Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 226-233
Received: 05-06-2020
Accepted: 08-07-2020

Balat JR
Ph.D. (Agri.) Student, Department of Genetics and Plant breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Patel JB
Associate Professor, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Delvadiya IR
Ph.D. (Agri.) Student, Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Joshiyara NS
M.Sc. (Hort.) Vegetable Science, Department of Horticulture, College of Horticulture, Junagadh Agricultural University, Junagadh, Gujarat, India

Corresponding Author:
Balat JR
Ph.D. (Agri.) Student, Department of Genetics and Plant breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Heterosis for fruit yield and its components in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

Balat JR, Patel JB, Delvadiya IR and Joshiyara NS

Abstract
The present investigation was carried out in four different seasons with aim to assess the heterobeltosis and standard heterosis in bottle gourd. The experimental materials comprised of 45 entries includes nine parents (ABG 1, Punjab Long, NDBG 132, Arka Bahar, Pusa Naveen, DBG 5, Samrat, DBG 6 and Santosh), their 36 F_1s developed through half diallel mating design excluding reciprocals. Parent ABG 1 was used as a standard check. The materials were evaluated in a Randomized Block Design with three replications over four environments during kharif 2018 and summer 2019 at Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh. Four environments were created by two seasons with two dates of sowing in each season. The analysis of variance pooled over environments revealed significant differences among environments, genotypes, parents and hybrids for all the traits studied except for fruit length due to environments. On pooled basis, seven hybrids over better parent and three hybrids over standard check exhibited significant and positive heterosis. Based on magnitude of significant and desirable heterobeltiosis, Pusa Naveen × Samrat (55.03 %), Punjab Long × DBG 5 (54.30 %), Samrat × DBG 6 (44.41 %), Punjab Long × Pusa Naveen (42.26 %) and ABG 1 × Arka Bahar (40.47 %) in pooled over environments were the best five significant and desirable heterobeltiotic cross combinations. Based on magnitude of significant and desirable standard heterosis, the best five crosses were ABG 1 × Arka Bahar (43.68 %), Arka Bahar × Pusa Naveen (31.36 %), NDBG 132 × Arka Bahar (30.38 %), Punjab Long × NDBG 132 (29.72 %) and NDBG 132 × Samrat (28.24 %) in E_1; ABG 1 × Arka Bahar (38.84 %), Arka Bahar × Pusa Naveen (32.49 %), Punjab Long × NDBG 132 (32.12 %), NDBG 132 × Arka Bahar (29.40 %) and ABG 1 × NDBG 132 (28.31 %) in E_2; ABG 1 × Arka Bahar (55.46 %), Punjab Long × DBG 5 (41.05 %), Punjab Long × NDBG 132 (38.65 %), Punjab Long × Pusa Naveen (33.62 %) and ABG 1 × NDBG 132 (28.38 %) in E_3; and Pusa Naveen × Samrat (46.43 %), NDBG 132 × Arka Bahar (41.84 %), NDBG 132 × Pusa Naveen (36.48 %), ABG 1 × Arka Bahar (36.22 %) and NDBG 132 × Santosh (35.97 %) in E_4 environment. Across the environments, ABG 1 × Arka Bahar (43.82 %), Punjab Long × NDBG 132 (30.28 %) and NDBG 132 × Arka Bahar (27.69 %) noted significant and desirable standard heterosis.

Keywords: Bottle gourd, Heterobeltiosis, Standard heterosis, SCA effects

Introduction
Bottle gourd [*Lagenaria siceraria* (Mol.) Standl. 2n = 2x = 22], is one of humankind's first domesticated plants. It is also known as white flower gourd, Ghiakadoo or Lauki, is an important cucurbitaceous vegetable crop belonging to family Cucurbitaceae and subfamily Cucurbitoidae. The *Lagenaria siceraria* is the only annual and monoecious cultivated species of bottle gourd, while other species are wild, perennial and dioecious. In India, bottle gourd is cultivated in 157 million hectares during 2017-18 with production of 2683 million tones and productivity of 17.08 tonnes per hectare (Anon., 2018) [2]. According to De Candolle (1882) [6], bottle gourd has been found in wild form in South Africa and India. However, Cutler and Whitaker (1961) [5] are of the view that probably it is indigenous to tropical Africa on the basis of variability in seeds and fruits.

In different parts of the Gujarat state, the local strains of bottle gourd are grown commercially by the farmer which results into low yield. Local strains are generally impure. In spite of its extensive cultivation in Gujarat state, the required attention has not been given on its improvement. Anand Bottle Gourd-1, the only variety released during 2004 and Gujarat Anand Bottle Gourd Hybrid 1 (GABGH 1), the only hybrid released during 2017 is available to growers for commercial cultivation in middle Gujarat and Saurashtra region. Hence, there is a great scope to improve the yield and quality of bottle gourd for Gujarat state.

Bottle gourd is highly cross pollinated crop. Cross pollination per cent ranges from 60 to 80 per cent, results into large variation in shape and size of fruits varies from very long slender to thick and round (Choudhary, 1987) [3]. In bottle gourd, male and female flowers originate separately on same plant. Therefore, it is a monocious plant.

The fruits being large in size and having greater number of seeds per fruit, proved to be more advantageous. Thus, the hybrid seed of this crop can be produced commercially with little investment. Further, 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.

Materials and methods

The experimental materials comprised of 45 entries includes nine parents (ABG 1, Punjab Long, NDBG 132, Arka Bahar, Pusa Naveen, DBG 5, Samrat, DBG 6 and Santosh), their 36 F_1s developed through half diallel mating design excluding reciprocals. Parent ABG 1 was used as a standard check. The materials were evaluated in a Randomized Block Design with three replications over four environments during *kharif* 2018 and *summer* 2019 at Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh. 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 1m, respectively. The recommended package of practices and plant protection measures were followed to raise a healthy crop of bottle gourd. Four environments were created by date of sowing in two different seasons. Five competitive plants per genotype in each replication in each environment were selected randomly for recording observations on different characters *viz*., number of node bearing first female flower, number of node bearing first male flower, vine length (cm), days to first picking, fruit length (cm), fruit equatorial diameter (cm), number of fruits per plant, average fruit weight per plant (kg), days to last picking and fruit yield per plant (kg). The analysis of variance for experimental design for all the characters studied was carried out in each environment as per the procedure suggested by Panse and Sukhatme (1985) [17]. Heterosis was estimated as the per cent increase (+) or decrease (-) in the mean value of F_1 hybrid over better parent (Heterobeltosis) and standard check variety ABG 1 (Standard heterosis). For the character like days to first opening female flower, days to first opening male flower, number of node bearing first female flower, number of node bearing first male flower and days to first picking, low scoring parents were considered as better parents for the estimation of heterobeltosis, whereas high scoring parents were considered as better parents for rest of the traits. Heterobeltiosis was estimated as per the procedure given by Fonseca and Patterson (1968) [8], while Standard heterosis referred as the superiority of F_1 over standard check ABG 1, was estimated as per the formula given by Meredith and Bridge (1972) [14].

Results and discussion

The analysis of variance for experimental design was carried out to ascertain the genuine differences among genotypes, parents and F_1s in individual environments as well as pooled over environments for 12 different quantitative characters (Table 1). Mean squares due to genotypes were significant for all the traits in all the environments indicating the existence of sufficient variability in the experimental material studied. Mean squares due to parents were significant for all the traits except for vine length in E_4 and for fruit yield per plant in E_3 and E_4 environments. Mean squares due to hybrids were significant for all the traits in all the environments except for number of node bearing first male flower in E_3, days to first picking in E_1, E_2 and E_3, and days to last picking in E_2, E_3 and E_4 environments. Mean squares due to parents *vs.* F_1s were significant for days to first opening male flower in E_4; for vine length in E_1; for fruit length in E_4; for fruit equatorial diameter in E_1, E_3 and E_4; for number of fruits per plant in E_1, E_2 and E_4; and for number of node bearing first female flower, number of node bearing first male flower, average fruit weight per plant and fruit yield per plant in all four environments. Thus, parents, hybrids and parents *vs.* hybrids played important role in contributing sufficient variability present in traits.

Pooled analysis of variance over environments revealed significant differences among the environments for all the characters except for fruit length indicates wide variation in environmental conditions or differential expression of traits under different environments (Table 2). Significant differences were also noted among genotypes, parents and hybrids for all the traits studied indicating the presence of sufficient diversity among the materials evaluated for all the characters. The comparison of parents *vs.* hybrids was found significant for all the traits studied except for days to first opening male flower and days to first picking, which indicated variation among parents as a group and among hybrids as a group revealing the presence of mean heterosis for most of the traits. The interaction of genotypes x environments was significant for number of node bearing first female flower, number of node bearing first male flower, vine length and fruit equatorial diameter and average fruit weight per plant, while interaction of hybrids x environments was significant for number of node bearing first female flower, vine length, fruit equatorial diameter and average fruit weight per plant. The interaction of parents x environments was significant for number of node bearing first female flower, number of node bearing first male flower, vine length and fruit equatorial diameter. The mean squares due to parents *vs.* hybrids x environments were significant only for number of node bearing first male flower and fruit equatorial diameter, indicated that the crosses as a group performed more or less similar to that of a parents as a separate group in all the environments for all the traits except for number of node bearing first male flower and fruit equatorial diameter.

The data revealed that degree of heterosis was subjective to crosses and varied from cross to cross for all the characters in individual environments as well as pooled over environments. Certain crosses evinced considerable high heterosis, while it was low in other crosses suggesting that the selection of parents has an important bearing on performance of any cross combination and that nature of gene action varied with the genetic architecture of the parents.

With respect to heterobeltiosis recorded for different cross combinations for fruit yield per plant, it was observed that Punjab Long × DBG 5 (54.39 %), Punjab Long × Pusa Naveen (38.52 %), Samrat × Santosh (33.69 %), ABG 1 × Arka Bahar (29.63 %) and DBG 6 × Santosh (29.03 %) in E_1; Punjab Long × DBG 5 (60.05 %), Punjab Long × Pusa Naveen (44.63 %), Samrat × Santosh (40.65 %), DBG 6 × Santosh (36.91 %) and Pusa Naveen × DBG 6 (36.87 %) in E_2; Pusa Naveen × Samrat (57.30 %), ABG 1 × Arka Bahar (55.46 %), Punjab Long × DBG 5 (45.17 %), Samrat × DBG 6 (38.18 %) and Punjab Long × Pusa Naveen (37.53 %) in E_3; Pusa Naveen × Samrat (99.31 %), Pusa Naveen × DBG 5 (64.34 %), Pusa Naveen × DBG 6 (60.68 %), Samrat × DBG 6 (58.33 %) and NDBG 132 × Arka Bahar (54.44 %) in E_4; and Pusa Naveen × Samrat (55.03 %), Punjab Long × DBG 5 (54.30 %), Samrat × DBG 6 (44.41 %), Punjab Long × Pusa Naveen (42.26 %) and ABG 1 × Arka Bahar (40.47 %) in pooled over environments were the best five significant and

desirable heterobeltiotic cross combinations (Table 3). The heterobeltiosis for fruit yield per plant varied in between -22.52 per cent (Arka Bahar × DBG 6) to 54.39 per cent (Punjab Long × DBG 5), -21.60 per cent (ABG 1 × DBG 5) to 60.05 per cent (Punjab Long × DBG 5), -35.28 per cent (Punjab Long × DBG 6) to 57.30 per cent (Pusa Naveen × Samrat), -48.21 per cent (ABG 1 × DBG 6) to 99.31 per cent (Pusa Naveen × Samrat) and -22.11 per cent (ABG 1 × DBG 6) to 55.03 per cent (Pusa Naveen × Samrat) in E_1, E_2, E_3, E_4 and pooled over environments, respectively (Table 3).

The overall performance of hybrids over four environments for fruit yield per plant indicated that seven cross combinations showed significant positive heterosis over better parent. The top ranked cross combination across the environments with respect to heterobeltiosis for fruit yield per plant, Pusa Naveen × Samrat noted the significant and desirable heterobeltiosis in all the individual environments with the highest and significant heterobeltosis of 99.31 per cent in E_4 followed by 57.30 per cent in E_3, 36.39 per cent in E_2 and 26.55 per cent in E_1 environment. On pooled basis, this cross exhibited significant and desirable heterobeltiosis for average fruit weight per plant (25.00 %). Similarly, the second and third best cross combinations across the environments with respect to heterobeltiosis for fruit yield per plant, Punjab Long × DBG 5 and Samrat × DBG 6 also exhibited the significant and desirable heterobeltiosis in all the individual environments. The top ranked cross combination across the environments with respect to *per se* performance for fruit yield per plant, ABG 1 × Arka Bahar noted the significant and positive heterobeltiosis of 40.47 per cent across the environments. It also exhibited the significant and positive heterobeltiosis of 29.63, 34.45, 55.46 and 36.22 per cent in E_1, E_2, E_3 and E_4 environments, respectively. These results are in agreement with the results for fruit yield per plant obtained earlier by Sharma *et al.* (2012) [20], Singh *et al.* (2012a) [23], Singh *et al.* (2012b) [25], Kumar *et al.* (2014) [12], Adarsh *et al.* (2017) [1], Mishra *et al.* (2019) [15] and Quamruzzaman *et al.* (2019) [19] in bottle gourd.

On pooled basis, one cross (Punjab Long × Pusa Naveen) for fruit length and two crosses (Pusa Naveen × Samrat and DBG 6 × Santosh) for average fruit weight per plant exhibited significant and desirable heterobeltiosis, while for rest of the traits *viz*. days to first opening female flower, days to first opening male flower, number of node bearing first female flower, number of node bearing first male flower, vine length, days to first picking, fruit equatorial diameter, number of fruits per plant and days to last picking, none of the cross manifested significant desirable heterobeltiosis. In individual environment as well as on pooled basis, it was observed that majority of crosses exhibited low to moderate heterobeltosis for fruit yield per plant as well as for important yield contributing characters. The results are in accordance with the results reported by several workers in bottle gourd for fruit length [Kouser (2006), Singh *et al.* (2012a)] [11, 23] and average fruit weight per plant [Singh *et al.* (1998), Pandey *et al.* (2004), Sharma *et al.* (2004), Sirohi and Rana (2007)] [24, 16, 21, 26].

With respect to individual environments, none of the cross combination noted the significant and desirable heterobeltiosis for average fruit weight per plant in any of the individual environments, while Pusa Naveen × Santosh (-29.75 %) and Punjab Long × NDBG 132 (-20.94 %) noted significant and desirable heterobeltiosis in E_4 environment for number of node bearing first female flower and number of node bearing first male flower, respectively. Total of 1, 4, 2 and 3 cross combinations for days to first opening female flower; 0, 1, 5 and 6 cross combinations for days to first opening male flower; 0, 2, 1, 2 cross combinations for vine length; 0, 2, 2 and 4 cross combinations for days to first picking; 5, 7, 6 and 9 cross combinations for fruit length; 0, 0, 4 and 1 cross combinations for fruit equatorial diameter; 1, 3, 0, and 8 cross combinations for number of fruits per plant; 5, 2, 3 and 3 cross combinations for days to last picking; and 8, 9, 7 and 13 cross combinations for fruit yield per plant exhibited significant and desirable heterobeltiosis in E_1, E_2, E_3 and E_4 environments, respectively (Table 4).

With respect to standard heterosis, the results showed that 8, 7, 6, 6 and 3 cross combinations noted significant and desirable standard heterosis in E_1, E_2, E_3, E_4 and pooled over environments, respectively (Table 3). Based on magnitude of significant and desirable standard heterosis, the best five crosses were ABG 1 × Arka Bahar (43.68 %), Arka Bahar × Pusa Naveen (31.36 %), NDBG 132 × Arka Bahar (30.38 %), Punjab Long × NDBG 132 (29.72 %) and NDBG 132 × Samrat (28.24 %) in E_1; ABG 1 × Arka Bahar (38.84 %), Arka Bahar × Pusa Naveen (32.49 %), Punjab Long × NDBG 132 (32.12 %), NDBG 132 × Arka Bahar (29.40 %) and ABG 1 × NDBG 132 (28.31 %) in E_2; ABG 1 × Arka Bahar (55.46 %), Punjab Long × DBG 5 (41.05 %), Punjab Long × NDBG 132 (38.65 %), Punjab Long × Pusa Naveen (33.62 %) and ABG 1 × NDBG 132 (28.38 %) in E_3; and Pusa Naveen × Samrat (46.43 %), NDBG 132 × Arka Bahar (41.84 %), NDBG 132 × Pusa Naveen (36.48 %), ABG 1 × Arka Bahar (36.22 %) and NDBG 132 × Santosh (35.97 %) in E_4 environment. Across the environments, ABG 1 × Arka Bahar (43.82 %), Punjab Long × NDBG 132 (30.28 %) and NDBG 132 × Arka Bahar (27.69 %) noted significant and desirable standard heterosis. The standard heterosis for fruit yield per plant varied in between -30.54 per cent (Punjab Long × Santosh) to 43.68 per cent (ABG 1 × Arka Bahar) in E_1, -34.85 per cent (Punjab Long × Santosh) to 38.84 per cent (ABG 1 × Arka Bahar) in E_2, -37.12 per cent (Punjab Long × DBG 6) to 55.46 per cent (ABG 1 × Arka Bahar) in E_3, -48.21 per cent (ABG 1 × DBG 6) to 46.43 per cent (Pusa Naveen × Samrat) in E_4 and -30.28 per cent (Punjab Long × DBG 6) to 43.82 per cent (ABG 1 × Arka Bahar) in pooled over environments. These results are in agreement with the results for fruit yield per plant obtained earlier by Adarsh *et al.* (2017) [1], Malviya *et al.* (2017) [13], Doloi *et al.* (2018) [7] and Mishra *et al.* (2019) [15] in bottle gourd.

As stated earlier, the top ranked cross combinations across the environments with respect to *per se* performance for fruit yield per plant, ABG 1 × Arka Bahar (43.82 %), Punjab Long × NDBG 132 (30.28 %) and NDBG 132 × Arka Bahar (27.69 %) noted significant and desirable standard heterosis. Among these crosses, ABG 1 × Arka Bahar noted the significant and desirable standard heterosis in all the individual environments with a heterosis of 43.68, 38.84, 55.46 and 36.22 per cent in E_1, E_2, E_3 and E_4 environments, respectively. This hybrid also noted significant and desirable standard heterosis on pooled basis for fruit equatorial diameter (40.91 %) and average fruit weight per plant (46.55 %). The second top ranked cross Punjab Long × NDBG 132 noted significant and positive heterosis of 29.72, 32.12 and 38.65 per cent in E_1, E_2 and E_3 environments, respectively. It also noted significant and desirable standard heterosis on pooled basis for days to first picking (8.10%), fruit equatorial diameter (21.34 %) and average fruit weight per plant (19.42 %). The third top ranked cross NDBG 132 × Arka Bahar noted significant and positive heterosis of 30.38, 29.40 and 41.84 per cent in E_1, E_2 and E_4

environments, respectively. It also noted significant and desirable standard heterosis on pooled basis for fruit equatorial diameter (33.79 %) and average fruit weight per plant (34.81 %). On pooled basis, 7 cross combinations for days to first picking, 33 cross combinations for fruit equatorial diameter and 23 cross combinations for average fruit weight per plant registered significant and standard heterosis in desired direction, while for days to first opening female flower, days to first opening male flower, number of node bearing first female flower, number of node bearing first male flower, vine length, fruit length, number of fruits per plant and days to last picking, none of the cross combination manifested significant desirable standard heterosis. The results are in accordance with the results reported by several workers in bottle gourd for days to first picking [Kouser (2006), Ghuge *et al.* (2016), Adarsh *et al.* (2017)] [11, 10] and for fruit weight [Choudhury and Singh (1971), Sirohi *et al.* (2005), Sharma *et al.* (2009), Gayakawad (2014), Ghuge *et al.* (2016), Parmar (2016)] [4, 27, 22, 9, 10, 18].

With respect to individual environments, none of the cross combination noted the significant and desirable standard heterosis for number of node bearing first female flower, number of node bearing first male flower, fruit length, number of fruits per plant and average fruit weight per plant in any of the environments, while 7, 2, 5 and 3 cross combinations for days to first opening female flower; 0, 2, 1 and 6 cross combinations for days to first opening male flower; 0, 2, 2 and 4 cross combinations for vine length; 22, 25, 25 and 13 cross combinations for days to first picking; 26, 26, 35 and 29 cross combinations fruit equatorial diameter; 1, 0, 2 and 2 cross combinations for days to last picking; and 8, 7, 6 and 6 cross combinations for fruit yield per plant exhibited significant and desirable standard heterosis in E_1, E_2, E_3 and E_4 environments, respectively (Table 4).

From commercial cultivation point of view, the superiority of new hybrid should be judged by comparing their performance with the best cultivated variety/hybrid. Variety ABG 1 released for general cultivation in Gujarat was, therefore, used as the standard check in order to obtain information regarding superiority of new hybrids over best cultivated variety. The top ten cross combinations across the environments with respect to *per se* performance for fruit yield per plant are listed in Table 5 along with their values of heterobeltosis, standard heterosis, sca effect as well as for component traits these hybrids showing significant and desirable heterosis over better parent and standard check variety ABG 1. All 10 cross combinations were found superior then ABG 1 in respect of fruit yield per plant, as it manifested significantly higher fruit yield than ABG 1. Out of these 10 cross combinations, only ABG 1 × Arka Bahar, Punjab Long × NDBG 132 and NDBG 132 × Arka Bahar were exhibited the significant standard heterosis over ABG 1 across the environments for fruit yield per plant. Among these three crosses, ABG 1 × Arka Bahar and Punjab Long × NDBG 132 were noted significant sca effect. These three cross combinations manifested significant standard heterosis in desired direction for yield components like fruit equatorial diameter and average fruit weight. As discussed earlier, ABG 1 × Arka Bahar cross combination also noted the significant and desirable standard heterosis in all individual environments as well as across the environments, while Punjab Long × NDBG 132 recorded significant and desirable standard heterosis in E_1, E_2, E_3 and pooled over environments, but it had non-significant but desirable standard heterosis in E_4 environment and NDBG 132 × Arka Bahar recorded significant and desirable standard heterosis in E_1, E_2, E_4 and pooled over environments, but it had non-significant but desirable standard heterosis in E_3 environment.

Among the three best standard heterotic hybrids, ABG 1 × Arka Bahar also noted significant and desirable heterobeltiosis for fruit yield per plant. The other cross Punjab Long × DBG 5 observed significant and desirable heterobeltiosis for fruit yield per plant while cross Pusa Naveen × Samrat manifested the significant and desirable heterobeltiosis for fruit yield per plant along with significant and desirable heterobeltiosis for average fruit weight per plant. Choudhury and Singh (1971) [4], Sirohi *et al.* (2005) [27], Sharma *et al.* (2009) [22], Gayakawad (2014), Ghuge *et al.* (2016) [10] and Parmar (2016) [18] have also reported heterosis in average fruit weight, which further substantiated these findings.

Table 1: Analysis of variance for different characters in individual environments in bottle gourd

Source of variation	df	E_1	E_2	E_3	E_4
Days to first opening female flower					
Replications	2	18.44	16.63	13.13	19.44
Genotypes	44	41.53**	20.02**	40.49**	38.98**
Parents	8	83.35**	45.10**	86.69**	76.89**
F_1s	35	33.04**	14.27**	30.77**	30.96**
P *vs.* F_1s	1	3.99	20.42	11.21	16.40
Error	88	7.46	7.08	7.83	7.05
Days to first opening male flower					
Replications	2	0.02	0.30	0.03	0.14
Genotypes	44	31.53**	18.35**	28.48**	28.46**
Parents	8	78.83**	36.85**	57.02**	37.02**
F_1s	35	21.62**	14.59**	22.57**	26.39**
P *vs.* F_1s	1	0.01	2.10	6.98	32.51*
Error	88	5.98	5.77	6.05	6.29
Number of node bearing first female flower					
Replications	2	0.52**	0.54**	0.20	0.22
Genotypes	44	0.63**	0.56**	0.81**	1.24**
Parents	8	1.15**	0.88**	1.27**	0.78**
F_1s	35	0.49**	0.48**	0.66**	1.24**
P *vs.* F_1s	1	1.63**	0.99**	2.58**	4.95**
Error	88	0.10	0.09	0.23	0.25
Number of node bearing first male flower					

Replications	2	0.90**	0.81**	0.49	0.38
Genotypes	44	0.68**	1.37**	0.71*	1.73**
Parents	8	1.15**	4.28**	1.11*	2.55**
F_1s	35	0.57**	0.69**	0.55	1.44**
P *vs.* F_1s	1	0.70*	1.84**	3.44**	5.20**
Error	88	0.15	0.14	0.42	0.39
Vine length (m)					
Replications	2	0.68	0.84	0.68	0.68
Genotypes	44	1.23**	1.26**	1.07**	1.05**
Parents	8	2.14**	1.00**	0.89*	0.71
F_1s	35	0.98**	1.34**	1.13**	1.52**
P *vs.* F_1s	1	2.65**	0.66	0.31	0.35
Error	88	0.34	0.36	0.38	0.41
Days to first picking					
Replications	2	6.65	8.11	8.11	6.54
Genotypes	44	22.20**	17.39*	19.94**	38.10**
Parents	8	52.75**	33.40**	44.64**	57.88**
F_1s	35	15.79	13.42	14.71	34.58**
P *vs.* F_1s	1	2.14	28.20	5.42	2.44
Error	88	10.33	9.79	10.04	10.76
Fruit length (cm)					
Replications	2	28.40	28.46	28.44	35.82
Genotypes	44	34.54**	33.94**	41.78**	44.15**
Parents	8	69.98**	66.03**	65.67**	46.85**
F_1s	35	26.31*	27.10*	37.23**	42.94**
P *vs.* F_1s	1	38.83	16.86	9.73	64.85*
Error	88	14.85	15.02	14.79	16.06
Fruit equatorial diameter (cm)					
Replications	2	0.93**	0.93**	1.02**	0.94**
Genotypes	44	1.69**	1.23**	1.37**	1.53**
Parents	8	3.00**	2.13**	2.56**	2.22**
F_1s	35	1.41**	1.05**	1.07**	1.34**
P *vs.* F_1s	1	0.85*	0.04	2.30**	2.70**
Error	88	0.15	0.13	0.16	0.17
Number of fruits per plant					
Replications	2	15.92**	16.28**	16.44**	16.52**
Genotypes	44	5.84**	6.04**	4.94**	4.81**
Parents	8	7.01**	8.03**	4.34**	2.78*
F_1s	35	5.44**	5.42**	5.18**	5.08**
P *vs.* F_1s	1	10.30**	11.67**	1.19	11.85**
Error	88	1.28	1.32	1.30	1.34
Average fruit weight per plant (kg)					
Replications	2	0.012	0.014	0.010	0.013
Genotypes	44	0.020**	0.019**	0.015**	0.021**
Parents	8	0.026**	0.029**	0.020**	0.025**
F_1s	35	0.018**	0.016**	0.013**	0.019**
P *vs.* F_1s	1	0.048**	0.043**	0.052**	0.081**
Error	88	0.004	0.004	0.004	0.004
Days to last picking					
Replications	2	29.77	28.17	31.60	35.40
Genotypes	44	54.71**	45.80*	40.79*	45.71*
Parents	8	93.92**	76.32**	63.37*	74.72*
F_1s	35	46.92*	39.33	35.83	39.09
P *vs.* F_1s	1	13.38	28.06	33.55	45.41
Error	88	28.94	27.67	26.40	28.65
Fruit yield per plant (kg)					
Replications	2	2.87	1.61	2.33	1.26
Genotypes	44	3.93**	3.51**	2.54**	2.66**
Parents	8	2.81*	2.59*	1.38	1.10
F_1s	35	3.72**	3.30**	2.67**	2.67**
P *vs.* F_1s	1	20.21**	18.27**	7.41**	15.23**
Error	88	1.29	1.02	0.83	0.54

*, ** Indicates significance at P = 0.05 and P = 0.01 levels, respectively

Table 2: Analysis of variance for different characters pooled over environments in bottle gourd

Source of variation	df	Days to first opening female flower	Days to first opening male flower	Number of node bearing first female flower	Number of node bearing first male flower	Vine length (m)	Days to first picking
Replication within environment	8	16.91*	0.12	0.37*	0.64*	0.72	7.35
Environments	3	307.90**	399.03**	161.30**	154.00**	8.96**	290.72**
Genotypes (G)	44	124.42**	90.35**	2.41**	3.07**	2.14**	77.08**
Parents (P)	8	280.85**	194.59**	3.17**	6.18**	2.70**	178.88**
F_1s (H)	35	90.84**	68.76**	2.04**	2.35**	1.98**	55.20**
P *vs.*F_1s	1	48.39**	12.28	9.31**	3.27**	3.24**	28.43
G × E	132	5.53	5.49	0.28**	0.48**	0.82**	6.84
P × E	24	3.72	5.04	0.30*	0.97**	0.68*	3.26
H × E	105	6.07	5.47	0.28**	0.30	0.87**	7.77
(P *vs.*F_1s) × E	3	1.21	9.77	0.28	2.64**	0.25	3.26
Pooled Error	352	7.36	6.00	0.17	0.28	0.37	10.29
Source of variation	**d.f**	**Fruit length (cm)**	**Fruit equatorial diameter (cm)**	**Number of fruits per plant**	**Average fruit weight per plant (kg)**	**Days to last picking**	**Fruit yield per plant (kg)**
Replication within environment	8	30.28*	0.95**	16.44**	0.008*	31.23	2.02*
Environments	3	23.09	1.14**	280.22**	0.02**	445.30**	132.72*
Genotypes (G)	44	119.83**	4.84**	19.65**	0.05**	167.51**	10.52**
Parents (P)	8	227.85**	9.15**	20.26**	0.09**	292.47**	6.26**
F_1s (H)	35	95.25**	3.87**	19.18**	0.04**	140.44**	10.10**
P *vs.*F_1s	1	115.67**	4.59**	31.15**	0.22**	115.42*	59.25**
G × E	132	11.53	0.32**	0.66	0.007**	6.50	0.71
P × E	24	6.89	0.26*	0.63	0.006	5.29	0.53
H × E	105	12.78	0.33**	0.65	0.007**	6.91	0.75
(P *vs.*F_1s) × E	3	4.87	0.43*	1.29	0.001	1.66	0.62
Pooled Error	352	15.15	0.16	1.30	0.004	27.91	0.92

Table 3: Estimates of heterobeltiosis (HB) and standard heterosis (SH) percentage for fruit yield per plant (kg) in individual and pooled over environments in bottle gourd

Sr. No.	Crosses	E_1		E_2		E_3		E_4		Pooled	
		BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
1	ABG 1 × Punjab Long	8.54	8.54	33.64	3.81	28.17*	28.17*	30.87*	30.87*	16.14	16.14
2	ABG 1 × NDBG 132	12.33	25.62*	12.58	28.31*	9.29	28.38*	4.34	4.34	12.39	22.91
3	ABG 1 × Arka Bahar	29.63**	43.68**	34.45**	38.84**	55.46**	55.46**	36.22**	36.22**	40.47**	43.82**
4	ABG 1 × Pusa Naveen	12.81	12.81	14.70	14.70	6.33	6.33	-11.48	-11.48	-11.66	7.17
5	ABG 1 × DBG 5	-15.44	-15.44	-21.60	-21.60	3.93	3.93	-1.02	-1.02	-9.76	-9.76
6	ABG 1 × Samrat	-16.26	-16.26	-20.87	-20.87	-22.71	-22.71	-23.47	-23.47	-20.32	-20.32
7	ABG 1 × DBG 6	-9.03	-9.03	-14.16	-14.16	-26.86*	-26.86*	-48.21**	-48.21**	-22.11	-22.11
8	ABG 1 × Santosh	-15.60	-15.60	-15.79	-15.79	-4.15	-4.15	1.02	1.02	-9.76	-9.76
9	Punjab Long × NDBG 132	16.01	29.72**	15.92	32.12**	18.03	38.65**	32.00*	17.86	19.13	30.28*
10	Punjab Long × Arka Bahar	-14.96	-5.75	-13.01	-10.16	-16.56	-17.47	-26.94	-32.91*	-16.93	-14.94
11	Punjab Long × Pusa Naveen	38.52**	13.96	44.63**	12.34	37.53**	33.62**	33.45	-0.26	42.26*	15.34
12	Punjab Long × DBG 5	54.39**	21.18*	60.05**	24.32*	45.17**	41.05**	50.51**	12.50	54.30**	25.10
13	Punjab Long × Samrat	9.11	-17.41	4.91	-18.51	8.54	5.46	38.57*	3.57	13.02	-8.37
14	Punjab Long × DBG 6	-5.56	-27.42*	-10.28	-30.31**	-35.28**	-37.12**	-2.39	-27.04*	-14.00	-30.28*
15	Punjab Long × Santosh	-10.38	-30.54**	-16.12	-34.85**	-21.44	-21.62	-12.99	-21.43	-14.01	-27.89*
16	NDBG 132 × Arka Bahar	16.59	30.38**	13.54	29.40**	-7.06	9.17	54.44**	41.84**	16.76	27.69*
17	NDBG 132 × Pusa Naveen	11.45	24.63*	9.55	24.86*	-9.29	6.55	52.86**	36.48**	12.39	22.91
18	NDBG 132 × DBG 5	-0.59	11.17	-10.03	2.54	-12.83	2.40	23.43	10.20	-2.37	6.77
19	NDBG 132 × Samrat	14.68	28.24**	6.21	21.05	6.32	24.89	34.57*	20.15	13.48	24.10
20	NDBG 132 × DBG 6	-8.37	2.46	-9.87	2.72	-23.98*	-10.70	8.29	-3.32	-9.84	-1.39
21	NDBG 132 × Santosh	-6.46	4.60	-9.55	3.09	-3.53	13.32	50.56**	35.97**	2.73	12.35
22	Arka Bahar × Pusa Naveen	18.52	31.36**	28.30**	32.49**	21.41	20.09	17.50	7.91	21.79	24.70
23	Arka Bahar × DBG 5	1.78	12.81	0.00	3.27	8.83	7.64	-4.17	-11.99	1.95	4.38
24	Arka Bahar × Samrat	-9.93	-0.16	-5.45	-2.36	1.10	0.00	-25.00	-31.12*	-8.95	-6.77
25	Arka Bahar × DBG 6	-22.52*	-14.12	-18.28	-15.61	-6.40	-7.42	-0.83	-8.93	-14.01	-11.95
26	Arka Bahar × Santosh	-4.89	5.42	0.35	3.63	11.82	11.57	3.61	-4.85	1.95	4.38

27	Pusa Naveen × DBG 5	25.55	3.28	28.71	-2.36	21.00	15.72	64.34**	19.90	33.83*	7.97
28	Pusa Naveen × Samrat	26.55*	4.11	36.39*	2.72	57.30**	24.67	99.31**	46.43**	55.03**	16.73
29	Pusa Naveen × DBG 6	26.75*	4.27	36.87*	3.09	32.78*	5.24	60.68**	-4.08	36.24*	2.59
30	Pusa Naveen × Santosh	8.18	-11.00	17.59	-11.43	0.66	0.44	22.32	10.46	14.25	-4.18
31	DBG 5 × Samrat	11.72	-12.32	12.92	-14.34	3.88	-0.66	-0.35	-26.79*	7.90	-12.95
32	DBG 5 × DBG 6	-4.18	-24.79*	-2.39	-25.95*	-23.74	-27.07*	-1.40	-28.06*	-8.40	-26.10
33	DBG 5 × Santosh	15.48	-9.36	16.75	-11.43	-7.44	-7.64	-17.80	-25.77	4.04	-12.75
34	Samrat × DBG 6	27.78*	-1.81	32.83*	-3.81	38.18*	5.90	58.33**	16.33	44.41*	2.99
35	Samrat × Santosh	33.69*	3.61	40.65**	2.36	-8.75	-8.95	-18.93	-26.79*	12.83	-5.38
36	DBG 6 × Santosh	29.03*	0.00	36.91*	-0.36	4.60	4.37	-4.52	-13.78	17.10	-1.79
Range of heterosis		-22.52 to 54.39	-30.54 to 43.68	-21.60 to 60.05	-34.85 to 38.84	-35.28 to 57.30	-37.12 to 55.46	-48.21 to 99.31	-48.21 to 46.43	-22.11 to 55.03	-30.28 to 43.82
Number of crosses showing significant desirable heterosis		8	8	9	7	7	6	13	6	7	3
S.E. ±		0.66		0.62		0.59		0.53		0.67	

Note: E_1, E_2, E_3, and E_4 are different environments

*, ** indicates significance at P = 0.05 and P = 0.01 levels, respectively

BP = Better parent heterosis (heterobeltiosis) and SH = Standard heterosis

Table 4: Number of crosses showing significant and desirable heterobeltiosis and standard heterosis for fruit yield per plant and its components in individual and pooled over environments in bottle gourd

Sr. No.	Character	E_1		E_2		E_3		E_4		Pooled	
		BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
1	Days to first opening female flower	1	7	4	2	2	5	3	3	0	0
2	Days to first opening male flower	0	0	1	2	5	1	6	6	0	0
3	Number of node bearing first female flower	0	0	0	0	0	0	1	0	0	0
4	Number of node bearing first male flower	0	0	0	0	0	0	1	0	0	0
5	Vine length (m)	0	0	2	2	1	2	2	4	0	0
6	Days to first picking	0	22	2	25	2	25	4	13	0	7
7	Fruit length (cm)	5	0	7	0	6	0	9	0	1	0
8	Fruit equatorial diameter (cm)	0	26	0	26	4	35	1	29	0	33
9	Number of fruits per plant	1	0	3	0	0	0	8	0	0	0
10	Average fruit weight per plant (kg)	0	0	0	0	0	0	0	0	2	23
11	Days to last picking	5	1	2	0	3	2	3	2	0	0
12	Fruit yield per plant (kg)	8	8	9	7	7	6	13	6	7	3

Table 5: Performance of top ten high yielding crosses for heterosis over better parent (BP) and standard check (ABG 1), their SCA effects for fruit yield per plant and component traits for which showing significant and desirable heterosis over standard check and better parent in pooled analysis

Sr. No.	Hybrids	Seed yield Per plant (g)	Heterosis over		SCA effects	Component characters showing significant and desirable heterosis over	
			BP	ABG 1		BP	ABG 1
1	ABG 1 × Arka Bahar	7.22	40.47**	43.82**	1.69**	-	FED, AFW
2	Punjab Long × NDBG 132	6.54	19.13	30.28*	0.88**	-	FED, AFW
3	NDBG 132 × Arka Bahar	6.41	16.76	27.69*	0.26	-	FED, AFW
4	Punjab Long × DBG 5	6.28	54.30**	25.10	1.63**	-	FED
5	Arka Bahar × Pusa Naveen	6.26	21.79	24.70	0.66**	-	FED, AFW
6	NDBG 132 × Samrat	6.23	13.48	24.10	0.75**	-	FED, AFW
7	ABG 1 × NDBG 132	6.17	12.39	22.91	0.24	-	FED
8	NDBG 132 × Pusa Naveen	6.17	12.39	22.91	0.17	-	FED, AFW
9	Pusa Naveen × Samrat	5.86	55.03**	16.73	0.93**	AFW	AFW
10	ABG 1 × Punjab Long	5.83	16.14	16.14	0.80**	-	-

Conclusion

On the basis of high *per se* performance, high heterosis and desirable sca effects with respect to fruit yield per plant, cross combinations ABG 1 × Arka Bahar (7.22 kg) and Punjab Long × NDBG 132 (6.54 kg) could be exploited for improvement in fruit yield of bottle gourd.

References

1. Adarsh A, Kumar R, Kumar A, Neetunand, Singh HK. Estimation of gene action and heterosis in bottle gourd (*Lagenaria siceraria* Mol. Standl.). Environ. Ecol. 2017; 35(2A):936-944.
2. Anonymous. Horticulture Statistics at a Glance 2018. Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India. (http://agricoop.nic.in/sites/default/files/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf) accessed on November 25, 2019.
3. Choudhary BR. *Vegetables*. 8th Revised Ed. National Book Trusts, New Delhi, 1987, 195.
4. Choudhury B, Singh B. Pusa Meghdoot, Pusa Manjari, two high yielding bottle gourd hybrids. Indian J Hort. 1971; 16(1):15-32.
5. Cutler HC, Whitaker TW. History and distribution of the cultivated cucurbits in the Americas. American Antiquity. 1961; 26(4):469-485.
6. De Candolle A. *Origin of Cultivated Species*. Hafner Publishing Co., London (Reprint 1967), 1882.

7. Doloi N, Patel JN, Acharya RR. Heterosis studies in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. Vegetos- An Int. J Pl. Res. 2018; 31(1):1-3.
8. Fonseca S, Patterson FL. Hybrid vigour in seven parental diallel cross in common winter wheat (*Triticum aestivum* L.). Crop Sci. 1968; 8(1):85-88.
9. Gayakawad PS. Heterosis and combining ability studies in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. M. Sc. (Hort.) Thesis (Unpublished) Submitted to University of Horticultural Sciences, Bagalkot, Karnataka, 2014.
10. Ghuge MB, Syamal MM, Karcho S. Heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.*]*. Indian J Agric. Res. 2016; 50(5):466-470.
11. Kouser P. Heterosis and combining ability studies in bottle gourd [*Lagenaria siceraria* (Molina) Standl.]. Ph.D. (Olericulture) Thesis (Unpublished) Submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir, Srinagar, 2006.
12. 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. 2014; 30(2):394-399.
13. Malviya AV, Bhanderi DR, Patel AI, Jadav NK, Patel UV. Heterosis for fruit yield and its components in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. Trends Biosci. 2017; 10(2):783-787.
14. Meredith WR, Bridge RR. Heterosis and gene action in cotton (*G. hirsutum* L.). Crop Sci. 1972; 12(3):304-310.
15. 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. 2019; 8(1):29-38.
16. Pandey SK, Srivastava SBL, Singh NP, Srivastava JP. Heterosis and combining ability for earliness in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). Veg. Sci. 2004; 31(1):11-16.
17. Panse VC, Sukhatme PV. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi, 1985.
18. Parmar SS. Heterosis and combining ability for yield and quality traits in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). M. Sc. (Agri.) Thesis (Unpublished) Submitted to Punjab Agricultural University, Ludhiana, 2016.
19. 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.
20. Sharma DR, Choudhary MR, Jakhar ML, Dadheech S. Heterosis in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). Int. J Life Sci. 2012; 1(3):212-216.
21. Sharma N, Malik YS, Sharma NK. Heterobeltiotic effects in long fruited bottle gourd. Haryana J Hort. Sci. 2004; 33(1-3):109-111.
22. Sharma N, Malik YS, Sharma NK. Estimate of economic heterosis for yield and yield related traits in bottle gourd (*Lagenaria siceraria* (Molina) Standl.). Haryana J Hort. Sci. 2009; 38(1):137-139.
23. Singh SK, Singh RK, Solankey SS, Upadhyaya AK. Studies on genetic causes of heterosis in bottle gourd (*Lagenaria siceraria* (Molina) Standl.) near Gangetic region of Varanasi. Asian J Hort. 2012a; 7(2):303-306.
24. Singh PK, Kumar JC, Sharma JR. Heterosis studies in long fruited bottle gourd. Veg. Sci. 1998; 25(1):55-57.
25. Singh SK, Upadhyay AK, Pandey J, Pandey AK. Studies on heterosis and combining ability in bottle gourd (*Lagenaria siceraria (*Mol.) Standl.) for yield traits. Annals Hort. 2012b; 5(2):246-251.
26. Sirohi S, Rana SC. Heterosis studies in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). Haryana J Hort. Sci. 2007; 36(3/4):363-364.
27. Sirohi S, Rana SC Rajkumar. Heterosis study in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). In: Abstract Book of National Seminar on Cucurbits, Sept. 22-23, G.B. Pant University of Agriculture and Technology, Pantnagar, 2005, 39.