The Pharma Innovation Journal 2023; 12(5): 3038-3045

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 3038-3045
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www.thepharmajournal.com
Received: 16-03-2023
Accepted: 19-04-2023

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Estimation of standard heterosis over environments for fruit yield and its components in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

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Abstract
Diallel analysis over environments in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] was undertaken with an aim to assess the standard heterosis for fruit yield and its component traits. The experimental material consisted of total 37 entries which include eight parents, 28 F_1 hybrids and one standard check (ABG 1). The material was evaluated in a Randomized Block Design replicated thrice during three different seasons *viz.*, late *Rabi* 2018-19 (E_1), Summer 2019 (E_2) and *Kharif* 2019 (E_3) at College farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari. The analysis of variance for individual as well as over environments revealed highly significant differences among genotypes, parents and hybrids for all the traits indicating ample amount of genetic variability among the parents and hybrids for all the traits. For fruit yield, the best performing hybrids over standard check (ABG 1) were JBG 17-03 × JBG 17-08 (43.85%), JBG 17-07 × DBG 6 (27.94%) and JBG 17-04 × DBG 6 (21.37%) in E_1; hybrid JBG 17-03 × JBG 17-08 (65.18%), JBG 17-04 × DBG 6 (53.78%) and JBG 17-10 × JBG 17-01 (48.82%) in E_2; hybrid JBG 17-03 × JBG 17-01 (23.87%), JBG 17-07 × JBG 17-03 (17.91%) and JBG 17-04 × JBG 17-10 (16.25%) in E_3; hybrid JBG 17-03 × JBG 17-08 (36.39%), JBG 17-04 × DBG 6 (26.27%) and JBG 17-03 × JBG 17-10 (22.01%) in pooled over environments.

Keywords: Bottle gourd, diallel analysis, standard heterosis, ABG 1, pooled over environments

Introduction

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.], belonging to the Cucurbitaceae family, is one of humankind's first domesticated plant and is native of Africa (Whitaker, 1971) [18]. The plants are annual, viny, pubescent herbs with large, white flowers borne on slender peduncles. The vines are quick-growing annuals with hairy stems, long forked tendrils and a musky odour. In India, it is commonly used as vegetable and cultivated as a field crop in the *Kharif* and summer seasons as well as throughout the year in areas where winter is mild. India has annual bottle gourd production of around 3.018 million metric tonnes from an area of about 0.188 million hectare with a productivity of about 16.053 tonnes per hectare (Anon., 2019-20) [1].

In bottle gourd, male and female flowers originate separately on the same plant therefore, it is a monoecious plant and a highly cross-pollinated crop. Cross pollination ranges from 60 to 80 per cent, results into large variation in shape and size of fruits which also varies from very long slender to thick and round (Choudhary, 1987) [4]. Also, low inbreeding depression, high heterosis percentage and low seed rate requirement per unit area, has distinct advantages in commercial exploitation of heterosis in this crop. Nature and magnitude of heterosis is one of the important aspect for selection of the right parents for crosses and also help in identification of superior cross combinations that may produce desirable transgressive segregants in advanced generations. According to Chaudhari *et al.*, (2011) [3], the phenomenon of heterosis has proven to be the most important genetic tool in enhancing yield of often cross pollinated and cross-pollinated crops in general. Bottle gourd being a monoecious and highly cross-pollinated crop, identification of best heterotic hybrids through heterosis breeding is a best methodology for yield enhancement in such crop.

Materials and Methods

For present investigation, the experimental material used comprised total 37 entries including eight parents (JBG 17-06, JBG 17-07, JBG 17-04, JBG 17-03, DBG 6, JBG 17-10, JBG 17-08, JBG 17-01), their 28 F_1 hybrids produced using 8 × 8 diallel mating design excluding reciprocals (method-II; model-I) and one standard check (ABG 1). The resulting materials were subjected to evaluation using Randomized Block Design with three replications over three environments during late *Rabi* 2018-19 (E_1), Summer 2019 (E_2) and *Kharif* 2019 (E_3) at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari. Each entry was sown in a single row plot of 10 m length keeping row-to-row and plant-to-plant distance of 2 m and 1 m, respectively. The recommended package of practices and plant protection measures were followed to raise a healthy bottle gourd crop. Five competitive plants per each entry in each replication and environment were randomly selected and tagged for the purpose of recording observations on 14 different traits *viz.*, first female flower appearing node, days to 50 per cent flowering, sex ratio (M:F), days to first fruit harvest, days to last fruit harvest, length of main vine (m), fruit shape, fruit skin colour, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of pickings, number of fruits per plant and fruit yield (kg/plant). For days to 50 per cent flowering, the observations were recorded on plot basis. The analysis of variance to test the variation amongst parents and hybrids for 12 quantitative traits was carried out using Randomized Block Design separately for each individual environment as per the procedure recommended by Panse and Sukhatme (1985) [14]. The superiority of hybrids was estimated as per cent increase (+) or decrease (–) in the mean value of F_1 hybrid over standard check (ABG 1) as standard heterosis according to the procedure given by Meredith and Bridge (1972) [12] using mean values for various traits over replications. For certain traits *viz.*, first female flower appearing node, days to 50 per cent flowering, sex ratio, days to first fruit harvest and days to last fruit harvest, negative heterosis was considered to be desirable and for rest of the aforesaid traits, positive heterosis was considered to be desirable for the estimation of heterosis. The test of significance for each individual environments were carried out by comparing the calculated 't' values with the tabulated 't' values at 5 per cent (1.96) and 1 per cent (2.58) levels of significance.

Results and Discussion

Analysis of Variance

The analysis of variance for the experimental design revealed highly significant differences among genotypes for 12 distinct quantitative traits evaluated in individual (Table 1) as well as pooled over environments (Table 2), indicating ample amount of genetic variability among populations. For individual environments, mean squares due to both parents and hybrids were found significant for all the traits in all the three seasons/environments revealing diverse response of parents as well as hybrids. High divergence in the parental lines for most of the traits indicated their suitability for developing divergent hybrids. For individual environments, mean square due to parents *vs* hybrids also revealed significant differences for all the traits in all the three environments except first female flower appearing node in E_1, days to first fruit harvest and fruit diameter in E_2 and fruit diameter in E_3. For pooled over environments, mean square due to genotypes × environment interaction (G × E) was significant for all the traits suggesting diverse response of the genotype for these traits at different environments. Similarly, the mean square due to parents × environment (P × E) was significant for all the traits except fruit length. In addition to this, mean square due to hybrid × environment (F_1 × E) was significant for all the traits. While out of all traits, the mean square due to parents *vs* hybrids × environment (P *vs* F_1 × E) was non-significant for first female flower appearing node, fruit length, fruit diameter and average fruit weight. Significant response of sources of variances in all the three seasons indicated the performance of hybrids as a group was different than that of parents for the given traits at individual as well as pooled over the environments, confirming the presence of considerable heterosis due to directional dominance, suggesting the ability of parent to result as favourable crosses, providing opportunity to sort out better hybrids for over seasons and simultaneously for specific season.

Table 1: Analysis of variance for various traits individual environments in bottle gourd

Source of Variations	DF	E_1 (Late *rabi*)	E_2 (Summer)	E_3 (*Kharif*)
First female flower appearing node				
Replication	2	2.05	1.63	7.23
Genotypes (G)	35	17.82**	14.94**	22.22**
Parents (P)	7	15.16**	16.77**	20.22**
Hybrids (F_1)	27	19.16**	14.50**	22.68**
P *vs* F_1	1	0.19	14.08**	23.93**
Error	70	1.17	1.54	2.77
Days to 50 per cent flowering				
Replication	2	0.29	0.84	6.26
Genotypes (G)	35	24.71**	19.50**	37.26**
Parents (P)	7	32.48**	21.02**	30.61**
Hybrids (F_1)	27	20.41**	19.25**	38.40**
P *vs* F_1	1	86.67**	15.69**	52.97**
Error	70	1.75	0.91	2.72
Sex ratio				
Replication	2	0.04	0.00	0.02
Genotypes (G)	35	7.10**	8.65**	7.67**
Parents (P)	7	3.99**	6.54**	10.58**
Hybrids (F_1)	27	5.61**	7.99**	6.11**
P *vs* F_1	1	68.97**	41.26**	29.29**
Error	70	0.01	0.02	0.02
Days to first fruit harvest				
Replication	2	0.17	0.92	0.61
Genotypes (G)	35	26.66**	26.89**	30.57**
Parents (P)	7	18.11**	43.56**	33.87**

Hybrids (F_1)	27	26.60**	23.53**	30.29**
P *vs* F_1	1	88.11**	0.90	15.00**
Error	70	0.67	0.38	0.33
Days to last fruit harvest				
Replication	2	0.01	0.45	0.24
Genotypes (G)	35	55.72**	69.94**	71.45**
Parents (P)	7	35.78**	94.14**	83.99**
Hybrids (F_1)	27	59.26**	65.09**	69.58**
P *vs* F_1	1	99.67**	31.37**	34.08**
Error	70	0.52	0.47	0.56
Length of main vine (m)				
Replication	2	0.05	0.03	0.00
Genotypes (G)	35	1.28**	1.21**	1.34**
Parents (P)	7	1.92**	1.59**	1.55**
Hybrids (F_1)	27	1.04**	1.07**	1.28**
P *vs* F_1	1	3.18**	2.32**	1.66**
Error	70	0.02	0.02	0.02
Fruit length				
Replication	2	15.78**	9.81	2.94
Genotypes (G)	35	160.00**	189.35**	147.91**
Parents (P)	7	210.78**	238.77**	163.47**
Hybrids (F_1)	27	148.18**	179.20**	145.62**
P *vs* F_1	1	123.69**	117.62**	100.71**
Error	70	2.91	9.56	4.61
Fruit diameter				
Replication	2	0.41	0.45	0.18
Genotypes (G)	35	6.49**	10.77**	10.90**
Parents (P)	7	6.28**	11.85**	19.07**
Hybrids (F_1)	27	6.70**	10.82**	9.18**
P *vs* F_1	1	2.35**	1.68	0.23
Error	70	0.17	0.48	0.21
Average fruit weight				
Replication	2	395.37	1009.69	288.52
Genotypes (G)	35	56231.60**	63849.00**	56929.91**
Parents (P)	7	22828.20**	21261.89**	36618.27**
Hybrids (F_1)	27	63319.56**	72876.74**	60958.24**
P *vs* F_1	1	98680.39**	118209.91**	90346.22**
Error	70	180.24	605.20	334.25
Number of pickings				
Replication	2	0.07	0.03	0.03
Genotypes (G)	35	2.97**	2.05**	1.72**
Parents (P)	7	1.62**	1.59**	1.47**
Hybrids (F_1)	27	3.07**	1.84**	1.56**
P *vs* F_1	1	9.70**	11.09**	7.50**
Error	70	0.04	0.02	0.02
Number of fruits per plant				
Replication	2	0.02	0.00	0.04
Genotypes (G)	35	3.75**	6.47**	4.23**
Parents (P)	7	2.67**	3.11**	8.25**
Hybrids (F_1)	27	3.47**	6.43**	3.19**
P *vs* F_1	1	18.78**	30.89**	4.19**
Error	70	0.02	0.02	0.02
Fruit yield				
Replication	2	0.03*	0.04*	0.03
Genotypes (G)	35	4.33**	6.87**	4.75**
Parents (P)	7	1.37**	1.27**	3.12**
Hybrids (F_1)	27	4.14**	6.74**	4.64**
P *vs* F_1	1	30.03**	49.67**	19.06**
Error	70	0.01	0.01	0.01

*and **indicate significance at 5% and 1% level of probability, respectively

Table 2: Analysis of variance for various traits pooled over environments in bottle gourd

Source of variation	DF	FFFN	DFPF	SR	DFFH	DLFH	LMV
Environment (E)	2	50.62**	368.98**	50.66**	238.57**	682.39**	7.80**
Repl. within Env.	6	3.63	2.46	0.02	0.57	0.23	0.02
Genotypes (G)	35	38.89**	64.44**	17.92**	60.22**	144.57**	3.56**
Parents (P)	7	31.82**	63.36**	14.49**	76.44**	174.79**	4.96**
Hybrids (F1)	27	41.15**	61.89**	14.46**	56.38**	140.80**	3.07**
P *vs* F1	1	27.49**	140.74**	135.21**	50.54**	34.82**	7.04**
G × E	70	8.04**	8.51**	2.75**	11.94**	26.27**	0.13**
P × E	14	10.16**	10.38**	3.31**	9.56**	19.56**	0.05**
F1 × E	27	7.59**	8.08**	2.63**	12.01**	26.56**	0.16**
(P *vs* F1) × E	2	5.35	7.29*	2.16**	26.73**	65.15**	0.06*
Pooled Error	210	1.83	1.79	0.02	0.46	0.52	0.02
Source of variation	**DF**	**FL**	**FD**	**AFW**	**NP**	**NFPP**	**FY**
Environment (E)	2	224.35**	4.74**	14781.51**	24.64**	48.97**	31.25**
Repl. within Env.	6	9.51	0.35	564.53	0.04	0.02	0.03**
Genotypes (G)	35	472.51**	26.96**	173021.70**	4.94**	10.44**	13.37**
Parents (P)	7	593.92**	35.32**	77724.02**	3.48**	10.06**	3.21**
Hybrids (F1)	27	445.89**	25.65**	192793.81**	4.46**	9.16**	12.97**
P *vs* F1	1	341.39**	3.64**	306258.34**	28.11**	47.50**	95.13**
G × E	70	12.38**	0.60**	1994.40**	0.90**	2.00**	1.29**
P × E	14	9.55	0.94**	1492.17**	0.61**	1.99**	1.28**
F1 × E	27	13.56**	0.52**	2180.36**	1.00**	1.96**	1.28**
(P *vs* F1) × E	2	0.32	0.31	489.09	0.09*	3.17**	1.82**
Pooled Error	210	5.69	0.29	373.23	0.02	0.02	0.01

* and ** indicate significance at 5% and 1% level of probability, respectively

[Note: DF: Degree of freedom; FFFN: First female flower appearing node; DFPF: Days to 50 per cent flowering; SR: Sex ratio; DFFH: Days to first fruit harvest; DLFH: Days to last fruit harvest; LMV: Length of main vine; FL: Fruit length; FD: Fruit diameter; AFW: Average fruit weight; NP: Number of pickings; NFPP: Number of fruits per plant; FY: Fruit yield]

Standard Heterosis

For commercial purposes, the superiority of newly developed F_1 hybrids must assessed by comparing their performances with the best cultivated hybrid/s or variety. For that purpose, ABG 1 was used as a standard check in the present investigation. Among 28 hybrids, standard heterosis for fruit yield registered significant results for 26 hybrids in E_1 and E_3, while 27 hybrids in E_2, out of which 19 hybrids in E_1; 24 hybrids in E_2 and 11 hybrids in E_3 exhibited significant standard heterosis with desired positive direction (Table 4). The standard heterosis for fruit yield ranged from -51.06% (JBG 17- 04 × JBG 17-01) to 43.85% (JBG 17-03 × JBG 17-08) in E_1; -40.03% (JBG 17-04 × JBG 17-01) to 65.18% (JBG 17-03 × JBG 17-08) in E_2 and -56.99% (JBG 17-04 × JBG 17-01) to 23.87% (JBG 17-03 × JBG 17-01) in E_3. The best performing hybrid for standard heterosis was JBG 17-03 × JBG 17-08 (43.85%) followed by JBG 17-07 × DBG 6 (27.94%) and JBG 17-04 × DBG 6 (21.37%) in E_1; hybrid JBG 17-03 × JBG 17-08 (65.18%) followed by JBG 17-04 × DBG 6 (53.78%) and JBG 17-10 × JBG 17- 01 (48.82%) in E_2; hybrid JBG 17-03 × JBG 17-01 (23.87%) followed by JBG 17-07 × JBG 17-03 (17.91%) and JBG 17-04 × JBG 17-10 (16.25%) in E_3 (Table 3). Result of first female flower appearing node was found significant for 23 hybrids in E_1; 25 hybrids in E_2 and 17 hybrids in E_3, out of which 23 hybrids in E_1; 25 hybrids in E_2 and 14 hybrids in E_3 reported significant and negative standard heterosis. The standard heterosis for first female flower appearing node ranged from -60.00% (JBG 17-07 × JBG 17-08) to 4.76% (JBG 17-06 × JBG 17-04) in E_1; -56.00% (JBG 17-07 × JBG 17-08) to -7.11% (JBG 17-04 × JBG 17-10) in E_2 and -53.20% (JBG 17-06 × JBG 17-03) to 27.59% (JBG 17-07 × DBG 6) in E_3. The best performing hybrid for standard heterosis was JBG 17-07 × JBG 17-08 (-60.00%) followed by JBG 17-07 × JBG 17-01 (-56.67%) and JBG 17-06 × JBG 17- 01 (-53.33%) in E_1; hybrid JBG 17-07 × JBG 17-08 (-56.00%) followed by JBG 17-10 × JBG 17-01 (-55.56%) and JBG 17-06 × JBG 17-01 (-53.33%) in E_2; hybrid JBG 17- 06 × JBG 17-03 (-53.20%) followed by DBG 6 × JBG 17-08 (-47.29%) and JBG 17- 07 × JBG 17-01 (-41.87%) in E_3. Days to 50 per cent flowering was found significant for 13 hybrids in E_1; 22 hybrids in E_2 and 15 hybrids in E_3, out of which significant and desirable negative standard heterosis was exhibited only for 1 hybrid in E_1 and E_3 whereas none of the hybrid registered significant and desirable negative standard heterosis in E_3. The standard heterosis for days to 50 per cent flowering ranged from -7.74% (DBG 6 × JBG 17-10) to 14.84% (JBG 17-08 × JBG 17-01) in E_1; -2.04% (JBG 17-06 × JBG 17-04) to 17.01% (JBG 17-06 × JBG 17-01 and JBG 17-07 × JBG 17-01) in E_2 and -6.33% (JBG 17-06 × JBG 17-10) to 21.52% (DBG 6 × JBG 17-08) in E_3. The best performing hybrid for standard heterosis was DBG 6 × JBG 17-10 (-7.74%) in E_1 while hybrid JBG 17-06 × JBG 17-10 (-6.33%) was the best performing hybrid for standard heterosis in E_3. Sex ratio was found significant for 26 hybrids in E_1; 24 hybrids in E_2 and 27 hybrids in E_3, out of which 20 hybrids in E_1; 18 hybrids in E_2 and seven hybrids in E_3 reported significant standard heterosis with desired negative direction. The standard heterosis for sex ratio ranged from -31.80% (JBG 17-07 × JBG 17-10) to 31.04% (JBG 17-06 × JBG 17-01) in E_1; -29.80% (JBG 17-10 × JBG 17-01) to 37.23% (JBG 17-06 × JBG 17-01) in E_2 and -21.37% (JBG 17- 07 × JBG 17-03) to 56.73% (JBG 17-03 × DBG 6) in E_3. The best performing hybrid for standard heterosis was JBG 17-07 × JBG 17-10 (-31.80%) followed by JBG 17-04 × JBG 17-10 (-25.76%) and JBG 17-07 × JBG 17-03 (-25.13%) in E_1; hybrid JBG 17- 10 × JBG 17-01 (-29.80%) followed by JBG 17-07 × JBG 17-10 (-28.97%) and DBG 6 × JBG 17-08 (-25.81%) in E_2; hybrid JBG 17-07 × JBG 17-03 (-21.37%) followed by JBG 17-07 × JBG 17-10 (-13.79%) and JBG 17-06 × JBG 17-08 (-11.43%) in E_3. Days to first fruit harvest found significant for 18 hybrids in E_1; 25 hybrids in E_2 and 26 hybrids in E_3, out of which nine hybrids in E_1; only one hybrid in E_2 and four hybrids in E_3 reported significant standard heterosis with desired negative direction. The standard heterosis for days to first fruit harvest ranged from -6.92% (DBG 6 × JBG 17-10) to 9.98% (JBG 17-07 × DBG 6) in E_1; -2.25% (JBG 17-06 × JBG 17-04) to 17.20% (JBG 17-04 × JBG 17-01) in E_2 and -5.63% (JBG 17-06 × JBG 17-10) to 16.44% (DBG 6 × JBG 17-08) in E_3. The best performing hybrid for standard heterosis was DBG 6 × JBG 17-10 (-6.92%) followed by JBG 17-07 × JBG 17-04 (-6.80%) and JBG 17-07 × JBG 17-08 (-6.12%) in E_1; hybrid JBG 17-06 × JBG 17-04 (-2.25%) in E_2; hybrid JBG 17-06 × JBG 17-10 (-5.63%) followed by JBG 17-03 × JBG 17-10 (-4.50%) and JBG 17-06 × JBG 17-04 (-3.72%) in E_3. Days to last fruit harvest was found significant for 26 hybrids in E_1; 20 hybrids in E_2 and 22 hybrids in E_3, out of which 22 hybrids in E_1; 13 hybrids in E_2 and 15 hybrids in E_3 reported significant standard heterosis with desired negative direction. The standard heterosis for days to last fruit harvest ranged from -9.08% (JBG 17-07 × JBG 17-04) to 5.49% (JBG 17-07 × DBG 6) in E_1; -8.40% (JBG 17-06 × JBG 17-04) to 9.49% (JBG 17-06 × JBG 17-01) in E_2 and -10.42% (JBG 17-06 × JBG 17-10) to 7.57% (DBG 6 × JBG 17-08) in E_3. The best performing hybrid for standard heterosis was JBG 17-07 × JBG 17-04 (-9.08%) followed by JBG 17-03 × JBG 17-08 (-8.64%) and JBG 17-03 × JBG 17-10 (-8.26%) in E_1; hybrid JBG 17-06 × JBG 17-04 (-8.40%) followed by JBG 17-06 × JBG 17-10 (-6.86%) and JBG 17-06 × JBG 17-07 (-6.48%) in E_2; hybrid JBG 17-06 × JBG 17- 10 (-10.42%) followed by JBG 17-04 × JBG 17-03 (-9.74%) and JBG 17-04 × DBG 6 (-6.82%) in E_3. Result for length of main vine found significant for 24 hybrids in E_1; 25 hybrids in E_2 and 23 hybrids in E_3, out of which 23 hybrids in E_1 and E_2 while 15 hybrids in E_3 reported significant standard heterosis with desired positive direction. The standard heterosis for length of main vine ranged from -8.67% (JBG 17-03 × JBG 17-01) to 35.88% (JBG 17-10 × JBG 17-08) in E_1; -7.73% (JBG 17-03 × JBG 17-01) to 34.69% (JBG 17-04 × JBG 17-10) in E_2 and -21.03% (JBG 17-03 × JBG 17-01) to 18.36% (JBG 17-10 × JBG 17-08) in E_3. The best performing hybrid for standard heterosis was JBG 17-10 × JBG 17-08 (35.88%) followed by DBG 6 × JBG 17-10 (31.31%) and JBG 17-04 × JBG 17-10 (28.06%) in E_1; hybrid JBG 17-04 × JBG 17-10 (34.69%) followed by JBG 17-10 × JBG 17-08 (32.96%) and DBG 6 × JBG 17-10 (27.33%) in E_2; hybrid JBG 17-10 × JBG 17-08 (18.36%) followed by JBG 17-07 × JBG 17-03 (15.59%) and DBG 6 × JBG 17-10 (14.92%) in E_3. Fruit length reported significant result for 23 hybrids in E_1; 15 hybrids in E_2 and 24 hybrids in E_3, out of which none of the hybrid in E_1 and E_3 reported significant and desired positive heterosis while only two hybrids in E_2 reported significant standard heterosis with desired positive direction. The standard heterosis for fruit length ranged from -70.72% (JBG 17-06 × JBG 17-01) to -0.17% (JBG 17-04 × DBG 6) in E_1; -61.16% (JBG 17-06 × JBG 17-01) to 23.61% (JBG 17-06 × DBG 6) in E_2 and -68.91% (DBG 6 × JBG 17-01) to 2.27% (JBG 17-06 × JBG 17-04) in E_3. The best performing hybrid for standard heterosis was JBG 17-06 × DBG 6 (23.61%) followed by JBG 17-04 × DBG 6 (18.21%) in E_2. Fruit diameter exhibited significant result for 27 hybrids in all three environments E_1, E_2 and E_3, out of which all 27 hybrids had reported significant standard heterosis with desired positive direction in all three environments E_1, E_2 and E_3. The standard heterosis for fruit diameter ranged from 8.92% (JBG 17-07 × JBG 17-08) to 137.18% (JBG 17-06 × JBG 17-01) in E_1; 16.82% (JBG 17-07 × JBG 17-08) to 218.09% (JBG 17-06 × JBG 17-01) in E_2 and 3.41% (JBG 17-07 × JBG 17-08) to 172.20% (JBG 17-06 × JBG 17-01) in E_3. The best performing hybrid for standard heterosis was JBG 17-06 × JBG 17-01 (137.18%) followed by DBG 6 × JBG 17-01 (135.21%) and JBG 17-07 × JBG 17-01 (100.91%) in E_1; hybrid JBG 17-06 × JBG 17-01 (218.09%) followed by DBG 6 × JBG 17-01 (181.76%) and JBG 17-07 × JBG 17-01 (122.72%) in E_2; hybrid JBG 17-06 × JBG 17-01 (172.20%) followed by DBG 6 × JBG 17-01 (118.95%) and JBG 17-07 × JBG 17-04 (73.40%) in E_3. Result of average fruit weight showed significant for 24 hybrids in E_1 and E_3, while 25 hybrids in E_2, out of which 21 hybrids reported significant standard heterosis with desired positive direction in E_1 and E_3 and 22 hybrids appeared with significant standard heterosis with desired positive direction in E_2. The standard heterosis for average fruit weight ranged from -44.89% (JBG 17- 04 × JBG 17-01) to 48.36% (JBG 17-08 × JBG 17-01) in E_1; -36.79% (JBG 17-04 × JBG 17-01) to 60.49% (JBG 17-08 × JBG 17-01) in E_2 and -37.67% (JBG 17-04 × JBG 17-01) to 53.44% (JBG 17-06 × JBG 17-01) in E_3. The best performing hybrid for standard heterosis was JBG 17-08 × JBG 17-01 (48.36%) followed by JBG 17-06 × JBG 17-01 (47.59%) and JBG 17-03 × JBG 17-08 (46.64%) in E_1; hybrid JBG 17-08 × JBG 17-01 (60.49%) followed by JBG 17-06 × JBG 17-01 (59.93%) and JBG 17-04 × DBG 6 (55.79%) in E_2; hybrid JBG 17-06 × JBG 17-01 (53.44%) followed by JBG 17-08 × JBG 17-01 (48.96%) and JBG 17-03 × DBG 6 (42.66%) in E_3. Result of number of pickings revealed significance for 23 hybrids in E_1 while 26 hybrids in E_2 and E_3. Out of which seven hybrids showed significant standard heterosis with desired positive direction in E_1 whereas 10 hybrids revealed significant standard heterosis with desired positive direction in E_2 and E_3. The standard heterosis for number of pickings ranged from -35.87% (JBG 17-10 × JBG 17-08) to 14.35% (JBG 17-07 × JBG 17-10 and JBG 17-04 × JBG 17-10) in E_1; -17.65% (JBG 17-06 × JBG 17-01 and JBG 17-03 × DBG 6) to 13.03% (DBG 6 × JBG 17-01) in E_2 and -27.62% (JBG 17-04 × JBG 17-03) to 12.38% (JBG 17-07 × JBG 17-03) in E_3. The best performing hybrid for standard heterosis was JBG 17-07 × JBG 17-10 and JBG 17-04 × JBG 17-10 (14.35%) followed by DBG 6 × JBG 17-01 (9.87%) and JBG 17-08 × JBG 17-01 (8.97%) in E_1; hybrid DBG 6 × JBG 17-01 (13.03%) followed by JBG 17-07 × JBG 17-10 and JBG 17-08 × JBG 17-01 (9.66%) and JBG 17-04 × JBG 17-08 (9.24%) in E_2; hybrid JBG 17-07 × JBG 17-03 (12.38%) followed by JBG 17-08 × JBG 17-01 (11.43%) and DBG 6 × JBG 17-01 (9.05%) in E_3. Number of fruits per plant exhibited significant result for 23 hybrids in E_1 and E_2, while 28 hybrids in E_3, out of which four hybrids in E_1; 11 hybrids in E_2 and only one hybrid in E_3 had reported significant standard heterosis with desired positive direction. The standard heterosis for number of fruits per plant ranged from -32.65% (JBG 17-06 × JBG 17-01) to 13.61% (JBG 17-07 × JBG 17-10) in E_1; -30.06% (JBG 17-03 × DBG 6) to 19.62% (JBG 17-04 × JBG 17- 08) in E_2 and -39.45% (JBG 17-03 × DBG 6) to 2.75% (JBG 17-07 × JBG 17-03) in E_3. The best performing hybrid for standard heterosis was JBG 17-07 × JBG 17-10 (13.61%) followed by JBG 17-04 × JBG 17-10 (8.84%) and JBG 17-06 × JBG 17-03 (8.50%) in E_1; hybrid JBG 17-04 × JBG 17-08 (19.62%) followed by DBG 6 × JBG 17-08 (16.77%) and JBG 17-10 × JBG 17-01 (16.46%) in E_2; hybrid 17-07 × JBG 17- 03 (2.75%) in E_3.

It was noted that several hybrids exhibiting higher heterosis over standard check ABG 1 for fruit yield, in general, also manifested desirable heterotic effects for most of the important yield components *e.g.*, hybrid JBG 17-03 × JBG 17-08, having highest standard heterosis for fruit yield in E_1 and E_2 reported significant heterosis in desired direction over standard check for its yield components as well as other traits like first female flower appearing node, sex ratio, days to first fruit harvest, days to last fruit harvest, length of main vine, fruit diameter, average fruit weight and number of fruits per plant; hybrid JBG 17-03 × JBG 17-01, having highest standard heterosis for fruit yield in E_3 reported significant heterosis in desired direction over standard check for its yield components as well as other traits like first female flower appearing node, sex ratio, days to last fruit harvest, fruit diameter and average fruit weight. These results suggested that standard heterosis for fruit yield resulted due to the desirable heterotic effects of yield contributing traits. Similar findings were reported by Singh *et al*. (2012*a*) [17], Yadav and Kumar (2012*a*) [19], Gayakawad (2014) [6], Kumar *et al*. (2014*b*) [9], Ghuge *et al*. (2016) [7], Doloi *et al*. (2018) [5], Mishra *et al*. (2019*b*) [13], Quamruzzaman *et al*. (2019) [16], Balat *et al*. (2020) [2], Jayanth *et al*. (2020) [8], Kumar and Ram (2021) [10], Lal *et al*. (2021) [11] and Patel and Mehta (2021) [15].

The top ten hybrids across the environments with respect to their *per se* performance for fruit yield are listed in Table 5 along with the magnitude of heterosis over standard check ABG 1, SCA effects as well as component traits with significant standard heterosis in desired direction. According to that, all the top ten hybrids significantly out yielded standard check ABG 1 and manifested significant standard heterosis for fruit yield in desirable direction across the environments. All the top ten hybrids also exhibited highly significant SCA effects in desired direction for fruit yield which defined that heterosis breeding in bottle gourd is rewarding.

The highest yielding hybrid across the environments JBG 17-03 × JBG 17-08 showed significant heterosis in desired direction over standard check ABG 1 for most of important yield contributing traits *viz*., first female flower appearing node, sex ratio, days to last fruit harvest, length of main vine, fruit diameter and average fruit weight. Similarly, following hybrids JBG 17-04 × DBG 6 and JBG 17-03 × JBG 17-10 also showed significant and desired heterosis over standard check for most of the important yield components including first female flower appearing node, days to last fruit harvest, length of main vine, fruit diameter and average fruit weight. This emphasized that high degree of standard heterosis for fruit yield might be resulted due to the significant and desirable heterosis observed for their important component traits. Similar relationship of heterosis for fruit yield and yield components in bottle gourd had also been reported by Yadav and Kumar (2012*a*) [19], Gayakawad (2014) [6], Kumar *et al*. (2014*b*) [9], Ghuge *et al*. (2016) [7], Doloi *et al*. (2018) [5], Mishra *et al*. (2019*b*) [13], Quamruzzaman *et al*. (2019) [16], Balat *et al*. (2020) [2], Jayanth *et al*. (2020) [8], Kumar and Ram (2021) [10], Lal *et al*. (2021) [11] and Patel and Mehta (2021) [15].

Table 3: Estimation of heterosis over standard check under individual environments for fruit yield (kg/plant) in bottle gourd

SN	Hybrids	E_1 (Late *rabi*)	E_2 (Summer)	E_3 (*Kharif*)
1.	JBG 17-06 × JBG 17-07	-8.32 **	3.83 **	-7.96 **
2.	JBG 17-06 × JBG 17-04	3.92 **	28.02 **	-5.50 **
3.	JBG 17-06 × JBG 17-03	4.14 **	10.63 **	-17.62 **
4.	JBG 17-06 × DBG 6	-1.80	11.20 **	-1.99
5.	JBG 17-06 × JBG 17-10	14.53 **	26.18 **	-4.78 **
6.	JBG 17-06 × JBG 17-08	6.47 **	0.15	5.73 **
7.	JBG 17-06 × JBG 17-01	-1.06	14.37 **	1.28
8.	JBG 17-07 × JBG 17-04	11.93 **	26.12 **	5.83 **
9.	JBG 17-07 × JBG 17-03	16.65 **	20.55 **	17.91 **
10.	JBG 17-07 × DBG 6	27.94 **	12.58 **	-5.68 **
11.	JBG 17-07 × JBG 17-10	20.78 **	24.95 **	7.30 **
12.	JBG 17-07 × JBG 17-08	-11.56 **	4.86 **	-12.55 **
13.	JBG 17-07 × JBG 17-01	5.36 **	3.94 **	5.02 **
14.	JBG 17-04 × JBG 17-03	-30.59 **	-37.01 **	-45.57 **
15.	JBG 17-04 × DBG 6	21.37 **	53.78 **	5.16 **
16.	JBG 17-04 × JBG 17-10	16.76 **	18.97 **	16.25 **
17.	JBG 17-04 × JBG 17-08	-16.91 **	-3.89 **	-24.96 **
18.	JBG 17-04 × JBG 17-01	-51.06 **	-40.03 **	-56.99 **
19.	JBG 17-03 × DBG 6	7.32 **	3.53 **	-14.21 **
20.	JBG 17-03 × JBG 17-10	17.82 **	41.05 **	8.10 **
21.	JBG 17-03 × JBG 17-08	43.85 **	65.18 **	3.03 **
22.	JBG 17-03 × JBG 17-01	13.63 **	26.48 **	23.87 **
23.	DBG 6 × JBG 17-10	3.55 **	18.66 **	-5.68 **
24.	DBG 6 × JBG 17-08	-11.56 **	23.47 **	-23.59 **
25.	DBG 6 × JBG 17-01	5.78 **	32.72 **	-11.65 **
26.	JBG 17-10 × JBG 17-08	-10.34 **	7.52 **	-15.54 **
27.	JBG 17-10 × JBG 17-01	19.35 **	48.82 **	-7.06 **
28.	JBG 17-08 × JBG 17-01	13.52 **	39.37 **	9.14 **
	S.Ed ±	0.08	0.08	0.08
	CD @ 5%	0.15	0.16	0.15
	CD @ 1%	0.20	0.21	0.20

*and ** indicate significance at 5% and 1% level of probability, respectively
[**Note:** S.E.D.: Standard error of difference; CD: Critical difference]

Table 4: Number of crosses showing significant and desirable standard heterosis for fruit yield, its components and allied traits in individual environment in bottle gourd

SN	Characters	E_1 (Late *rabi*)	E_2 (Summer)	E_3 (*Kharif*)
1	First female flower appearing node	23	25	14
2	Days to 50 per cent flowering	1	0	1
3	Sex ratio	20	18	7
4	Days to first fruit harvest	9	1	4
5	Days to last fruit harvest	22	13	15
6	Length of main vine (m)	23	23	15
7	Fruit length (cm)	0	2	0
8	Fruit diameter (cm)	27	27	27
9	Average fruit weight (g)	21	22	21
10	Number of pickings	7	10	10
11	Number of fruits per plant	4	11	1
12	Fruit yield (kg/plant)	19	24	11

Table 5: Performance of top ten (10) high yielding hybrids for standard heterosis, their SCA effects and significant components for fruit yield in pooled analysis

Hybrids	Fruit yield	Standard Heterosis	SCA Effect	Components with significant and desirable standard heterosis
JBG 17-03 × JBG 17-08	9.02	36.39 **	2.25**	FFFN, SR, DLFH, LMV, FD, AFW
JBG 17-04 × DBG 6	8.35	26.27 **	2.30**	FFFN, DLFH, LMV, FD, AFW
JBG 17-03 × JBG 17-10	8.07	22.01 **	0.76**	FFFN, DLFH, LMV, FD, AFW
JBG 17-03 × JBG 17-01	8.04	21.48 **	1.37**	FFFN, SR, DLFH, FD, AFW
JBG 17-08 × JBG 17-01	7.97	20.46 **	1.38**	LMV, FD, AFW, NP
JBG 17-10 × JBG 17-01	7.92	19.67 **	0.78**	FFFN, SR, DLFH, LMV, FD, AFW
JBG 17-07 × JBG 17-03	7.83	18.38 **	0.96**	FFFN, SR, DLFH, LMV, FD, AFW, NP, NFPP
JBG 17-07 × JBG 17-10	7.76	17.37 **	0.42**	FFFN, SR, LMV, FD, AFW, NP, NFPP
JBG 17-04 × JBG 17-10	7.76	17.30 **	1.02**	SR, DLFH, LMV, FD, AFW, NP
JBG 17-07 × JBG 17-04	7.57	14.43 **	1.27**	FFFN, DLFH, FD, AFW

* and ** indicate significance at 5% and 1% level of probability, respectively

[Note:- SCA: Specific combining ability; FFFN: First female flower appearing node; DFPF: Days to 50 per cent flowering; SR: Sex ratio; DFFH: Days to first fruit harvest; DLFH: Days to last fruit harvest; LMV: Length of main vine; FL: Fruit length; FD: Fruit diameter; AFW: Average fruit weight; NP: Number of pickings; NFPP: Number of fruits per plant; FY: Fruit yield]

Conclusion

The magnitude of heterosis varied from cross to cross for all the traits studied, of these, the traits of economic importance in bottle gourd are resulted as fruit yield and their yield components. Thus, the heterotic response obtained for such traits is of greater importance for the purpose of plant improvement. The measure of heterosis over better parental value has relatively limited importance and is of more academic interest. On the contrary, the heterosis measured over the standard check variety (standard or economic heterosis) is of much practical importance. The estimation of standard heterosis for yield and its components would therefore be useful to judge the best hybrid combination for exploitation of superior hybrids. On the basis of higher *per* se performance, higher standard heterosis and desirable SCA effects with respect to fruit yield, hybrid JBG 17-03 × JBG 17-08, JBG 17-04 × DBG 6 and JBG 17-03 × JBG 17-10 registered highly significant standard heterosis over the environments thus providing ample scope to isolate best performing genotypes in later segregating generations.

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