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Estimation of heterosis for fruit yield and its component traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

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Abstract
The present investigation was undertaken to generate information about the magnitude of heterobeltiosis and standard heterosis for fruit yield and its component characters in bottle gourd. The experimental material consisted of nine female parents, four male parents and their resultant 36 hybrids developed by using line × tester mating design and one standard check GABGH-1. The experiment was laid out in randomized block design with three replications at the Main Vegetable Research Station Farm, Anand Agricultural University, Anand during *Kharif*, 2021. Among the 36 hybrids developed, eight hybrids showed significantly positive heterosis over better parent and 10 hybrids showed significant positive heterosis over standard check GABGH-1 for fruit yield. As per better parent heterosis, the best performing positively significant hybrids for fruit yield per vine were ABGS 11-18 × Arka Bahar, ABGS 11-24 × Arka Bahar and ABGS 11-23 × ABG 1 and for standard heterosis, the best performing positively significant hybrids for fruit yield per vine were ABGS 11-22 × Punjab Komal, ABGS 11-23 × ABG 1 and ABGS 11-17 × ABG 1. These cross combinations can be further exploited in breeding programmes in bottle gourd.

Keywords: Heterobeltiosis, standard heterosis, bottle gourd, line × tester mating design

Introduction
Bottle gourd, [*Lagenaria siceraria* (Mol.) Standl.] also called white-flowered gourd or calabash gourd, running or climbing vine of the gourd family (Cucurbitaceae), native to tropical Africa but cultivated in warm climates around the world. It has chromosome number 2n=2x=22. The genus *Lagenaria* consists of five other wild species, namely *Lagenaria brevifilora* (Benth) Roberty, *Lagenaria rufa* (Gilg) C Jeffrey, *Lagenaria sphaerica* E Mey, *Lagenaria abyssinia* (Hook. F.) C Jeffrey and *Lagenaria guineensis* (G Den) C Jeffrey, of which *L. siceraria* is the most cultivated. Within the species siceraria, two morphologically distinct sub-species of bottle gourd have been recognized *viz.*, *L. siceraria* ssp. *Siceraria* and *L. siceraria* ssp. *Asiatica* (Chimonyo and Modi, 2013). The edible 100 g bottle gourd fruit contains 96.3 per cent moisture, 2.9 per cent carbohydrate, 0.2 per cent protein, 0.1 per cent fat and 0.5 per cent mineral matter. Cucurbits share about 5.6 per cent of the total vegetable production in India (Rai and Rai, 2016) [19]. The total area under cultivation in the country is approximately 0.187 million hectares and annual production in the country is 3.011 MT (Anon., 2018) [3].
Most bottle gourd varieties available for cultivation in our country have lost their potentiality. Therefore, it is essential to increase its productivity through various new strategies. The development of hybrid with high yield and improved fruit quality is one of these ways to increase its productivity.
Heterosis is amounting to superiority of F_1 hybrid in a desirable direction over either or both its parent and standard check is manifested via an increase in vigour, growth rate, size, yield, quality and other characteristics. The principle objective of heterosis breeding is to gain a quantum jump in yield and quality attributes in vegetable crops (Jayanth and Lal, 2020) [10]. The exploitation of hybrid vigour in bottle gourd could increase the yield.

Material and methods
The present investigation was undertaken in summer 2021 for crossing and *Kharif* 2021 for evaluation at the Main Vegetable Research Station farm, Anand Agricultural University,

Anand. The experimental material was comprised of nine lines (female parents), four testers (male parents), 36 hybrids and one standard check. These lines and testers were crossed in line × tester mating design to obtain 36 cross combinations. The experiment was laid out in randomized block design with three replications. The lines were ABGS 11-17 (L_1), ABGS 11-22 (L_2), ABGS 11-24 (L_3), ABGS 11-25 (L_4), ABGS 11-26 (L_5), ABGS 11-27 (L_6), ABGS 11-19 (L_7), ABGS 11-18 (L_8) and ABGS 11-23 (L_9) and testers were ABG 1 (T_1), Punjab Komal (T_2), Arka Bahar (T_3) and Pusa Naveen (T_4) and one standard check was GABGH 1. Bottle gourd is a monoecious crop species. The flowers are large, unisexual, white, solitary, hence staminate and pistillate flowers are borne separately on same plants. The seeds of 36 F_1 hybrids were produced by hand pollination and Parent seeds were obtained by selfing of parent plants sown for crossing block at Main Vegetable Research Station, Anand Agricultural University, Anand during the summer of 2021. The package of practices will be followed as per the recommendations for raising the healthy crop. Observations were recorded for the characters *viz*., days to first male flower, days to first female flower, node number to first male flower, node number to first female flower, main vine length, fruit number per vine, fruit weight, fruit length, fruit girth, fruit yield per vine, moisture content, total phenol content, total soluble solids (°Brix) and total soluble sugar. The experimental plot wise mean values of randomly selected 5 plants was used in each statistical analysis for different characters. The estimation of heterosis over better parent and standard check is more realistic. Hence, in the present investigation, heterosis was estimated over better parent (BP) and standard check, referred to as heterobeltiosis and standard heterosis, respectively. The *per se performance* of all the replications for each parents, hybrids and check for all characters was computed and used in estimation of heterosis.

Result and discussion

The analysis of variance showed that mean sum of squares (Table 1) due to genotypes was highly significant for fruit yield and yield contributing traits. This indicated that experimental material used in the present study had sufficient variability for different characters. Parents variances were found highly significant for all the characters except main vine length and moisture content. The variance of hybrids were significant for all the characters indicating the presence of significant genetic variability among the hybrids for all the characters under study. The analysis of variance of parents *vs* hybrids were significant for all characters except node number to first male flower, node number to first female flower, fruit girth, moisture content and total soluble sugar indicating significant amount of heterosis generated in the present investigation.

For days to first male flower and days to first female flower, the parent which took minimum days for flowering was considered to be a better parent and for node number to first male flower and node number to first female flower, the parent which flowered on lowest node number was considered to be a better parent and as per this heterosis were calculated. For these characters heterotic effect in the negative direction were desirable. The heterotic effects were in positive direction for all the characters except above mentioned characters.

Days to first male flower

As per better parent heterosis, the best performing negatively significant hybrids (Table 2) for days to first male flower were ABGS 11-26 × ABG 1 (-4.90%), ABGS 11-19 × Pusa Naveen (-4.55%), ABGS 11-18 × Pusa Naveen (-3.92%) and ABGS 11-24 × Arka Bahar (-3.86%). As per standard heterosis, the best performing negatively significant hybrids for days to first male flower were ABGS 11-23 × Punjab Komal (-8.36%), ABGS 11-25 × Punjab Komal (-8.06%), ABGS 11-24 × Arka Bahar (-4.99%) and ABGS 11-19 × Pusa Naveen (-4.55%). These results were in agreement with Singh *et al*. (2012) [21], Gayakwad (2014) [7], Ray *et al*. (2015) [18], Khot (2017) [11], Doloi *et al*. (2018) [5] and Kumar and Ram (2021) [12]. These results were also partial agreement with Yadav and Kumar (2012), Ghuge *et al*. (2016) [8] and Lal *et al*. (2021) [13]. But, the findings of the present investigation differed from the reports of Janaranjani *et al*. (2016) [9] as they reported only negative estimates of various heterotic effects.

Days to first female flower

According to better parent heterosis, the best performing negatively significant hybrids (Table 2) for days to first female flower were ABGS 11-19 × Pusa Naveen (-4.35%), ABGS 11-26 × ABG 1 (-4.02%) and ABGS 11-18 × Pusa Naveen (-4.00%). As per standard heterosis, the best performing negatively significant hybrids for days to first female flower were ABGS 11-25 × Punjab Komal (-6.71%), ABGS 11-23 × Punjab Komal (-5.35%) and ABGS 11-22 × Punjab Komal (-4.34%). These findings were similar with Singh *et al*. (2012) [21], Yadav and Kumar (2012), Gayakwad (2014) [7], Ray *et al*. (2015) [18], Janaranjani *et al*. (2016) [9], Ghuge *et al*. (2016) [8], Adarsh *et al*. (2017) [1], Khot (2017) [11], Doloi *et al*. (2018) [5] and Kumar and Ram (2021) [12]. These results were also in partial agreement with Mishra *et al*. (2019) [14] and Dhakne *et al*. (2021) [6].

Node number to first male flower

The best performing negatively significant hybrid for node number to first male flower (Table 2), according to better parent heterosis was ABGS 11-17 × Arka Bahar (-10.06%). As per standard heterosis, the best performing negatively significant hybrids for node number to first male flower were ABGS 11-16 × Punjab Komal (-17.54%), ABGS 11-25 × Punjab Komal (-17.06%), ABGS 11-22 × Punjab Komal (-17.04%) and ABGS 11-17 × Punjab Komal (-13.98%). These results were similar with Yadav and Kumar (2012), Ray *et al*. (2015) [18], Ghuge *et al*. (2016) [8], Doloi *et al*. (2018) [5], Kumar and Ram (2021) [12] and Lal *et al*. (2021) [13].

Node Number to First Female Flower

As per heterobeltiosis, the well-performing negatively significant hybrids (Table 2), for node number to first female flower were ABGS 11-17 × Arka Bahar (-21.31%), ABGS 11-19 × ABG 1 (-18.95%) and ABGS 11-23 × Arka Bahar (-12.56%). According to economic heterosis, the best performing negatively significant hybrids for node number to first female flower were ABGS 11-23 × Punjab Komal (-25.23%), ABGS 11-25 × Pusa Naveen (-21.22%), ABGS 11-26 × Punjab Komal (-20.26%) and ABGS 11-18 × Arka Bahar (-16.94%). Similar results were obtained by Yadav and Kumar (2012), Ray *et al*. (2015) [18], Adarsh *et al*. (2017) [1], Kumar and Ram (2021) [12] and Lal *et al*. (2021) [13] for heterobeltiosis and standard heterosis. Ghuge *et al*. (2016) [8] and Mishra *et al*. (2019) [14] reported similar results for heterobeltiosis and standard heterosis. These results were partial agreement with Khot (2017) [11] findings. But, the findings of the present investigation differed from the reports of Janaranjani *et al*. (2016) [9] as they reported only negative estimates of various heterotic effects.

Main Vine Length
For main vine length, ABGS 11-27 × Pusa Naveen (35.01%), ABGS 11-24 × ABG 1 (32.29%), ABGS 11-18 × Pusa Naveen (30.75%) and ABGS 11-25 × Punjab Komal (23.28%) showed positive significant heterobeltiosis (Table 3). As per standard heterosis, the best performing positively significant hybrids for main vine length were ABGS 11-24 × ABG 1 (38.48%), ABGS 11-18 × ABG 1 (22.47%), ABGS 11-27 × Pusa Naveen (20.53%) and ABGS 11-26 × Arka Bahar (18.29%). These results were in accordance with Shaikh *et al*. (2011) [20], Singh *et al*. (2012) [21], Gayakwad (2014) [7], Mishra *et al*. (2019) [14], Khot (2017) [11], Jayanth and Lal (2020) [10], Mauriya *et al*. (2020) [15], Kumar and Ram (2021) [12] and Lal *et al*. (2021) [13]. These results were in partial agreement with Ghuge *et al*. (2016) [8] and Janaranjani *et al*. (2016) [9]. But, the findings of the present investigation differed from the reports of Patel and Mehta (2021) [16] as they reported only positive estimates of standard heterosis.

Fruit Number per Vine
Out of 36 cross hybrids, 24 hybrids were significant, among them eight hybrids were positively significant for heterobeltiosis and 21 hybrids were significant, among them 13 hybrids were positively significant for standard heterosis (Table 3). According to better parent heterosis, the best performing positively significant hybrids for fruit number per vine were ABGS 11-24 × Arka Bahar (47.33%), ABGS 11-18 × Arka Bahar (41.13%), ABGS 11-23 × ABG 1 (26.58%) and ABGS 11-17 × ABG 1 (21.24%). As per standard heterosis, the best performing positively significant hybrids for fruit number per vine were ABGS 11-22 × Punjab Komal (51.12%), ABGS 11-23 × Punjab Komal (41.96%), ABGS 11-23 × ABG 1 (39.84%) and ABGS 11-26 × Pusa Naveen (39.67%). The results were in akin with the findings of Kumar *et al*. (2011), Singh *et al*. (2012) [21], Yadav and Kumar (2012), Gayakwad (2014) [7], Janaranjani *et al*. (2016) [9], Ray *et al*. (2015) [18], Ghuge *et al*. (2016) [8] and Adarsh *et al*. (2017) [1], Mishra *et al*. (2019) [14] and Kumar and Ram (2021) [12]. These results were in partial agreement with findings of Jayanth and Lal (2020) [10] and Patel and Mehta (2021) [16]. However, the findings of the present investigation differed from the reports of Lal *et al*. (2021) [13] as they reported mostly negative estimates of heterobeltiosis and standard heterosis.

Fruit Weight
The positively significant heterobeltiosis for fruit weight was ABGS 11-18 × Arka Bahar (12.55%) (Table 3). For fruit weight most of the crosses in negative direction because fruit weight should not more than optimum level otherwise it can be considered as over mature fruit. The best performing hybrid, ABGS 11-18 × Arka Bahar (11.02%) showed positive significant standard heterosis. These results were in conformity with those reported by Yadav and Kumar (2012), Janaranjani *et al*. (2016) [9], Ray *et al*. (2015) [18] and Adarsh *et al*. (2017) [1], Doloi *et al*. (2018) [5], Mishra *et al*. (2019) [14], Kumar and Ram (2021) [12], Lal *et al*. (2021) [13] and Rambabu *et al*. (2021) [17]. The results were in partial agreement with the reports of Gayakwad (2014) [7] and Dhanke *et al*. (2021) [6] as they reported moderate to high estimates of heterotic effect with higher magnitude in the positive direction. However, the findings of the present investigation differed from the reports of Singh *et al*. (2012) [21], Jayanth and Lal (2020) [10] and Patel and Mehta (2021) [16] as they reported only positive estimates of heterobeltiosis and standard heterosis.

Fruit Length
Based on heterobeltiosis, the positively significant hybrids for fruit length were ABGS 11-24 × ABG 1 (11.58%) and ABGS 11-19 × Arka Bahar (11.13%) (Table 3). As per standard heterosis, the best performing positively significant hybrids for fruit length were ABGS 11-24 × ABG 1 (35.73%), ABGS 11-19 × Arka Bahar (34.83%), ABGS 11-26 × Arka Bahar (29.22%), ABGS 11-23 × Arka Bahar (27.99%) and ABGS 11-17 × ABG 1 (27.94%). These results were in similar agreement with Yadav and Kumar (2012), Gayakwad (2014) [7], Janaranjani *et al*. (2016) [9], Ray *et al*. (2015) [18], Doloi *et al*. (2018) [5] Mishra *et al*. (2019) [14], Jayanth and Lal (2020) [10], Dhanke *et al*. (2021) [6] and Rambabu *et al*. (2021) [17]. These results were in partial agreement with Ghuge *et al*. (2016) [8], Adarsh *et al*. (2017) [1] and Lal *et al*. (2021) [13]. However, the findings of the present investigation differed from the reports of Patel and Mehta (2021) [16] as they reported mostly positive estimates of heterobeltiosis and standard heterosis.

Fruit Girth
The positively significant heterobeltiosis for fruit girth was ABGS 11-26 × ABG 1 (18.38%) (Table 4). The superior positively significant hybrids for fruit girth were ABGS 11-26 × Punjab Komal (34.55%), ABGS 11-19 × Punjab Komal (29.23%), ABGS 11-25 × Punjab Komal (21.68%) and ABGS 11-24 × Punjab Komal (17.83%) for economic heterosis. These results were in accordance with Shaikh *et al*. (2011) [20], Janaranjani *et al*. (2016) [9], Ray *et al*. (2015) [18], Doloi *et al*. (2018) [5] Kumar and Ram (2021) [12] and Rambabu *et al*. (2021) [17]. These results were in partial agreement with Singh *et al*. (2012) [21] and Mishra *et al*. (2019) [14].

Fruit Yield per Vine
For fruit yield per vine, out of 36 cross hybrids, 25 hybrids were significant, among them, eight hybrids were positively significant for heterobeltiosis and 26 hybrids were significant, among them 10 hybrids were positively significant for standard heterosis (Table 4). As per better parent heterosis, the best performing positively significant hybrids for fruit yield per vine were ABGS 11-18 × Arka Bahar (60.50%), ABGS 11-24 × Arka Bahar (55.66%), ABGS 11-23 × ABG 1 (39.02%), ABGS 11-17 × ABG 1 (38.08%), ABGS 11-24 × ABG 1(36.82%) and ABGS 11-27 × Arka Bahar (23.02%). As per standard heterosis, the best performing positively significant hybrids for fruit yield per vine were ABGS 11-22 × Punjab Komal (54.07%), ABGS 11-23 × ABG 1 (33.26%), ABGS 11-17 × ABG 1 (32.35%), ABGS 11-18 × Arka Bahar (31.45%), ABGS 11-24 × ABG 1 (31.15%) and ABGS 11-24 × Arka Bahar (29.71%). These results were in agreement with Shaikh *et al*. (2011) [20], Yadav and Kumar (2012), Gayakwad (2014) [7], Ray *et al*. (2015) [18], Adarsh *et al*. (2017) [1], Mishra *et al*. (2019) [14], Doloi *et al*. (2018) [5], Balat *et al*. (2020) [2] Kumar and Ram (2021) [12] and Rambabu *et al*. (2021) [17]. These results were in partial agreement with Ghuge *et al*.

(2016) [8] and Dhakne *et al*. (2021) [6]. However, the findings of the present investigation differed from the reports of Singh *et al*. (2012) [21], Jayanth and Lal (2020) [10], Patel and Mehta (2021) [16] as they reported most of all positive estimates of heterobeltiosis and standard heterosis. But, Mauriya *et al*. (2020) [15] reported most of all negative estimates of heterobeltiosis and standard heterosis.

Moisture Content

The remarkable hybrid for moisture content was ABGS 11-25 × Pusa Naveen (2.20%) (Table 4). Out of 36 cross hybrids, three hybrids were significant, among them none of the hybrids were positively significant. The similar results were also reported by Shaikh *et al*. (2011) [20] for heterobeltiosis and standard heterosis.

Total Phenol Content

According to better parent heterosis, the best performing positively significant hybrids for total phenol content were ABGS 11-27 × Pusa Naveen (18.16%), ABGS 11-24 × Arka Bahar (18.14%), ABGS 11-19 × Pusa Naveen (16.84%) and ABGS 11-23 × ABG 1 (16.15%) (Table 4). As per standard heterosis, the best performing positively significant hybrids for total phenol content were ABGS 11-27 × Pusa Naveen (18.12%), ABGS 11-19 × Pusa Naveen (16.80%) and ABGS 11-25 × ABG 1 (12.69%).

Total Acidity

The hybrids, ABGS 11-27 × Arka Bahar (11.28%), ABGS 11-23 × Pusa Naveen (9.82%), ABGS 11-27 × Pusa Naveen (9.16%) and ABGS 11-26 × Pusa Naveen (8.87%) showed positive significant heterobeltiosis (Table 5). For standard heterosis, the leading positively significant hybrids for total acidity were ABGS 11-27 × ABG 1 (11.03%), ABGS 11-23 × ABG 1 (10.64%), ABGS 11-27 × Arka Bahar (10.64%) and ABGS 11-19 × ABG 1 (9.86%).

Total Soluble Solids (°Brix)

According to heterobeltiosis, the good performing positively significant hybrids for TSS were ABGS 11-26 × Pusa Naveen (10.61%), ABGS 11-23 × Punjab Komal (9.99%) and ABGS 11-22 × Punjab Komal (8.12%) (Table 5). As per standard heterosis, the best performing positively significant hybrids for TSS were ABGS 11-23 × Punjab Komal (25.49%), and ABGS 11-22 × Punjab Komal (23.36%), ABGS 11-26 × Punjab Komal (20.41%) and ABGS 11-25 × Punjab Komal (20.08%). These results were in agreement with Janranjani *et al*. (2016) [9] and Rambabu *et al*. (2021) [17] as they recorded moderate heterosis in both directions. These findings were in partial agreement with Shaikh *et al*. (2011) [20], Kumar and Ram (2021) [12], Patel and Mehta (2021) [16] and Lal *et al*. (2021) [13] (for heterobeltiosis). But, Doloi *et al*. (2018) [5] and Mauriya *et al*. (2020) [15] reported most of all negative estimates of standard heterosis. However, Lal *et al*. (2021) [13] reported most of all positive estimates of standard heterosis.

Total Soluble Sugar

The best performing positively significant heterobeltiosis for total soluble sugar were ABGS 11-24 × Arka Bahar (25.91%), ABGS 11-19 × ABG 1 (24.83%) and ABGS 11-17 × Arka Bahar (24.41%) (Table 5). As per standard heterosis, the best performing positively significant hybrids for total soluble sugar were ABGS 11-25 × Punjab Komal (33.62%), ABGS 11-23 × Punjab Komal (32.40%), ABGS 11-18 × Punjab Komal (32.16%) and ABGS 11-25 × Pusa Naveen (28.49%). These results were in partial agreement with Rambabu *et al*. (2021) [17], Kumar and Ram (2021) [12] and Lal *et al*. (2021) [13] for heterobeltiosis and standard heterosis. However, Doloi *et al*. (2018) [5] reported most of all negative estimates of standard heterosis.

Significant levels of desirable heterobeltiosis and standard heterosis was registered in the current investigation for fruit yield per vine and its component characters. These suggests the magnitude of heterosis breeding for improvement of this crop. Out of 36 hybrids developed, ABGS 11-22 × Punjab Komal, ABGS 11-23 × ABG 1, ABGS 11-17 × ABG 1, ABGS 11-18 × Arka Bahar, ABGS 11-24 × ABG 1, ABGS 11-24 × Arka Bahar and ABGS 11-26 × Pusa Naveen were most promising cross combinations for fruit yield per vine on the basis of *per se* performance and standard heterosis. Therefore, these cross combinations may be favoured for commercial cultivation as hybrids after critical evaluation in varied environments or over locations. These hybrids may also be further advanced for development of superior desirable recombinants as improved varieties.

Fig 1: Field view of Experimental site (*Kharif*, 2021)

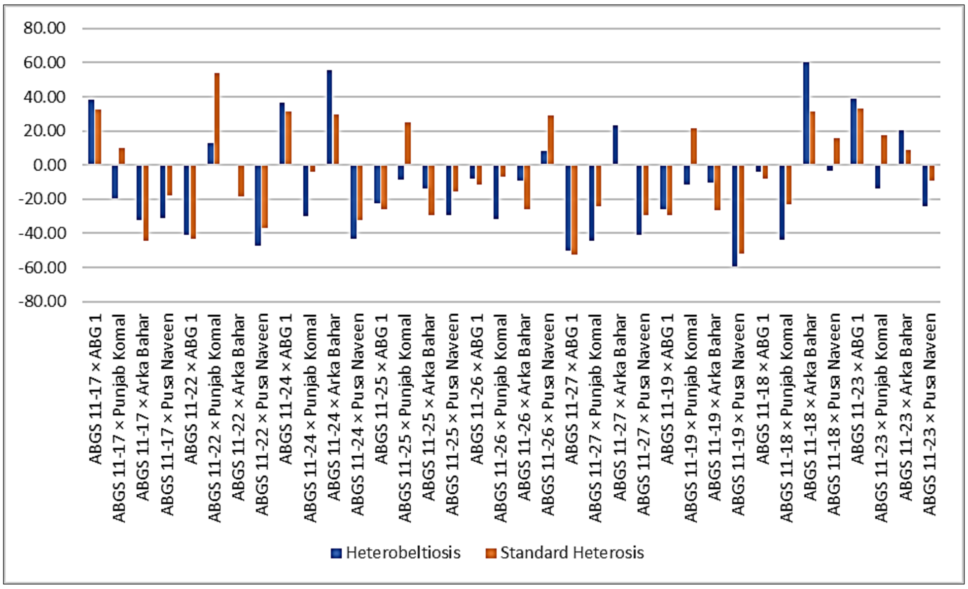

Fig 2: Heterobeltiosis and Standard heterosis of hybrids for fruit yield per vine

Table 1: Analysis of variances (mean squares) for various characters

Source of variation			d.f.	DFMF	DFFF	NFMF	NFFF	MVL	FNPV	FW	FL
Replications			2	0.22	0.06	0.25	0.23	1.07	1.92**	4943.61	10.40
Genotypes			49	5.74**	6.60**	10.60**	23.54**	5.57**	5.41**	18541.13**	184.95**
(a)	**Parents**		12	5.70**	5.29**	17.46**	27.03**	1.20	4.58**	8874.60**	127.58**
	(i)	**Females**	8	1.90	1.71	12.64**	18.01**	1.23	0.77**	7624.06**	16.08**
	(ii)	**Males**	3	13.95**	11.77**	35.22**	35.35**	1.50	5.49**	5449.00	396.38**
	(iii)	**Females *vs* Males**	1	11.31**	14.51**	2.77	74.32**	0.02	32.29**	29155.56**	213.16**
(b)	**Hybrids**		35	5.53**	7.24**	8.82**	23.61**	7.28**	5.48**	21957.16**	213.94**
(c)	**Parents *vs* Hybrids**		1	19.21**	5.93*	1.03	0.97	3.32*	18.68**	11235.41*	40.39**
Error			98	1.13	1.12	0.87	1.38	0.71	0.35	2563.63	5.85
Total			149	2.64	2.91	4.06	8.66	2.31	2.03	7849.92	64.81

Table 1: Cont.…

Source of variation			d.f.	FG	FYPV	MC	TPC	TA	TSS (°Brix)	TSS
Replications			2	0.25	0.78*	0.38	0.03	0.000004	0.03	0.002
Genotypes			49	33.98**	4.30**	1.51**	21.85**	0.00033**	1.44**	0.626**
(a)	**Parents**		12	67.67**	3.34**	1.32	13.28**	0.00023**	0.93**	0.628**
	(i)	**Females**	8	5.78**	0.86**	0.66	12.54**	0.00022**	0.11**	0.622**
	(ii)	**Males**	3	167.45**	3.48**	1.29	14.77**	0.00028**	1.16**	0.853**
	(iii)	**Females *vs* Males**	1	263.52**	22.82**	6.65**	14.72**	0.00013*	6.75**	0.003
(b)	**Hybrids**		35	24.35**	4.65**	1.63**	25.56**	0.00037**	1.58**	0.661**
(c)	**Parents *vs* Hybrids**		1	0.23	7.00**	0.88	4.89*	0.00079**	3.22**	0.007
Error			98	1.49	0.22	0.81	0.73	0.000031	0.04	0.012
Total			149	12.16	1.57	1.04	7.66	0.000132	0.50	0.214

*, **: Significant at 0.05 and 0.01 levels of probability, respectively.

(**DFMF** – Days to first male flower, **DFFF** – Days to first female flower, **NFMF** – Node number to first male flower, **NFFF** – Node number to first female flower, **MVL** – Main vine length, **FNPV** – Fruit number per vine, **FW** – Fruit weight, **FL** – Fruit length, **FG** – Fruit girth, **FYPV** – Fruit yield per vine, **MC** – Moisture content, **TPC** – Total phenol content, **TA** – Total acidity, **TSS** – Total soluble solids, **TSS** – Total soluble sugar)

Table 2: Estimates of better parent heterosis (BPH) and standard heterosis (SH) in per cent for days to first male flower, days to first female flower, node number to first male flower and node number to first female flower

Hybrids	DFMF		DFFF		NFMF		NFFF	
	BPH	SH	BPH	SH	BPH	SH	BPH	SH
L1 × T1	-0.49	3.45	2.09	6.08**	2.91	31.52**	17.01**	26.70**
L1 × T2	12.28**	3.89*	10.03**	3.18	0.55	-13.98*	44.23**	13.68*
L1 × T3	2.08	0.88	5.44**	4.67*	-10.06*	12.32*	9.75*	22.28**
L1 × T4	-0.29	-0.29	-1.36	-0.07	20.86**	0.24	33.05**	0.46

L2 × T1	1.74	2.93	1.52	4.56*	31.05**	18.01**	14.56**	24.05**
L2 × T2	3.65	-4.11*	2.01	-4.34*	-3.02	-17.04**	12.38	-11.42*
L2 × T3	0.82	-0.37	2.55	1.81	8.42	-2.37	-4.71	6.17
L2 × T4	-0.73	-0.73	-0.24	1.06	5.14	-12.80*	31.71**	-0.55
L3 × T1	2.20	2.35	1.94	4.56*	18.36**	21.16**	36.48**	22.65**
L3 × T2	4.75*	-3.08	7.79**	1.09	26.87**	8.53	50.77**	18.84**
L3 × T3	-3.86*	-4.99*	-2.04	-2.75	-0.69	1.66	43.95**	29.37**
L3 × T4	-1.61	-1.61	-2.43	-1.16	40.37**	16.42**	26.34**	-4.60
L4 × T1	-2.72	-0.29	-1.33	1.66	1.00	-4.03	31.55**	20.17**
L4 × T2	-0.63	-8.06**	-0.52	-6.71**	-3.05	-17.06**	24.77**	-1.66
L4 × T3	0.74	-0.44	1.50	0.77	21.70**	15.64**	17.60**	7.42
L4 × T4	-1.61	-1.61	-2.68	-1.41	5.43	-12.56*	4.34	-21.22**
L5 × T1	-4.90*	-4.62*	-4.02*	-3.33	5.74	4.74	-12.31*	-11.18*
L5 × T2	4.20*	-3.59	6.02**	-0.58	-3.60	-17.54**	1.17	-20.26**
L5 × T3	0.30	-0.88	4.83*	4.07*	9.57	8.53	16.91**	18.42**
L5 × T4	-0.29	-0.29	0.86	1.59	6.43	-11.73*	35.93**	2.63
L6 × T1	-2.07	0.44	4.39*	6.73**	2.60	12.32*	-8.16	-0.55
L6 × T2	6.89**	-1.10	5.79**	-0.80	26.87**	8.53	33.18**	4.97
L6 × T3	3.26	2.05	1.99	1.25	-0.87	8.53	4.96	16.94*
L6 × T4	0.55	0.55	1.19	2.50	27.43**	5.69	35.61**	2.39
L7 × T1	0.07	0.66	-1.35	0.22	3.02	-11.14*	-18.95**	-12.23*
L7 × T2	6.81**	-1.17	5.71**	-0.87	22.33**	4.64	30.14**	2.58
L7 × T3	-0.37	-1.54	1.09	0.36	7.17	-7.56	13.72**	26.70**
L7 × T4	-4.55*	-4.55*	-4.35*	-3.10	14.14*	-5.33	24.88**	-5.71
L8 × T1	2.16	4.11*	4.61*	8.70**	14.32*	9.72	6.44	12.34*
L8 × T2	4.75*	-3.08	5.81**	-0.77	4.16	-10.90*	8.41	-14.55**
L8 × T3	-1.04	-2.20	-1.38	-2.10	5.43	1.18	-21.31**	-16.94**
L8 × T4	-3.92*	-3.92*	-4.00*	-2.75	16.29*	-3.55	35.61**	2.39
L9 × T1	-2.08	-3.37	-0.27	-0.63	12.40*	8.67	13.95**	23.39**
L9 × T2	-0.95	-8.36**	0.93	-5.35**	1.94	-12.80*	-5.14	-25.23**
L9 × T3	-0.45	-1.76	1.17	0.43	-0.42	-3.72	-12.56**	-2.58
L9 × T4	2.97	1.61	2.11	1.74	27.51**	5.76	13.41	-14.36**
S.Em ±	0.87		0.86		0.76		0.96	
Range								
Minimum	-4.90	-8.36	-4.35	-6.71	-10.06	-17.54	-21.31	-25.23
Maximum	12.28	4.11	10.03	8.70	40.37	31.52	50.77	29.37
No. of sig. crosses	10	9	13	10	15	17	26	22
Positive	6	2	10	7	14	7	22	14
Negative	4	7	3	3	1	10	4	8

*, **: Significant at 0.05 and 0.01 levels of probability, respectively.

Table 3: Estimates of better parent heterosis (BPH) and standard heterosis (SH) in per cent for main vine length, fruit number per vine, fruit weight and fruit length

Hybrids	MVL		FNPV		FW		FL	
	BPH	SH	BPH	SH	BPH	SH	BPH	SH
L1 × T1	5.67	10.61	21.24**	33.94**	7.37	-1.19	6.57	27.94**
L1 × T2	0.42	-8.59	-12.69*	17.00*	-7.42	-5.26	-35.01**	-34.45**
L1 × T3	5.92	4.71	-5.31	-21.47*	-26.39**	-27.38**	5.20	27.63**
L1 × T4	17.67*	7.11	-15.37*	9.67	-10.81	-18.86**	-11.94*	-11.18
L2 × T1	-32.87**	-29.73**	-31.66**	-24.50**	-16.40**	-23.06**	-14.51**	2.64
L2 × T2	-10.25	-13.35	12.77*	51.12**	-3.36	-1.10	-37.09**	-30.42**
L2 × T3	11.73	10.46	6.49	-11.68	-6.45	-7.72	2.17	23.95**
L2 × T4	-20.68*	-23.42**	-39.53**	-21.64*	-11.00	-19.03**	2.46	13.32*
L3 × T1	32.29**	38.48**	16.22*	28.39**	5.72	0.21	11.58*	35.73**
L3 × T2	7.24	11.56	-8.50	22.61**	-23.78**	-22.00**	-34.33**	-20.12**
L3 × T3	5.70	9.96	47.33**	29.36**	0.04	-1.31	4.83	27.52**

L3 × T4	-13.52	-10.04	-28.22**	-6.98	-22.63**	-26.66**	-15.46**	2.84
L4 × T1	-20.05**	-16.31*	-25.44**	-17.63*	-2.26	-10.05	-6.74	11.97*
L4 × T2	23.28**	16.58*	-5.13	27.13**	-4.68	-2.46	-23.10**	-20.92**
L4 × T3	-30.88**	-31.67**	7.66	-10.70	-19.85**	-20.94**	5.09	27.49**
L4 × T4	-16.65*	-21.18**	-24.91**	-2.69	-4.66	-13.27*	0.54	3.40
L5 × T1	-32.97**	-29.83**	-3.89	6.18	-1.61	-9.45	-20.38**	-4.41
L5 × T2	-9.45	-12.21	-27.55**	-2.92	-5.47	-3.26	-38.66**	-30.62**
L5 × T3	19.65*	18.29*	20.50*	-0.06	-23.55**	-24.59**	6.51	29.22**
L5 × T4	17.45*	13.88	7.77	39.67**	-1.03	-9.96	-19.89**	-9.40
L6 × T1	-40.43**	-37.64**	-33.37**	-26.39**	-30.03**	-35.61**	-2.75	16.76**
L6 × T2	9.24	-4.22	-31.65**	-8.41	-19.43**	-17.55**	-34.36**	-32.48**
L6 × T3	4.85	3.65	7.45	-10.88	9.24	7.76	-2.54	18.24**
L6 × T4	35.01**	20.53**	-39.93**	-22.15**	1.72	-7.46	-1.56	1.25
L7 × T1	7.48	12.51	-21.24**	-12.99	-12.16*	-19.16**	2.27	22.79**
L7 × T2	-3.93	-0.61	-7.26	24.27**	-6.05	-3.86	-47.57**	-42.05**
L7 × T3	8.20	11.94	-8.16	-17.52*	-10.36	-11.57*	11.13*	34.83**
L7 × T4	-8.12	-4.94	-52.92**	-38.98**	-13.50*	-20.98**	-53.84**	-48.97**
L8 × T1	17.00*	22.47**	-15.75*	-6.93	4.24	-3.01	4.20	25.10**
L8 × T2	-14.57	-24.41**	-19.65**	7.67	-31.28**	-29.67**	-40.94**	-33.17**
L8 × T3	11.50	10.23	41.13**	17.06*	12.55*	11.02*	-16.35**	1.49
L8 × T4	30.75**	16.73*	0.27	29.94**	-6.70	-13.18*	-8.59	3.43
L9 × T1	0.98	5.70	26.58**	39.84**	-4.37	-7.33	2.09	22.56**
L9 × T2	-3.06	0.08	5.94	41.96**	-21.67**	-19.84**	-37.98**	-28.37**
L9 × T3	-4.64	-1.56	19.18*	12.76	-1.80	-3.14	5.49	27.99**
L9 × T4	-0.77	2.43	-27.12**	-5.55	1.44	-1.70	-3.19	11.82*
S.Em ±	0.69		0.48		41.34		1.97	
Range								
Minimum	-40.43	-37.64	-52.92	-38.98	-31.28	-35.61	-53.84	-48.97
Maximum	35.01	38.48	47.33	51.12	12.55	11.02	11.58	35.73
No. of sig. crosses	15	14	24	21	13	18	18	27
Positive	8	6	8	13	1	1	2	17
Negative	7	8	16	8	12	17	16	10

*, **: Significant at 0.05 and 0.01 levels of probability, respectively.

Table 4: Estimates of better parent heterosis (BPH) and standard heterosis (SH) in per cent for fruit girth, fruit yield per vine, moisture content and total acidity

Hybrids	FG		FYPV		MC		TPC	
	BPH	SH	BPH	SH	BPH	SH	BPH	SH
L1 × T1	-0.92	-9.91	38.08**	32.35**	0.12	0.13	-4.93	-22.33**
L1 × T2	-35.56**	11.15*	-19.65**	9.80	-0.48	0.38	-5.98	-25.11**
L1 × T3	-3.63	-7.39	-32.41**	-44.65**	-1.98*	-1.54	-1.60	-9.57**
L1 × T4	3.26	16.33**	-31.15**	-17.65*	0.67	-0.09	-21.89**	-21.92**
L2 × T1	-7.35	-15.76**	-40.91**	-43.36**	-0.78	-0.77	-16.29**	-13.52**
L2 × T2	-32.27**	16.83**	12.75*	54.07**	-1.05	-0.19	-24.28**	-21.77**
L2 × T3	-6.03	-9.69	-0.64	-18.63*	-1.25	-0.81	0.38	3.70
L2 × T4	-21.57**	-11.65*	-47.04**	-36.65**	0.09	-0.06	-13.75**	-10.89**
L3 × T1	-2.67	-11.01*	36.82**	31.15**	-0.04	-0.02	-11.37**	-22.31**
L3 × T2	-31.69**	17.83**	-29.80**	-4.07	-1.42	-0.56	-4.74	-16.50**
L3 × T3	-3.93	-7.67	55.66**	29.71**	-0.85	-0.40	18.14**	8.56*
L3 × T4	-18.20**	-7.86	-43.38**	-32.28**	0.50	-0.26	-6.95*	-6.98*
L4 × T1	-6.82	-13.25**	-22.58*	-25.79**	-0.69	-0.68	13.09**	12.69**
L4 × T2	-29.46**	21.68**	-8.61	24.89**	-1.18	-0.32	-0.25	-0.60
L4 × T3	-13.18*	-16.56**	-14.00	-29.56**	0.06	0.50	-2.88	-3.23
L4 × T4	-15.91**	-5.26	-29.32**	-15.46	2.20**	1.43	-19.30**	-19.32**
L5 × T1	18.38**	7.64	-7.87	-11.69	0.00	0.01	-29.19**	-27.36**
L5 × T2	-22.00**	34.55**	-31.68	-6.64	0.52	1.39	4.01	6.69
L5 × T3	-12.70*	-16.10**	-9.21	-25.64**	-2.16**	-1.72**	-2.38	0.13
L5 × T4	-16.94**	-6.43	8.13	29.34**	-0.20	-0.64	-23.72**	-21.75**
L6 × T1	-19.96**	-24.95**	-50.20**	-52.26**	-0.72	-0.70	-3.69	-7.52*
L6 × T2	-33.24**	15.16**	-44.43**	-24.06**	-0.74	0.12	-21.25**	-24.38**
L6 × T3	6.78	2.62	23.02*	0.75	-2.44**	-2.01*	-2.33	-6.21
L6 × T4	-10.09*	1.29	-40.86**	-29.26**	-0.66	-1.41	18.16**	18.12**
L7 × T1	-7.24	-10.11*	-26.04**	-29.11**	-1.76*	-1.74*	-10.73**	-11.27**
L7 × T2	-25.08**	29.23**	-11.15	21.42*	-1.74*	-0.89	-12.62**	-13.14**
L7 × T3	-8.73	-11.55*	-10.50	-26.70**	-0.32	0.13	-23.35**	-23.81**
L7 × T4	-20.92**	-10.91*	-59.65**	-51.73**	0.42	-0.34	16.84**	16.80**

L8 × T1	-8.53	-16.83**	-4.01	-7.99	-0.34	-0.32	-14.78**	-15.59**
L8 × T2	-37.31**	8.14	-43.65**	-23.00**	-1.14	-0.28	10.55**	9.51**
L8 × T3	-7.11	-10.73*	60.50**	31.45**	-0.37	0.08	-34.99**	-35.60**
L8 × T4	-19.58**	-9.41	-3.40	15.54	0.36	-0.18	9.35**	9.31**
L9 × T1	-9.86	-11.08*	39.02**	33.26**	0.33	0.35	16.15**	-5.10
L9 × T2	-40.50**	2.62	-14.02*	17.50*	-0.19	0.67	0.00	-23.43**
L9 × T3	-11.52*	-12.72*	20.60*	8.60	-1.54*	-1.10	-3.55	-11.37**
L9 × T4	-10.13*	1.24	-24.21**	-9.35	0.58	0.12	-34.27**	-34.30**
S.Em ±	0.99		0.38		0.74		0.70	
Range								
Minimum	-40.50	-24.95	-59.65	-52.26	-2.44	-2.01	-34.99	-35.60
Maximum	18.38	34.55	60.50	54.07	2.20	1.43	18.16	18.12
No. of sig. crosses	22	22	25	26	7	3	23	29
Positive	1	8	8	10	1	-	7	6
Negative	21	14	17	16	6	3	16	23

*, **: Significant at 0.05 and 0.01 levels of probability, respectively.

Table 5: Estimates of better parent heterosis (BPH) and standard heterosis (SH) in per cent for total phenol content, total soluble solids (°Brix) and total soluble sugar

Hybrids	**TA**		**TSS (°Brix)**		**TSS**	
	BPH	SH	BPH	SH	BPH	SH
L1 × T1	-1.89	0.19	3.37	-16.97**	-13.80**	-24.84**
L1 × T2	5.74	-3.87	-29.60**	-19.67**	-18.83**	6.04
L1 × T3	7.20**	6.58**	-11.89**	-23.44**	24.41**	2.72
L1 × T4	5.83*	-1.74	-26.71**	-24.67**	-13.75**	-10.70**
L2 × T1	-3.98	-1.93	-12.55**	-29.75**	-21.34**	-24.69**
L2 × T2	-10.61**	-8.70**	8.12*	23.36**	-16.68**	8.84*
L2 × T3	0.38	2.51	-7.36	-19.51**	3.83	-0.58
L2 × T4	-13.07**	-11.22**	-16.11**	-13.77**	9.00*	12.85**
L3 × T1	5.68*	7.93**	-17.14**	-33.44**	-11.89**	-12.26**
L3 × T2	-4.03	-7.93**	-14.37**	-2.30	-35.32**	-15.51**
L3 × T3	-1.95	-2.51	-13.77**	-25.08**	25.91**	25.38**
L3 × T4	1.01	-3.09	-17.62**	-15.33**	-5.01	-1.66
L4 × T1	4.23	9.67**	-17.14**	-33.44**	-1.74	22.15**
L4 × T2	-11.76**	-7.16**	5.24	20.08**	2.29	33.62**
L4 × T3	1.29	6.58*	-6.51	-18.77**	-36.51**	-21.08**
L4 × T4	-5.70*	-0.77	4.63	7.54	3.36	28.49**
L5 × T1	-4.36	-2.32	2.96	-17.30**	-36.90**	-26.67**
L5 × T2	-4.44	-8.32**	5.53	20.41**	-14.18**	12.11**
L5 × T3	7.39**	6.77*	2.08	-11.31**	-15.99**	-2.36
L5 × T4	8.87**	4.45	10.61**	13.69**	2.47	19.08**
L6 × T1	8.71**	11.03**	-31.33**	-44.84**	-11.06**	-22.45**
L6 × T2	4.07	-1.16	-31.32**	-21.64**	-36.68**	-17.29**
L6 × T3	11.28**	10.64**	-15.09**	-26.23**	0.67	-16.88**
L6 × T4	9.16**	3.68	-24.48**	-22.38**	21.18**	25.46**
L7 × T1	5.97*	9.86**	3.78	-16.64**	24.83**	9.03*
L7 × T2	-13.62**	-10.44**	-13.51**	-1.31	-40.83**	-22.71**
L7 × T3	-3.73	-0.19	3.21	-10.33**	-3.95	-16.11**
L7 × T4	-4.85	-1.35	-12.68**	-10.25**	-1.65	1.82
L8 × T1	6.44*	8.70**	5.47	-14.67**	-27.28**	-13.86**
L8 × T2	-5.68*	-3.68	3.88	18.52**	1.16	32.16**
L8 × T3	1.52	3.68	1.23	-12.05**	-27.75**	-14.42**
L8 × T4	-8.14**	-6.19*	5.90	8.85*	5.68	25.16**
L9 × T1	8.33**	10.64**	-8.27	-26.31**	3.86	14.63**
L9 × T2	4.50	-1.16	9.99**	25.49**	1.35	32.40**
L9 × T3	4.09	3.48	-10.57*	-22.30**	-19.95**	-11.65**
L9 × T4	9.82**	3.87	-5.50	-2.87	-7.53*	2.05
S.Em ±	0.0046		0.15		0.089	
Range						
Minimum	-13.62	-11.22	-31.33	-44.84	-40.83	-26.67
Maximum	11.28	11.03	10.61	25.49	25.91	33.62
No. of sig. crosses	19	17	20	32	23	29
Positive	11	10	3	7	5	13
Negative	8	7	17	25	18	16

*, **: Significant at 0.05 and 0.01 levels of probability, respectively.

Conclusion

Significant levels of desirable heterobeltiosis and standard heterosis was registered in the current investigation for fruit yield per vine and its component characters. Out of 36 hybrids developed, ABGS 11-22 × Punjab Komal, ABGS 11-23 × ABG 1, ABGS 11-17 × ABG 1, ABGS 11-18 × Arka Bahar, ABGS 11-24 × ABG 1 and ABGS 11-24 × Arka Bahar were most promising cross combinations for fruit yield per vine on the basis of heterobeltiosis and standard heterosis. Therefore, these cross combinations may be favoured for commercial cultivation as hybrids after critical evaluation in varied environments or over locations. These hybrids may also be further advanced for development of superior desirable recombinants as improved varieties.

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