g _i)	0.32		0.40		0.57		0.02		0.05		0.06	
Range	-1.57 to 0.91		-1.99 to 1.29		-2.28 to 1.86		-0.22 to 0.44		-0.67 to 0.46		-0.67 to 0.52	

* $p \leq 0.05$ (5%); ** $p \leq 0.01$ (1%). The letter on parthesis indicate study of parent. G = Good combiner; A = Average combiner; P = Poor combiner.**Table 7:** Estimation of general combining ability effect associated with each parent for twelve characters in brinjal

Parents	Fruit length		Fruit girth		Plant height		Fruit weight		Fruit volume		Fruit yield per plant	
PLR 1	-0.67	**P	0.15	A	4.91	**G	14.37	**G	14.97	**G	-0.06	A
GRB 7	-0.16	A	-0.97	**P	-6.45	**P	-18.72	**P	-15.19	**P	0.18	**G
GJB 3	0.95	**G	4.45	**G	-5.01	**P	16.06	**G	18.01	**G	-0.59	**P
JBCL-16-12	-1.07	**P	-0.12	A	1.53	**G	-5.92	**P	-5.76	**P	-0.04	A
ISD-006	-0.35	**P	-0.36	A	5.96	**G	-9.63	**P	-14.95	**P	0.24	**G
JNB-110	0.47	**G	-2.03	A	3.71	**G	-5.50	**P	-3.35	**P	0.09	* A
DOLI 5	0.82	**G	-1.11	**P	-4.65	**P	9.34	**G	6.28	**G	0.19	**G
S.E. (g _i)	0.12		0.25		0.36		1.59		1.14		0.03	
Range	-1.07 to 0.95		-2.03 to 4.45		-6.45 to 5.96		-18.72 to 16.06		-15.19 to 18.01		-0.59 to 0.24	

Conclusion

The cross PLR 1 x JBCL-16-12 recorded high fruit yield per plant and reported higher heterotic effect along with positive sca effect for fruit yield per plant and its contributing characters in brinjal. Hence, this cross was identified as potential for getting good transgressive segregants for fruit yield per plant and its contributing characters and suggested to further evaluation for generation advancement in future breeding programme to isolate good transgressive segregants for fruit yield per plant.

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