E-ISSN: 2618-0618
P-ISSN: 2618-060X
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www.agronomyjournals.com
2024; 7(1): 100-103
Received: 14-10-2023
Accepted: 16-11-2023

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Standard heterosis for yield and its attributing traits in brinjal (*Solanum melongena* L.)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i1b.194

Abstract
The study of heterosis is a basic prerequisite for the exploitation of transient hybrid vigour. Six phenotypically diverse parents were used for hybridization following half diallel mating design to obtain fifteen hybrids. Evaluation of hybrids along with the parents and standard check (GAOB-2) was conducted followed by randomised complete block design with three replications. The analysis of variance revealed that considerable genetic variation was present among genotypes, parents and hybrids for all characters under investigation. With regards to *per se* performance, AB-08-14 and AB-08-14 × GBL-3 registered the highest *per se* performance for yield attributing traits. Among 15 hybrids, significant and positive standard heterosis was observed in 11 hybrids for fruit yield plant^{-1} and the highest standard heterosis (%) for fruit yield plant^{-1} was observed in AB-08-14 × GBL-3 over standard check and it can be commercially exploited after assessing their stability.

Keywords: Hybrid, standard heterosis, half diallel mating design, genotypes

Introduction
Brinjal (*Solanum melongena* L.) is an important vegetable grown worldwide. The word "Brinjal" is a corruption of the Sanskrit word "*vatin-gan*". It belongs to the family Solanaceae, has a chromosome number of 2n = 24 and cultivated extensively in different parts of India and is considered to be one of the most remunerative vegetables (Pramanik *et al.*, 2012) [15]. According to Vavilov (1928) [21], the center of origin of the brinjal is the Indo-Burma region.

India exports both fresh and frozen brinjal to more than 30 countries around the year. Based upon its highest production potential and availability of the produce to consumers and due to its versatile use in Indian food, it is also termed as "Poor man's vegetable". Production of eggplant has increased by 50 % in the past decade, likewise the demand due to awareness of its health benefits. Despite its economic importance, eggplant breeding is lagging compared to other solanaceous crops like pepper or tomato. Additionally, there are also regional preferences for fruit shape, size, taste, colour, *etc.* as these traits are vary significantly with the type of cultivar. The use of heterosis breeding for yield and yield-related traits relevant to hybrid development has made and can continue making significant contributions to improving eggplant new varieties. The lack of appropriate hybrids for specific areas and purposes is the major problem in popularizing the hybrids of brinjal.

Heterosis is a phenomenon in which a progeny of distinct individuals exhibits higher/lower values for the traits than the average of any of the original parents used for the development of the hybrid. The F_1 generation depicts itself by rapid growth and development, higher productivity, greater vitality, resistance and uniformity. Nagai and Kada (1926) [12] were the first to observe hybrid vigour in eggplant. Ease of handling the flowers during artificial emasculation, pollination and realization of a higher number of hybrid seeds per effective pollination causes a higher yield of hybrids. The diallel analysis is a good approach for screening parents to use in hybrid development as compared to other mating designs. There are different types of diallel crosses, but half diallel crosses are more controllable for breeders than full diallel analysis in terms of the number of reciprocal crosses (Christie and Shattuck, 1992) [4].

Materials and Methods

The present experiment was carried out at Regional Horticulture Research Station, Navsari, which is situated 12 km away from the "The Dandi", geographically a coastal region of south Gujarat at the latitude of 20°37' N and longitude of 72°54' E with an altitude of 11.89 metres above the mean sea level. The experimental material comprised of 6 parents, 15 cross combinations and 1 standard check (GAOB-2). The genotypes used as parents and their sources are listed in Table 1. For hybridization, each of the 6 lines were crossed with each other by following half diallel mating design during Rabi 2020-21 to produce 15 hybrids. Randomized block design with three replications was used for the evaluation of genotypes during Rabi 2021-22.

This study evaluates thirteen traits *viz.*, days to 50 % flowering, plant height (cm), number of branches plant^{-1}, fruit length (cm), fruit diameter (cm), fruit weight (g), number of fruits plant^{-1}, number of marketable fruits plant^{-1}, fruit yield plant^{-1} (kg), total soluble solids (°Brix), vitamin C (mg 100^{-1})**,** total phenol content (mg 100^{-1}) and total anthocyanin content (mg 100^{-1}) from randomly selected five tagged and average values were computed. Data were analyzed by the methods outlined by Panse and Sukhatme (1985) [13] using the mean values of randomly selected plants in each replication from all genotypes to find out the significance of the treatment effect. The significance was tested by referring to the values of the F table (Fisher and Yates, 1953) [7]. The magnitude of heterosis was estimated with standard check hybrid and calculated as a percentage increase or decrease of F_1 as over standard check using the method of Fonseca and Patterson (1968) [8].

Table 1: The details of parents used in the half diallel mating design

Parents	Genotypes	Source
P1	AB-08-14	JAU, Junagadh
P2	GBL-3	NAU, Navsari
P3	NBB-1	AAU, Anand
P4	JDNB-110	NBPGR collection
P5	NBL-15	NAU, Navsari
P6	Pusa Kranti	NAU, Navsari

Results and Discussions

The phenomenon of heterosis is nowadays used as an important and efficient tool for achieving higher yields. The result of the analysis of variance computed for yield and yield attributing characters presented in Table 2. A perusal of data revealed that the differences due to various genotypes were highly significant for all the characters under study indicating that experimental material has sufficient genetic variability for all characters under investigation. The genotypic variance was further partitioned into variance due to parents, hybrid and parents *vs* hybrids. The mean square due to parents as well as hybrids was also significant for all traits. The mean square due to parents *vs* hybrids was significant for all traits except days to 50 % flowering and fruit diameter indicating that the performance of hybrids as a group was different than that of parents and indicating the presence of considerable heterosis due to directional dominance. The findings of Desai *et al.* (2016) [5], Sharma *et al.* (2016) [19], Ramani *et al.* (2017) [17] and Timmareddygari *et al.* (2021) [20] were in accordance with this results.

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, 1989) [6]. The magnitude of heterosis varied from hybrid to hybrid for all the characters studied. Among all characters, the character of economic importance for brinjal is fruit yield and the heterosis response obtained for this character is of great importance for practical plant breeding. The estimation of standard heterosis for 15 hybrids over standard check GAOB-2 with respect to different traits is presented in Table 3 and heterosis for a number of fruits plant^{-1} and fruit yield plant^{-1} is graphically depicted in Figure 1.

Among 15 hybrids, significant and positive standard heterosis observed in 11 hybrids for fruit yield plant^{-1}. Three hybrids *viz.*, AB-08-14 × Pusa Kranti, GBL-3 × Pusa Kranti, JDNB-110 × Pusa Kranti recorded for highly significant positive heterosis for fruit yield plant^{-1} and considering *per se* performance of hybrids for fruit yield plant^{-1}, the 3 best cross combinations were, AB-08-14 × GBL-3 (3.46 kg), AB-08-14 × Pusa Kranti (2.97 kg) and NBB-1 × JDNB-110 (2.95 kg). These hybrids also proved superior in terms of early flowering, fruit weight, fruit diameter, plant height and number of branches plant^{-1}. Considering the mean performance, among the parents, AB-08-14 (2.32 kg), Pusa Kranti (2.23 kg) and GBL-3(2.15 kg) registered highest *per se* performance for fruit yield plant^{-1}. A critical analysis of parents and hybrids *per se* performance revealed that hybrids involving AB-08-14 and GBL-3 as one of the parent recorded higher fruit yield with other yield attributing traits *viz.*, fruit diameter, fruit length and fruit weight.

Evidences suggest that heterosis of a complex character, such as yield in the present investigation is much regulated by the hybrid vigour, expressed by its component character *viz.*, the number of fruits plant^{-1} and fruit weight. (Sinha and Khanna, 1975). Number of fruits and fruit weight are the important traits of yield which proved right because the parents involved in these crosses top ranking *per se* performance for these traits. Significant and positive standard heterosis for yield and its attributing traits also reported by Ramani *et al.* (2015) [17], Ansari and Singh (2016) [1], Biswas *et al.* (2016) [3], Desai *et al.* (2016) [5], Ansari (2017) [2], Khapte *et al.* (2017) [10], Patel *et al.* (2017) [14], Pramila *et al.* (2017) [16], Kalaiyarasi *et al.* (2018) [9], Zeal *et al.* (2019) [22], Makasare *et al.* (2020) [23] and Rameshkumar *et al.* (2020) [18], Timmareddygari *et al.* (2020) [20] in brinjal.

Table 2: The ANOVA (mean sum of square) of parents and their hybrids for various characters in brinjal

Source of Variation	d.f.	DFF	PH	NB	FL	FD	FW	NFP	NMFP	FYP	TSS	VIC	TPC	TAC
Replication	2	6.14	4.37	2.47	1.49	0.13	50.34	4.68	18.77	0.063	0.04	0.96	4.64	3.95
Genotypes	20	38.55**	684.78**	10.13**	7.26**	1.90**	326.12**	182.82**	145.16**	0.89**	0.66**	35.08**	102.55**	61.34**
Parents	5	59.28**	551.06**	12.36**	7.25**	1.68**	316.72**	102.73**	86.31**	0.47**	0.34**	4.81**	114.31**	51.71**
Hybrids	14	33.02*	731.26**	9.68**	7.59**	2.08**	275.60**	214.00**	161.54**	0.84**	0.75**	40.43**	96.14**	60.49**
Parents *vs* Hybrids	1	12.29	702.78**	5.45*	2.65*	0.40	1080.35**	146.74**	210.08**	3.64**	0.86**	111.45**	133.45**	121.51**
Error	40	15.45	32.77	0.98	0.53	0.12	28.68	10.09	6.11	0.061	0.06	0.711	1.31	2.06
Total	62	22.60	242.18	3.98	2.73	0.69	122.10	65.64	51.37	0.32	0.25	11.80	34.07	21.24

*- Significant at 5 % and **- Significant at 1 %

DFF = Days to 50 % Flowering
PH = Plant Height (cm)
NB = Number of Branches Plant^{-1}
FL = Fruit Length (cm)
FD = Fruit Diameter (cm)
FW = Fruit Weight (g)
NFP = Number of Fruits Plant^{-1}
NMFP = Number of Marketable Fruits Plant^{-1}
FYP = Fruit Yield Plant^{-1} (kg)
TSS = Total Soluble Solids (°Brix)
VIC = Vitamin C (mg 100^{-1})
TPC = Total Phenol Content (mg 100^{-1})
TAC = Total Anthocyanin Content (mg 100^{-1})

Table 3: Magnitude of standard heterosis (%) over GAOB-2 for different characters in brinjal

Sr. No.	Hybrids	Days to 50 % Flowering	Plant Height (cm)	Number of Branches Plant^{-1}	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Yield Plant^{-1}
1	P1 × P2	-12.37*	27.06**	38.88**	8.24	48.42**	10.76
2	P1 × P3	-6.43	2.09	28.80**	26.64**	-7.54	2.56
3	P1 × P4	-12.87**	49.30**	61.11**	9.35	-0.64	1.53
4	P1 × P5	-14.85**	-11.16	-1.11	-6.43	-15.05*	-21.53**
5	P1 × P6	-11.88*	7.81	13.11	33.86**	6.08	24.10**
6	P2 × P3	-4.455	36.05**	26.66*	-8.42	-20.68**	-4.61
7	P2 × P4	-6.436	11.59	36.66**	-6.45	-16.86*	-2.56
8	P2 × P5	-9.90*	6.03	1.11	-14.82*	-12.53	-2.05
9	P2 × P6	-7.42	9.70	14.44	0.750	10.29	23.59**
10	P3 × P4	0.49	11.36	37.77**	-0.34	-14.0*	5.64
11	P3 × P5	-1.98	2.09	-28.88**	-12.17	10.2	6.66
12	P3 × P6	-4.95	9.78	-10.00	26.21**	-7.5	15.38*
13	P4 × P5	-9.90*	22.60**	4.44	30.45**	-8.0	12.82*
14	P4 × P6	-7.42	14.83*	8.88	40.46**	11.9	20.51**
15	P5 × P6	-17.82**	-28.87**	-14.44	-11.56	-32.89**	-26.15**
	SEd (±)	3.16	5.18	0.79	0.58	0.28	3.88
	CD @ 5 %	6.38	10.46	1.60	1.18	0.58	7.83
	CD @ 1 %	8.53	13.99	2.14	1.58	0.78	10.47
	Range	-17.82 to 0.49	-28.87 to 49.31	-28.88 to 61.11	-14.82 to 40.46	-32.89 to 48.42	-26.15 to 24.10

Table 3: Magnitude of standard heterosis (%) over GAOB-2 for different characters in brinjal (conti…)

Sr. No.	Hybrids	Number of Fruits Plant^{-1}	Number of Marketable Fruits plant^{-1}	Fruit Yield Plant^{-1} (kg)	Total Soluble Solids (°Brix)	Vitamin C (mg 100^{-1})	Total Phenol Content (mg 100^{-1})	Total Anthocyanin Content (mg 100^{-1})
1	P1 × P2	78.53**	77.42**	101.53**	14.87**	28.33**	-68.94**	42.12**
2	P1 × P3	44.93**	50.59**	53.23**	20.66**	29.29**	-72.62**	56.89**
3	P1 × P4	21.96*	30.59**	25.64*	23.96**	24.39**	-60.50**	77.23**
4	P1 × P5	31.31**	38.10**	5.23	19.83**	31.06**	-41.47**	50.23**
5	P1 × P6	27.56**	35.91**	73.21**	2.47	10.84**	-51.88**	8.97
6	P2 × P3	-7.78	-6.55	-8.80	50.41**	41.79*	-33.03**	41.08**
7	P2 × P4	48.03**	57.98**	52.26**	27.27**	30.85**	-53.77**	37.00**
8	P2 × P5	37.93**	41.56**	39.71**	7.43	2.01	-44.16**	15.51
9	P2 × P6	7.52	12.96	35.45**	9.91	7.13	-32.22**	79.75**
10	P3 × P4	52.83**	54.79**	69.93**	18.18**	34.10**	-38.53**	-32.47**
11	P3 × P5	0.14	1.15	11.32	5.78	-4.09	-70.91**	-25.87*
12	P3 × P6	-13.91**	-10.54	0.56	7.43	-29.32**	-49.28**	20.84
13	P4 × P5	49.09*	59.38**	71.78**	16.52**	25.44**	-73.96**	43.13**
14	P4 × P6	11.16	18.56*	39.06**	6.61	-32.71**	-73.96**	119.21**
15	P5 × P6	103.31*	105.34**	47.59**	1.65	-39.68**	-42.81**	73.03**
	S.Ed (±)	2.57	2.00	0.19	0.19	0.70	0.09	1.18
	CD @ 5 %	5.18	4.05	0.40	0.40	1.43	0.18	2.39
	CD @ 1 %	6.93	5.41	0.53	0.53	1.91	0.25	3.20
	Range	-13.91 to 103.31	-10.54 to 105.34	-8.80 to 01.53	1.65 to 50.41	-39.68 to 41.79	-73.96 to -32.22	-32.47 to 119.21

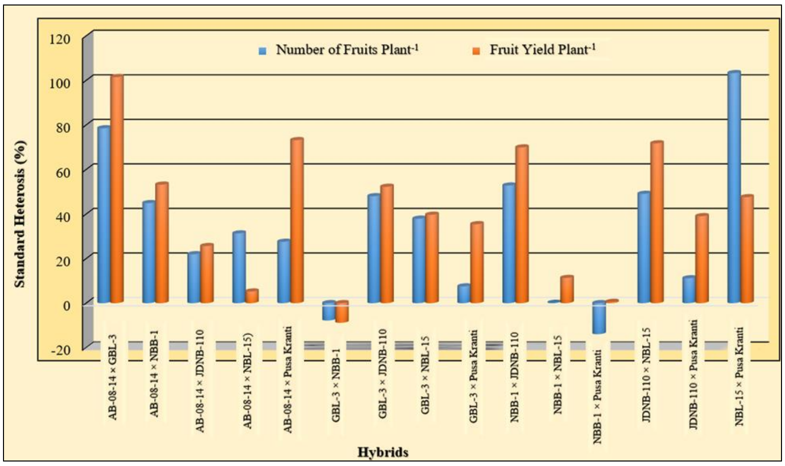

Fig 1: Magnitude of standard heterosis (%) for number of fruits plant^{-1} and fruit yield plant^{-1}

Conclusions

It is evident from above results that AB-08-14 × GBL-3, AB-08-14 × Pusa Kranti and JDNB-110 × NBL-15 were found promising for fruit yield plant^{-1} and yield attributing traits. As this kind of genetic variation cannot be fixed, heterosis breeding is an effective approach for crop improvement and breeding method like, diallel selective mating and recurrent selection can also be used in advance generation.

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