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Study of heterobeltiosis 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 heterobeltiosis for fruit yield and its component traits. The experimental material consisted of total 36 entries which include eight parents and their 28 F_1 hybrids. 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 better parent were JBG 17-03 × JBG 17-08 (54.41%), JBG 17-07 × DBG 6 (52.05%) and JBG 17-04 × DBG 6 (45.43%) in E_1; hybrid JBG 17-04 × DBG 6 (81.31%), JBG 17-03 × JBG 17-08 (59.63%) and JBG 17-10 × JBG 17-01 (57.95%) in E_2; hybrid JBG 17-03 × JBG 17-01 (65.93%), JBG 17-07 × JBG 17-03 (52.98%) and JBG 17-06 × DBG 6 (36.57%) in E_3 and hybrid JBG 17-03 × JBG 17-08 (50.02%), JBG 17-03 × JBG 17-01 (48.38%) and JBG 17-04 × DBG 6 (48.21%) in pooled over environments.

Keywords: Bottle gourd, diallel analysis, heterobeltiosis, pooled over environments

1. 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) [17]. 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.

2. Materials and Methods

The experimental material used for the present investigation consisted total 36 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) and their 28 F_1 hybrids produced using 8 × 8 diallel mating design excluding reciprocals (method-II; model-I). 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 better parents as heterobeltiosis according to the procedure given by Fonseca and Patterson (1968) [6] 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, low scoring parents were considered to be the better parents for the estimation of heterosis and for rest of the aforesaid traits, high scoring parents were considered to be the better parents. The test of significance of heterobeltiosis 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.

3. Results and Discussion

3.1 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.

3.2 Heterobeltiosis

An evaluation of hybrids in terms of heterotic performance over better parent for fruit yield (kg/plant) (Table 3) revealed that among 28 hybrids, significant fruit yield resulted for 26 hybrids in E_1 (Late *Rabi*) and 27 hybrids in E_2 (Summer) and E_3 (*Kharif*), out of which 23 hybrids in E_1, 22 hybrids in E_2 and 17 hybrids in E_3 revealed significant heterobeltiosis with desirable positive direction (Table 4). The heterobeltiosis for fruit yield ranged from -41.36% (JBG 17-04 × JBG 17-01) to 54.41% (JBG 17-03 × JBG 17-08) in E_1; -36.35% (JBG 17-04 × JBG 17-01) to 81.31% (JBG 17-04 × DBG 6) in E_2 and -50.63% (JBG 17-04 × JBG 17-01) to 65.93% (JBG 17-03 × JBG 17-01) in E_3. The best performing hybrid for heterobeltiosis was JBG 17-03 × JBG 17-08 (54.41%) followed by JBG 17-07 × DBG 6 (52.05%) and JBG 17-04 × DBG 6 (45.43%) in E_1; hybrid JBG 17-04 × DBG 6 (81.31%) followed by JBG 17-03 × JBG 17-08 (59.63%) and JBG 17-10 × JBG 17-01 (57.95%) in E_2; hybrid JBG 17-03 × JBG 17-01 (65.93%) followed by JBG 17-07 × JBG 17-03 (52.98%) and JBG 17-06 × DBG 6 (36.57%) in E_3. Result of first female flower appearing node was found significant for 16 hybrids in season E_1 whereas 13 hybrids in E_2 and E_3, out of which, three hybrids in E_1 and only one hybrid in E_3 exhibited significant and negative heterobeltiosis. None of the hybrid was found significant in desired negative direction in E_2. The heterobeltiosis for first female flower appearing node ranged from -34.38% (JBG 17-07 × JBG 17-08) to 87.39% (JBG 17-07 × DBG 6) in E_1; -19.35% (JBG 17-10 × JBG 17-01) to 118.68% (JBG 17-07 × DBG 6) in E_2 and -31.65% (JBG 17-06 × JBG 17-03) to 219.75% (JBG 17-07 × DBG 6) in E_3. The best performing hybrid for heterobeltiosis was JBG 17-07 × JBG 17-08 (-34.38%) followed by JBG 17-03 × JBG 17-08 (-26.11%) and JBG 17-06 × JBG 17-03 (-25.50%) in E_1, while hybrid JBG 17-06 × JBG 17-03 (-31.65%) was best performing for heterobeltiosis in E_3. Days to 50 per cent flowering was found significant for 18 hybrids in E_1; 19 hybrids in E_2 and 13 hybrids in E_3, out of which significant and desirable negative better parent heterosis was exhibited for 10 hybrids in E_1 and E_2 whereas six hybrids in E_3. The better parent heterosis for days to 50 per cent flowering ranged from -13.86% (DBG 6 × JBG 17-10) to 17.69% (JBG 17-03 × DBG 6) in E_1; -7.69% (JBG 17-06 × JBG 17-04) to 13.16% (JBG 17-06 × JBG 17-01 and JBG 17-07 × JBG 17-01) in E_2 and -17.78% (JBG 17-06 × JBG 17-10) to 15.82% (JBG 17-08 × JBG 17-01) in E_3. The best performing hybrid for better parent heterosis was DBG 6 × JBG 17-10 (-13.86%) followed by JBG 17-06 × JBG 17-10 (-11.49%) and JBG 17-07 × JBG 17-04 (-10.06%) in E_1; hybrid JBG 17-06 × JBG 17-04 (-7.69%) followed by JBG 17-04 × JBG 17-08 (-

7.32%) and JBG 17-07 × JBG 17-08 (-5.03%) in E_2; hybrid JBG 17-06 × JBG 17-10 (-17.78%) followed by JBG 17-06 × JBG 17-04 (-14.44%) and JBG 17-07 × JBG 17-04 (-9.30%) in E_3. Sex ratio was found significant for 27 hybrids in E_1; 28 hybrids in E_2 and E_3, out of which 27 hybrids in E_1; 24 hybrids in E_2 and 26 hybrids in E_3 had reported significant and desirable negative heterobeltiosis. The heterobeltiosis for sex ratio ranged from -42.29% (JBG 17-06 × JBG 17-03) to -0.84% (JBG 17-06 × JBG 17-01) in E_1; -46.95% (JBG 17-03 × JBG 17-08) to 16.63% (JBG 17-06 × JBG 17-01) in E_2 and -47.96% (JBG 17-07 × JBG 17-03) to 4.40% (JBG 17-04 × JBG 17-10) in E_3. The best performing hybrid for heterobeltiosis was JBG 17-06 × JBG 17-03 (-42.29%) followed by JBG 17-07 × JBG 17-10 (-39.14%) and JBG 17-07 × JBG 17-03 (-38.61%) in E_1; hybrid JBG 17-03 × JBG 17-08 (-46.95%) followed by JBG 17-06 × JBG 17-03 (-46.56%) and JBG 17-07 × JBG 17-03 (-41.63%) in E_2; hybrid JBG 17-07 × JBG 17-03 (-47.96%) followed by JBG 17-06 × JBG 17-08 (-42.65%) and JBG 17-03 × JBG 17-01 (-39.35%) in E_3. Days to first fruit harvest was found significant for 22 hybrids in E_1; 24 hybrids in E_2 and E_3, out of which significant and desirable negative heterobeltiosis was exhibited for 13 hybrids in E_1; five hybrids in E_2 and nine hybrids in E_3. For days to first fruit harvest, heterobeltiosis was ranged from -12.47% (DBG 6 × JBG 17-10) to 14.59% (JBG 17-03 × DBG 6) in E_1; -10.57% (DBG 6 × JBG 17-10) to 17.76% (JBG 17-04 × JBG 17-01) in E_2 and -9.25% (JBG 17-04 × DBG 6) to 15.48% (JBG 17-04 × JBG 17-01) in E_3. The best performing hybrid for heterobeltiosis was DBG 6 × JBG 17-10 (-12.47%) followed by JBG 17-07 × JBG 17-04 (-10.46%) and JBG 17-07 × JBG 17-08 (-9.80%) in E_1; hybrid DBG 6 × JBG 17-10 (-10.57%) followed by JBG 17-04 × DBG 6 (-7.47%) and JBG 17-04 × JBG 17-03 (-2.99%) in E_2; hybrid JBG 17-04 × DBG 6 (-9.25%) followed by JBG 17-06 × JBG 17-10 (-8.91%) and JBG 17-06 × JBG 17-04 (-7.07%) in E_3. Days to last fruit harvest was found significant for 25 hybrids in E_1; 22 hybrids in E_2 and E_3, out of which significant and desirable negative better parent heterosis was exhibited for 12 hybrids in E_1; three hybrids in E_2 and nine hybrids in E_3. For days to last fruit harvest, better parent heterosis was ranged from -8.96% (JBG 17-07 × JBG 17-04) to 12.90% (JBG 17-03 × DBG 6) in E_1; -8.88% (JBG 17-04 × DBG 6) to 18.62% (JBG 17-06 × JBG 17-01) in E_2 and -10.86% (JBG 17-04 × DBG 6) to 16.31% (JBG 17-04 × JBG 17-01) in E_3. The best performing hybrid for better parent heterosis was JBG 17-07 × JBG 17-04 (-8.96%) followed by JBG 17-04 × JBG 17-10 (-8.14%) and DBG 6 × JBG 17-10 (-7.84%) in E_1; hybrid JBG 17-04 × DBG 6 (-8.88%) followed by DBG 6 × JBG 17-10 (-6.82%) and JBG 17-04 × JBG 17-10 (-3.17%) in E_2; hybrid JBG 17-04 × DBG 6 (-10.86%) followed by JBG 17-04 × JBG 17-03 (-8.95%) and JBG 17-06 × JBG 17-10 (-7.61%) in E_3. Length of main vine was found significant for 16 hybrids in E_1; 14 hybrids in E_2 and 18 hybrids in E_3, out of which eight hybrids in E_1; five hybrids in E_2 and nine hybrids in E_3 reported significant and desirable positive heterobeltiosis. The heterobeltiosis for length of main vine ranged from -22.52% (JBG 17-03 × JBG 17-01) to 7.94% (JBG 17-10 × JBG 17-08) in E_1; -23.72% (JBG 17-03 × JBG 17-01) to 9.78% (JBG 17-04 × JBG 17-10) in E_2 and -27.19% (JBG 17-03 × JBG 17-01) to 8.05% (JBG 17-10 × JBG 17-08) in E_3. The best performing hybrid for heterobeltiosis was JBG 17-10 × JBG 17-08 (7.94%) followed by DBG 6 × JBG 17-01 (6.29%) and JBG 17-06 × JBG 17-03 (5.92%) in E_1; hybrid JBG 17-04 × JBG 17-10 (9.78%) followed by JBG 17-10 × JBG 17-08 (8.37%) and JBG 17-04 × DBG 6 (4.14%) in E_2; hybrid JBG 17-10 × JBG 17-08 (8.05%) followed by JBG 17-07 × JBG 17-03 (6.57%) and JBG 17-06 × DBG 6 (5.02%) in E_3. Fruit length was reported significant for 17 hybrids in E_1; 16 hybrids in E_2 and 11 hybrids in E_3, out of which eight hybrids in E_1; six hybrids in E_2 and five hybrids in E_3 exhibited significant and desirable positive better parent heterosis. The better parent heterosis for fruit length ranged from -63.85% (DBG 6 × JBG 17-01) to 26.85% (JBG 17-03 × JBG 17-10) in E_1; -61.46% (DBG 6 × JBG 17-01) to 34.44% (JBG 17-06 × JBG 17-04) in E_2 and -63.99% (DBG 6 × JBG 17-01) to 30.30% (JBG 17-06 × JBG 17-04) in E_3. The best performing hybrid for better parent heterosis was JBG 17-03 × JBG 17-10 (26.85%) followed by JBG 17-06 × JBG 17-04 (22.69%) and JBG 17-10 × JBG 17-01 (20.06%) in E_1; hybrid JBG 17-06 × JBG 17-04 (34.44%) followed by JBG 17-10 × JBG 17-01 (26.35%) and JBG 17-03 × JBG 17-10 (25.07%) in E_2; hybrid JBG 17-06 × JBG 17-04 (30.30%) followed by JBG 17-04 × JBG 17-10 (21.97%) and JBG 17-06 × DBG 6 (18.14%) in E_3. Fruit diameter was reported significant for 19 hybrids in E_1; 13 hybrids in E_2 and 16 hybrids in E_3, out of which seven hybrids in E_1; five hybrids in E_2 and E_3 reported significant and desirable positive heterobeltiosis. The heterobeltiosis for fruit diameter ranged from -40.67% (JBG 17-04 × JBG 17-01) to 26.18% (JBG 17-03 × DBG 6) in E_1; -47.80% (JBG 17-04 × JBG 17-01) to 29.83% (JBG 17-03 × DBG 6) in E_2 and -51.47% (JBG 17-04 × JBG 17-01) to 25.74% (JBG 17-03 × DBG 6) in E_3. The best performing hybrid for heterobeltiosis was JBG 17-03 × DBG 6 (26.18%) followed by JBG 17-07 × JBG 17-04 (20.58%) and JBG 17-07 × JBG 17-03 (19.49%) in E_1; hybrid JBG 17-03 × DBG 6 (29.83%) followed by JBG 17-07 × JBG 17-03 (21.54%) and JBG 17-06 × JBG 17-07 (16.32%) in E_2; hybrid JBG 17-03 × DBG 6 (25.74%) followed by JBG 17-07 × JBG 17-03 (22.91%) and JBG 17-07 × JBG 17-04 (20.03%) in E_3. Average fruit weight reported significant result for 21 hybrids in E_1; 19 hybrids in E_2 and 20 hybrids in E_3, out of which 14 hybrids in E_1; 12 hybrids in E_2 and 11 hybrids in E_3 reported significant and desirable positive better parent heterosis. The better parent heterosis for average fruit weight ranged from -50.71% (JBG 17-04 × JBG 17-01) to 45.43% (JBG 17-04 × DBG 6) in E_1; -47.97% (JBG 17-04 × JBG 17-01) to 47.19% (JBG 17-04 × DBG 6) in E_2 and -50.90% (JBG 17-04 × JBG 17-01) to 33.33% (JBG 17-04 × DBG 6) in E_3. The best performing hybrid for better parent heterosis was JBG 17-04 × DBG 6 (45.43%) followed by JBG 17-08 × JBG 17-01 (32.70%) and JBG 17-07 × DBG 6 (30.10%) in E_1; hybrid JBG 17-04 × DBG 6 (47.19%) followed by JBG 17-08 × JBG 17-01 (32.10%) and JBG 17-07 × DBG 6 (30.93%) in E_2; hybrid JBG 17-04 × DBG 6 (33.33%) followed by JBG 17-07 × DBG 6 (28.14%) and JBG 17-07 × JBG 17-04 (28.04%) in E_3. Result for number of pickings exhibited significant for 22 hybrids in E_1 and 24 hybrids in E_2 and E_3, out of which 14 hybrids in E_1 while 15 hybrids in E_2 and E_3 reported significant and desirable positive heterobeltiosis. The heterobeltiosis for number of pickings ranged from -34.05% (JBG 17-06 × JBG 17-07) to 34.46% (DBG 6 × JBG 17-08) in E_1; -17.89% (JBG 17-07 × JBG 17-01) to 27.27% (JBG 17-06 × JBG 17-10) in E_2 and -27.96% (JBG 17-04 × JBG 17-03) to 29.28% (JBG 17-08 × JBG 17-01) in E_3. The best performing hybrid for heterobeltiosis was DBG 6 × JBG 17-08 (34.46%) followed by JBG 17-04 × JBG 17-10 (31.44%)

and DBG 6 × JBG 17-01 (26.94%) in E_1; hybrid JBG 17-06 × JBG 17-10 (27.27%) followed by DBG 6 × JBG 17-01 (26.96%) and DBG 6 × JBG 17-08 (23.92%) in E_2; hybrid JBG 17-08 × JBG 17-01 (29.28%) followed by JBG 17-06 × JBG 17-03 (23.78%) and JBG 17-06 × JBG 17-08 (23.20%) in E_3. Number of fruits per plant exhibited significant result for 22 hybrids in E_1; 28 hybrids in E_2 and 26 hybrids in E_3, out of which 16 hybrids in E_1; 20 hybrids in E_2 and eight hybrids in E_3 showed significant better parent heterosis with desired positive direction. The better parent heterosis for number of fruits per plant ranged from -14.95% (DBG 6 × JBG 17-10) to 42.41% (JBG 17-06 × JBG 17-03) in E_1; -26.33% (JBG 17-03 × DBG 6) to 44.31% (JBG 17-10 × JBG 17-01) in E_2 and -31.25% (JBG 17-03 × DBG 6) to 59.07% (JBG 17-03 × JBG 17-01) in E_3. The best performing hybrid for heterobeltiosis was JBG 17-06 × JBG 17-03 (42.41%) followed by JBG 17-07 × JBG 17-03 (26.91%) and JBG 17-07 × JBG 17-10 (18.86%) in E_1; hybrid JBG 17-10 × JBG 17-01 (44.31%) followed by JBG 17-04 × JBG 17-10 (25.10%) and JBG 17-06 × JBG 17-03 (23.55%) in E_2; hybrid JBG 17-03 × JBG 17-01 (59.07%) followed by JBG 17-06 × JBG 17-03 (34.67%) and JBG 17-07 × JBG 17-03 (30.74%) in E_3.

It was observed that majority of hybrids exhibiting higher heterobeltiosis for fruit yield, in general, also reported desirable heterotic effects for many of their important yield components *e.g.* hybrid JBG 17-03 × JBG 17-08, having highest heterobeltiosis for fruit yield in E_1 reported significant heterobeltiosis in desired direction for its yield components as well as other traits like first female flower appearing node, sex ratio, length of main vine, fruit length, average fruit weight, number of pickings and number of fruits per plant; hybrid JBG 17-04 × DBG 6, having highest heterobeltiosis for fruit yield in E_2, also showed significant and desired heterobeltiosis for its yield components and other traits like days to 50 per cent flowering, sex ratio, days to first fruit harvest, days to last fruit harvest, length of main vine, fruit length, average fruit weight, number of pickings and number of fruits per plant; hybrid JBG 17-03 ×JBG 17-01 with highest heterobeltiosis for fruit yield in E_3 registered significant and desired heterobeltiosis for yield components like sex ratio, average fruit weight and number of fruits per plant. These results suggested that heterobeltiosis for fruit yield resulted due to the desirable heterotic effects of yield contributing traits. Similar findings were reported by Gayakawad (2014) [7], Ghuge *et al.* (2016) [8], 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) [9], Kumar and Ram (2021) [11], Lal *et al.* (2021) [12] and Patel and Mehta (2021) [15].

The top ten hybrids across the seasons with respect to their *per se* performance for fruit yield are listed in Table 5 along with the magnitude of heterosis over better parent, SCA effects as well as component traits with significant heterosis in desired direction. According to that, all the top ten hybrids manifested highly significant heterobeltiosis and SCA effects for fruit yield in desirable direction across the environments 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 better parent for most of important yield contributing traits *viz*., sex ratio, length of main vine, average fruit weight, number of pickings, number of fruits per plant. Similarly, following hybrid JBG 17-04 × DBG 6 also showed significant and desired heterosis over better parent for most of the important yield components including first female flower appearing node, days to 50 per cent flowering, sex ratio, days to first fruit harvest, days to last fruit harvest, average fruit weight and number of pickings. This emphasized that high degree of better parent heterosis for fruit yield might be resulted due to the significant and desirable heterobeltiosis 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*) [18], Gayakawad (2014) [7], Kumar *et al.* (2014*b*) [10], Ghuge *et al.* (2016) [8], 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) [9], Kumar and Ram (2021) [11], Lal *et al.* (2021) [12] and Patel and Mehta (2021) [15].

Table 1: Analysis of variance for various characters 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 characters 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 (F_1)	27	41.15**	61.89**	14.46**	56.38**	140.80**	3.07**
P *vs* F_1	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**
F_1 × E	27	7.59**	8.08**	2.63**	12.01**	26.56**	0.16**
(P *vs* F_1) × 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 (F_1)	27	445.89**	25.65**	192793.81**	4.46**	9.16**	12.97**
P *vs* F_1	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**
F_1 × E	27	13.56**	0.52**	2180.36**	1.00**	1.96**	1.28**
(P *vs* F_1) × 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]

Table 3: Estimates of heterosis over better parent 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	8.95 **	-3.93 **	19.42 **
2.	JBG 17-06 × JBG 17-04	24.52 **	18.45 **	8.48 **
3.	JBG 17-06 × JBG 17-03	11.78 **	2.37 *	14.79 **
4.	JBG 17-06 × DBG 6	21.05 **	2.89 *	36.57 **
5.	JBG 17-06 × JBG 17-10	9.15 **	16.75 **	-13.99 **
6.	JBG 17-06 × JBG 17-08	27.33 **	-7.33 **	23.25 **
7.	JBG 17-06 × JBG 17-01	21.96 **	5.82 **	35.66 **
8.	JBG 17-07 × JBG 17-04	33.02 **	33.71 **	21.48 **
9.	JBG 17-07 × JBG 17-03	25.21 **	27.80 **	52.98 **
10.	JBG 17-07 × DBG 6	52.05 **	19.35 **	22.37 **
11.	JBG 17-07 × JBG 17-10	15.11 **	32.47 **	-3.08 **
12.	JBG 17-07 × JBG 17-08	5.10 **	1.33	1.93
13.	JBG 17-07 × JBG 17-01	25.20 **	10.19 **	36.26 **
14.	JBG 17-04 × JBG 17-03	-25.50 **	-25.74 **	-37.52 **
15.	JBG 17-04 × DBG 6	45.43 **	81.31 **	20.72 **
16.	JBG 17-04 × JBG 17-10	11.27 **	30.36 **	5.01 **
17.	JBG 17-04 × JBG 17-08	-0.63	-7.11 **	-13.87 **
18.	JBG 17-04 × JBG 17-01	-41.36 **	-36.35 **	-50.63 **
19.	JBG 17-03 × DBG 6	15.20 **	23.03 **	23.11 **
20.	JBG 17-03 × JBG 17-10	12.28 **	54.57 **	-2.35 *
21.	JBG 17-03 × JBG 17-08	54.41 **	59.63 **	20.10 **
22.	JBG 17-03 × JBG 17-01	21.97 **	34.24 **	65.93 **
23.	DBG 6 × JBG 17-10	-1.31	30.03 **	-14.81 **
24.	DBG 6 × JBG 17-08	5.77 **	19.32 **	-10.93 **
25.	DBG 6 × JBG 17-01	37.78 **	40.86 **	18.34 **
26.	JBG 17-10 × JBG 17-08	-14.55 **	3.90 **	-23.71 **
27.	JBG 17-10 × JBG 17-01	13.74 **	57.95 **	-16.05 **
28.	JBG 17-08 × JBG 17-01	35.76 **	34.68 **	27.22 **
	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**.Ed.: Standard error of difference; CD: Critical difference]

Table 4: Number of crosses showing significant and desirable heterobeltiosis 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	3	0	1
2	Days to 50 per cent flowering	10	10	6
3	Sex ratio	27	24	26
4	Days to first fruit harvest	13	5	9
5	Days to last fruit harvest	12	3	9
6	Length of main vine (m)	8	5	9
7	Fruit length (cm)	8	6	5
8	Fruit diameter (cm)	7	5	5
9	Average fruit weight (g)	14	12	11
10	Number of pickings	14	15	15
11	Number of fruits per plant	16	20	8
12	Fruit yield (kg/plant)	23	22	17

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

Hybrids	Fruit yield	Heterosis over better parent	SCA Effect	Components with significant and desirable heterobeltiosis
JBG 17-03 × JBG 17-08	9.02	50.02 **	2.25**	SR, LMV, AFW, NP, NFPP
JBG 17-04 × DBG 6	8.35	48.21 **	2.30**	FFFN, DFPF, SR, DFFH, DLFH, AFW, NP
JBG 17-03 × JBG 17-10	8.07	19.05 **	0.76**	SR, DLFH, FL, AFW, NP
JBG 17-03 × JBG 17-01	8.04	48.38 **	1.37**	SR, AFW, NFPP
JBG 17-08 × JBG 17-01	7.97	32.50 **	1.38**	FFFN, AFW, NP
JBG 17-10 × JBG 17-01	7.92	16.77 **	0.78**	SR, FL, NP, NFPP
JBG 17-07 × JBG 17-03	7.83	39.30 **	0.96**	FFFN, SR, FD, NP, NFPP
JBG 17-07 × JBG 17-10	7.76	14.52 **	0.42**	FFFN, SR, NP, NFPP
JBG 17-04 × JBG 17-10	7.76	14.46 **	1.02**	FFFN, SR, DFFH, DLFH, LMV, FL, AFW, NP, NFPP
JBG 17-07 × JBG 17-04	7.57	34.31 **	1.27**	FFFN, DFPF, SR, DFFH, DLFH, FD, AFW, NFPP

* 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]

4. 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 estimation of heterosis for yield and yield component traits would therefore be useful to judge the best hybrid combination for exploitation of superior hybrids. Based on high *per* se performance, high heterobeltiosis 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 significant and high magnitude of heterobeltiosis over the environments thus providing the best chances to isolate high yielding and earlier maturing genotypes in later segregating generations.

5. References

1. Anonymous, NHB, 2019-20. Retrieved from https://nhb.gov.in/statistics/horticulturecrops/second/2019-2020 (3rd Advance Estimate) 34.pdf.
2. Balat JR, Patel JB, Delvadiya IR, Joshiyara NS. Heterosis for fruit yield and its components in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. Journal of Pharmacognosy and Phytochemistry. 2020;9(5):226-233.
3. Chaudhari KN, Chaudhary RF, Patel DK, Kanwal Ashish, Patel HN, Pathak HC, *et al*. Heterosis for seed yield and yield components over environments in castor (*Ricinus communis* L.). Electronic Journal of Plant Breeding. 2011;2(3):372-376.
4. Choudhary BR. Vegetables. 8th Revised Ed. National Book Trusts, New Delhi. 1987, 195p.
5. Doloi N, Patel JN, Acharya RR. Heterosis Studies in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.]. Vegetos 2018;31:1.
6. Fonseca S, Patterson FC. Hybrid vigour in seven parent diallel in common wheat (*T. aestivum* L.). Crop Sci. 1968;8:85-88.
7. Gayakawad PS. M.Sc. (Hort.) Thesis, University of Horticultural Sciences, Bagalkot, 2014.
8. Ghuge MB, Syamal MM, Karcho S. Heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. Indian J Agric. Res. 2016;50:466-470.
9. Jayanth S, Makhan L, Duhan DS, Sagar. Exploitation of heterosis for yield and its contributing traits in bottle gourd [*Lagenaria siceraria* (Molina) Standl.]. Journal of Pharmacognosy and Phytochemistry. 2020;9(1):1641-1646.
10. Kumar A, Yadav GC, Pandey V, Prasad R. Mean performance of parents and F_1's for earliness and marketable yield related traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. Annls. Biol. 2014b;30(2):394-399.
11. Kumar P, Ram CN. Estimation of heterosis in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). The Pharma Innovation Journal. 2021;10 (7):1044-1053.
12. Lal M, Ram CN, Nath S, Gautam SK. Estimation of heterosis in Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] for growth and earliness. The Pharma Innovation Journal. 2021;10(7):1585-1592.

13. Mishra S, Pandey S, Kumar N, Pandey VP, Singh T. Studies on the extent of heterosis for the quantitative characters in *kharif* season bottle gourd [*Lagenaria siceraria* (Molina) standl.]. J Pharmacog. Phytochem. 2019b;8(1):29-38.
14. Panse VC, Sukhatme PV. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi, 1985.
15. Patel HR, Mehta DR. Elucidation of heterosis and inbreeding depression for fruit yield and its component traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. The Pharma Innovation Journal. 2021;10(6):646-654.
16. Quamruzzaman AKM, Salim MMR, Akhter L, Hasan T, Mazed K, Chowdhury MAZ. Genetic architecture of yield in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). Agril. Sci. 2019;10:567-576.
17. Whitakar TW. Men across the sea. (Eds. J.C. Kelly, C.W. Pennigton and R.L. Rands). 1971, p. 320-327.
18. Yadav YC, Kumar S. Assessment of standard heterosis for crop advancement in bottle gourd [*Lagenaria siceraria* (Molina) Standl.]. Int. J Plant. Sci. 2012a;**7**(1):181-184.