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ASSESSMENT OF HETEROSIS AND GENE ACTION FOR YIELD AND ITS COMPONENT TRAITS IN BOTTLE GOURD (*Lagenaria siceraria* MOL. Standl.)

Ankita Tiwari[1] and V.K. Tripathi[2]*

[1]Department of Vegetables Science, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur - 208 002, U.P., India.
[2]Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur - 208 002, U.P., India.
*Corresponding authors E-mail : drvktripathicsa@gmail.com

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ABSTRACT

The present investigation was undertaken to assess heterosis and gene action for yield and its contributing traits in bottle gourd. Using the line × tester mating design, this study investigated the Heterosis and Gene Action for yield-related traits in bottle gourd. In *summer* season of 2024, at the Vegetable farm, Chandra Shekhar Azad University of Agriculture & Technology, Kalyanpur, Kanpur (U. P.), evaluated thirty crossings derived from ten lines and three testers. The tests were conducted using a randomised block design with 3 replications, 30 F_1's and their 13 parents were evaluated. Significant heterotic variation was seen among the hybrids. Heterobeltiosis in fruit length ranged from -32.30 to 16.03%, with SBC/DRB-206-1 × Pusa Naveen having the highest positive heterosis. Fruit circumference showed heterobeltiosis ranging from -24.76 to 54.19%, with VRBG-21 × Kalyanpur Long Green having the highest positive value. Fruit weight showed heterobeltiosis from -32.73 to 34.97%, with the highest being SBC/DRB-201-1 × Kashi Ganga. Heterobeltiosis varied from -27.23 to 25.11%, with VRBG-21 × Kashi Ganga outperforming other varieties. VRBG-21 × Kashi Ganga had the most heterobeltiosis, whereas VRBG-21 × Kalyanpur Long Green had the highest standard heterosis (49.25%). Fruit yield per plant varied from -50.04 to 52.60%. For yield traits, SCA variance was greater than GCA variance, suggesting a predominance of non-additive gene action. The superior hybrids found could be helpful for heterosis breeding and bottle gourd production enhancement.

Key words : Bottle gourd, Heterosis, Yield, Gene action.

Introduction

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] is an important cucurbit vegetable cultivated widely in tropical and subtropical regions, including India, Bangladesh, Malaysia, Indonesia, China, Japan, the Philippines, Taiwan, Thailand, South Africa and Sudan. The crop is valued primarily for its tender fruits, which are consumed as a cooked vegetable, while its young leaves and tender shoots are also used as vegetables (Mkhize *et al.*, 2021). Bottle gourd is characterized by its high-water content and appreciable nutritional value; 100 g of edible portion contains approximately 1.1 g protein, 15.1 g carbohydrates, 0.1 g fat and 0.6 g minerals, besides several vitamins and other essential nutrients (Saeed *et al.*, 2022). The fruits and seeds also possess potential nutritional and industrial value owing to their oil and protein content (Hassan *et al.*, 2008). The crop has further attracted attention for its traditional medicinal and functional properties, with different plant parts being reported to possess diverse bioactive and pharmacological properties (Ahmad *et al.*, 2011).

The increasing demand for bottle gourd in domestic and international markets has emphasized the need for high-yielding hybrids possessing desirable fruit quality and broad adaptability (Janaranjani *et al.*, 2016). However, productivity is constrained by inadequate availability of superior hybrids, limited exploitation of available genetic variability, biotic stresses and fluctuations in environmental conditions (Maurya *et al.*, 2021 and Yadav *et al.*, 2025). India possesses considerable bottle gourd germplasm encompassing diverse cultivated and wild forms, providing substantial scope for genetic improvement through

systematic breeding. Exploitation of this genetic variability through hybridization can facilitate the development of superior hybrids with enhanced yield, quality and stability.

Heterosis breeding provides an effective approach for exploiting non-additive genetic variation and developing superior F_1 hybrids. Estimation of heterosis over the better parent and standard check helps identify hybrid combinations with desirable performance for yield and its component traits. In addition, understanding the relative contribution of additive and non-additive gene effects is essential for selecting an appropriate breeding strategy. Therefore, the present investigation entitled "Assessment of Heterosis and Gene Action for Yield and Its Component Traits in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.]" was undertaken to estimate heterosis and gene action for important growth, flowering, yield and quality traits and to identify promising hybrid combinations for their potential utilization in bottle gourd breeding programmes.

Materials and Methods

Experimental material and design

The investigation was conducted at the Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture & Technology, Kalyanpur, Kanpur, Uttar Pradesh, India. During *summer* 2024, ten promising lines, namely VRBG-21 (L1), VRBG-67 (L2), SBC/DRB-201-3 (L3), SBC/DRB-125-1 (L4), SBC/DRB-75 (L5), SBC/DRB-201-1 (L6), SBC/DRB-206-1 (L7), SBC/DRB-201-2 (L8), NDBG-18 (L9) and one additional line [L10], along with three testers, Kalyanpur Long Green (T_1), Pusa Naveen (T_2) and Kashi Ganga (T_3), were used for hybridization. Crosses were made following a line × tester mating design, resulting in 30 F_1 hybrids. Thus, the experimental material comprised 30 F_1 hybrids, 13 parents (10 lines and 3 testers) and one standard check, *Sarita*, totalling 44 genotypes. The parents and F_1 hybrids were evaluated during summer 2025 in a Randomized Block Design with three replications. Each genotype was grown in a 4.0 m long single-row plot with 3.0 m row-to-row and 0.75 m plant-to-plant spacing. Six healthy and uniform plants per plot were selected for recording observations. Recommended agronomic and plant protection practices were followed throughout the crop period.

Observation and statistical analysis

Observations were recorded for days to first male flowering, days to first female flowering, node number to first male flower, node number to first female flower, number of primary branches per plant, vine length, days to first female harvest, fruit length, fruit circumference, individual fruit weight, number of fruits per plant, fruit yield per plant, ascorbic acid, total sugar and dry matter. Vine length was measured at final harvest, flowering and harvesting dates were recorded from sowing, fruit dimensions were measured using standard measuring instruments, and fruit weight was recorded using a digital balance. Fruit yield per plant was calculated from the cumulative weight of fruits harvested from each plant. Biochemical traits were estimated following standard analytical procedures.

Heterobeltiosis and standard heterosis were estimated as percentage deviation of the F_1 performance over the better parent and standard check (*Sarita*), respectively, following Fonseca and Patterson (1968). Genetic components of variation and gene action were estimated using the numerical approach proposed by Jinks and Hayman (1953) and Hayman (1954).

Results and Discussion

Heterosis was estimated in the F_1 hybrids as the percentage increase or decrease in hybrid performance over the better parent (heterobeltiosis) and the standard check cultivar *Sarita* (economic heterosis). Heterobeltiosis was used to assess the superiority of the F_1 hybrids over their respective better parents, whereas economic heterosis indicated the relative superiority of the hybrids over the commercially cultivated standard check. The magnitude and direction of heterosis were estimated for the yield and quality attributes evaluated in the experiment. The estimates of heterobeltiosis and economic heterosis in the F_1 generation are presented in Table 1.

Days to first staminate flower anthesis, heterosis over better parent (BP) ranged from -22.56% in SBC/DRB-201-2 × Pusa Naveen to 16.79% in VRBG-67 × Kalyanpur Long Green. Significant negative heterosis was recorded for SBC/DRB-201-2 × PUSA NAVEEN (-22.56%) exhibited the highest desirable heterosis, followed by SBC/DRB-201-1 × PUSA NAVEEN (-14.19%), SBC/DRB-75 × KASHI GANGA (-13.55%) and SBC/DRB-206-1 × KALYANPUR LONG GREEN (-7.89%). SBC/DRB-201-2 Pusa Naveen, the standard check heterosis (SC) was 16.72%, while in SBC/DRB-201-2× Kalyanpur Long Green, it was 13.45%. The maximum negative standard heterosis was recorded by SBC/DRB-201-2 × PUSA NAVEEN (-16.72%), followed by SBC/DRB-201-1 × PUSA NAVEEN (-12.78%), SBC/DRB-75 × KASHI GANGA (-12.13%), NDBG-18 × PUSA NAVEEN (-10.16%). Days before the first pistillate flower anthesis, better parent heterosis varied from –23.62% in SBC/DRB-201-2 × Pusa Naveen

Table 1 : Identification of superior crosses in bottle gourd based on heterosis.

Trait	Range of Heterosis (%)		No. ofSuperior crosses over			Superior Crosses based on Heterosis	
	Better Parent (BP)	Standard Check (Sarita)	MP	BP	SC	Heterobeltiosis	Standard Heterosis (Sarita)
DFSF	-22.56% (SBC/DRB-201-2 × Pusa Naveen) to 16.79% (VRBG-67 × Kalyanpur Long Green)	-16.72%, (SBC/DRB-201-2 Pusa Naveen) to 13.45% (SBC/DRB-201-2× Kalyanpur Long Green)	19	22	28	SBC/DRB-201-2 × PUSA NAVEEN (-22.56%) SBC/DRB-201-1 × PUSA NAVEEN (-14.19%) SBC/DRB-75 × KASHI GANGA (-13.55%) SBC/DRB-206-1 × KALYANPUR LONG GREEN (-7.89%)	SBC/DRB-201-2 × PUSA NAVEEN (-16.72%) SBC/DRB-201-1 × PUSA NAVEEN (-12.78%) SBC/DRB-75 × KASHI GANGA (-12.13%) NDBG-18 × PUSA NAVEEN (-10.16%)
DFPF	-23.62% (SBC/DRB-201-2 × Pusa Naveen) to 12.10% (VRBG-67 × Kalyanpur Long Green)	-14.60% (SBC/DRB-201-2 × Pusa Naveen), to8.43% (SBC/DRB-206-1 × Kashi Ganga)	18	24	28	SBC/DRB-201-2 × PUSA NAVEEN (-23.62%) SBC/DRB-201-2 × KASHI GANGA (-13.57%) SBC/DRB-201-1 ×PUSA NAVEEN (-12.00%) SBC/DRB-206-1 × KALYANPUR LONG GREEN (-9.88%)	SBC/DRB-201-2 × PUSA NAVEEN (-14.60%) SBC/DRB-201-1 × PUSA NAVEEN (-13.48%) SBC/DRB-206-1 × KALYANPUR LONG GREEN (-12.92%) NDBG-18 × KALYANPUR LONG GREEN (-12.92%)
NFSF	-47.66% (SBC/DRB-201-2 × Kalyanpur Long Green) to 39.03% (VRBG-67 × Pusa Naveen)	47.66%(SBC/DRB-201-2 Kalyanpur Long Green), to 54.73%(SBC/DRB-75 Pusa Naveen)	17	23	24	SBC/DRB-201-2 × KALYANPUR LONG GREEN (-47.66%) VRBG-67 × KASHI GANGA (-41.45%) NDBG-18 ×KALYANPUR LONG GREEN (-41.28%) SBC/DRB-201-3 × KASHI GANGA (-38.68%)	VRBG-67 × KASHI GANGA (-40.58%) SBC/DRB-201-2 × KALYANPUR LONG GREEN (-40.47%) SBC/DRB-206-1 × PUSA NAVEEN (-38.11%) NDBG-18 × KALYANPUR LONG GREEN (-38.11%)
NFPF	-24.44% (SBC/DRB-75 × Kalyanpur Long Green) to 25.67% (SBC/DRB-201-1 × Kalyanpur Long Green)	31.25% (SBC/DRB-75 Kalyanpur Long Green) to 4.94% (SBC/DRB-201-1 Kalyanpur Long Green)	20	25	26	SBC/DRB-75 × KALYANPUR LONG GREEN (-31.23%) NDBG-18 × PUSA NAVEEN (-25.51%) SBC/DRB-125-1 × PUSA NAVEEN (-24.54%) SBC/DRB-201-2 × PUSA NAVEEN (-23.13%)	SBC/DRB-75 × KALYANPUR LONG GREEN (-31.25%) SBC/DRB-125-1 × PUSA NAVEEN (-30.35%) SBC/DRB-75 × PUSA NAVEEN (-27.66%) SBC/DRB-206-1 × KASHI GANGA (-24.97%)
NPBP	-43.98% (BGP-6 × Kalyanpur Long Green) to 41.82% (SBC/DRB-201-3 × Pusa Naveen)	BGP-6 × Kalyanpur Long Green (-42.30%) to SBC/DRB-201-3 × Pusa Naveen (12.00%)	9	7	3	SBC/DRB-201-3 × PUSA NAVEEN (41.82%) SBC/DRB-75 × KASHI GANGA (20.74%) SBC/DRB-206-1 × PUSA NAVEEN (19.75%) SBC/DRB-201-2 × PUSA NAVEEN (10.02%)	BGP-6 × KALYANPUR LONG GREEN (-42.30%) SBC/DRB-201-1 × KASHI GANGA (-40.68%) SBC/DRB-201-2 × KALYANPUR LONG GREEN (-35.78%) VRBG-21 × KASHI GANGA (-34.71%)
VL	-24.56% (SBC/DRB-125-1 × Pusa Naveen) to 34.98% (SBC/DRB-125-1 × Kashi Ganga)	-40.35% (SBC/DRB-125-1 Pusa Naveen) to 16.51% (VRBG-67 Pusa Naveen)	10	8	14	VRBG-67 × PUSA NAVEEN (14.36%) NDBG-18 × PUSA NAVEEN (9.59%) SBC/DRB-125-1 × PUSA NAVEEN (8.09%) SBC/DRB-206-1 × KASHI GANGA (6.38%)	SBC/DRB-75 × KASHI GANGA (19.00%) SBC/DRB-201-1 × KASHI GANGA (17.36%) BGP-6 × KASHI GANGA (17.36%) VRBG-67 × PUSA NAVEEN (16.51%)
DFFH	-11.54% (NDBG-18 × Kalyanpur Long Green) to 5.29% (BGP-6 × Kalyanpur Long Green)	-9.80% (NDBG-18 × Kalyanpur Long Green) to 7.35% (BGP-6 × Kalyanpur Long Green)	26	29	3	NDBG-18 × KALYANPUR LONG GREEN (-11.54%) VRBG-67 × PUSA NAVEEN (-8.74%) SBC/DRB-201-3 × PUSA NAVEEN (-7.73%) SBC/DRB-201-3 × KASHI GANGA (-6.60%)	NDBG-18 × KALYANPUR LONG GREEN (-9.80%) VRBG-67 × PUSA NAVEEN (-7.84%) SBC/DRB-201-3 × PUSA NAVEEN (-6.37%)
FL	-32.30% (VRBG-67 × Kashi Ganga) to 16.03% (SBC/ DRB-206-1 × Pusa Naveen)	-11.75% (VRBG-67 × Kashi Ganga) to 29.27% (SBC/DRB-201-3 × Kalyanpur Long Green)	10	6	17	SBC/DRB-206-1 × PUSA NAVEEN (16.03%) VRBG-21 × PUSA NAVEEN (15.56%) SBC/DRB-125-1 × PUSA NAVEEN (10.81%) BGP-6 × PUSA NAVEEN (10.73%)	SBC/DRB-201-3 × KALYANPUR LONG GREEN (29.27%) SBC/DRB-206-1 × PUSA NAVEEN (28.91%) SBC/DRB-201-1 × KALYANPUR LONG GREEN (28.52%)
FC	-24.76% (SBC/DRB-201-1 × Kashi Ganga) to 54.19% (SBC/DRB-75 × Kalyanpur Long Green)	-24.32% (SBC/DRB-201-3 × Pusa Naveen) to 38.00% (SBC/DRB-125-1 × Kashi Ganga)	20	11	15	VRBG-21 × KALYANPUR LONG GREEN (54.19%) SBC/DRB-75 × KALYANPUR LONG GREEN (53.49%) SBC/DRB-125-1 × PUSA NAVEEN (45.11%) SBC/DRB-201-1 × KALYANPUR LONG GREEN (43.95%)	SBC/DRB-125-1 × KASHI GANGA (38.00%) VRBG-21 × KALYANPUR LONG GREEN (36.88%) SBC/DRB-75 × KALYANPUR LONG GREEN (36.26%) BGP-6 × KASHI GANGA (27.84%)

Table 1 continued....

Table 1 continued....

Trait	Range of Heterosis (%)		No. ofSuperior crosses over			Superior Crosses based on Heterosis	
	Better Parent (BP)	Standard Check (Sarita)	MP	BP	SC	Heterobeltiosis	Standard Heterosis (Sarita)
FW	-32.73% (SBC/DRB-201-2 × Kalyanpur Long Green) to 34.97% (SBC/DRB-201-1 × Kashi Ganga)	-15.46% (SBC/DRB-125-1 × Kashi Ganga) to 32.65% (SBC/DRB-201-1 × Kashi Ganga)	**15**	**11**	**12**	SBC/DRB-201-1 × KASHI GANGA (34.97%) SBC/DRB-75 × PUSA NAVEEN (31.30%) VRBG-21 × KASHI GANGA (21.94%) NDBG-18 × PUSA NAVEEN (20.61%)	SBC/DRB-201-1 × KASHI GANGA (32.65%) SBC/DRB-206-1 × KASHI GANGA (23.02%) VRBG-21 × KALYANPUR LONG GREEN (21.99%) SBC/DRB-75 × PUSA NAVEEN (18.21%) VRBG-21 × KASHI GANGA (16.49%)
NFPP	-27.23% (NDBG-18 × Kashi Ganga) to 25.11% (VRBG-21 × Kashi Ganga)	-39.33% (NDBG-18 × Kashi Ganga) to 16.55% (SBC/DRB-201-2 × Kalyanpur Long Green)	**5**	**4**	**5**	VRBG-21 × KASHI GANGA (25.11%) NDBG-18 × PUSA NAVEEN (14.66%) SBC/DRB-201-1 × KASHI GANGA (14.75%) SBC/DRB-201-2 × KALYANPUR LONG GREEN (13.89%)	VRBG-67 × KALYANPUR LONG GREEN (29.16%) NDBG-18 × PUSA NAVEEN (26.65%) SBC/DRB-201-2 × KALYANPUR LONG GREEN (16.55%)
FYPP	-50.04% (BGP-6 × Kalyanpur Long Green) to 52.60% (VRBG-21 × Kashi Ganga)	-11.22% (SBC/DRB-201-1 × Kashi Ganga) to 49.25% (VRBG-21 × Kalyanpur Long Green)	**17**	**8**	**22**	VRBG-21 × PUSA NAVEEN (33.18%) VRBG-21 × KASHI GANGA (52.60%) VRBG-67 × KASHI GANGA (15.72%) SBC/DRB-75 × PUSA NAVEEN (25.99%)	VRBG-21 × KALYANPUR LONG GREEN (49.25%) VRBG-67 × KASHI GANGA (47.84%) SBC/DRB-206-1 × PUSA NAVEEN (47.37%)
TSS	-42.16% (SBC/DRB-201-1 × Pusa Naveen) to 24.67% (VRBG-67 × Pusa Naveen)	-24.70% (VRBG-67 × Kashi Ganga) to 30.40% (SBC/DRB-75 × Kalyanpur Long Green)	**13**	**7**	**11**	VRBG-67 × PUSA NAVEEN (24.67%) VRBG-21 × PUSA NAVEEN (19.58%) SBC/DRB-75 × KALYANPUR LONG GREEN (19.26%) BGP-6 × PUSA NAVEEN (16.73%)	SBC/DRB-75 × KALYANPUR LONG GREEN (30.40%) BGP-6 × KALYANPUR LONG GREEN (24.78%) VRBG-21 × PUSA NAVEEN (20.90%) SBC/DRB-201-2 × KALYANPUR LONG GREEN (20.90%)
ASC	-20.63% (SBC/DRB-125-1× Kalyanpur Long Green) to 7.51% (SBC/DRB-206-1 × Kalyanpur Long Green)	SBC/DRB-125-1 × Kalyanpur Long Green (-16.44%) to SBC/DRB-206-1 × Kalyanpur Long Green (13.19%)	**12**	**4**	**17**	SBC/DRB-206-1 × KALYANPUR LONG GREEN (7.51%) SBC/DRB-75 × KASHI GANGA (6.93%) NDBG-18 × KALYANPUR LONG GREEN (5.64%)	SBC/DRB-206-1 × KALYANPUR LONG GREEN (13.19%) VRBG-21 × PUSA NAVEEN (12.23%) NDBG-18 × KALYANPUR LONG GREEN (11.23%)
TS	-27.31% (SBC/DRB-206-1× Kashi Ganga) to 3.72% (SBC/DRB-125-1 × Kashi Ganga)	VRBG-21 × Kalyanpur Long Green (-19.90%) to SBC/DRB-125-1 × Kashi Ganga (14.30%)	**7**	**1**	**16**	SBC/DRB-125-1 × KASHI GANGA (3.72%) SBC/DRB-206-1 × KALYANPUR LONG GREEN (1.37%) SBC/DRB-206-1 × PUSA NAVEEN (0.00)	SBC/DRB-125-1 × KASHI GANGA (14.30%) SBC/DRB-206-1 × KALYANPUR LONG GREEN (10.20%) SBC/DRB-206-1 × PUSA NAVEEN (10.20%)
DM	-35.42% (VRBG-21 × Kalyanpur Long Green) to 23.59% (BGP-6 × Kalyanpur Long Green)	SBC/DRB-206-1 × Kashi Ganga (-30.50%) SBC/DRB-75 × Kashi Ganga (21.04%)	**16**	**9**	**13**	BGP-6 × KALYANPUR LONG GREEN (23.59%) SBC/DRB-75 × KASHI GANGA (19.49%) NDBG-18 × KALYANPUR LONG GREEN (15.92%)	SBC/DRB-75 × KASHI GANGA (21.04%) BGP-6 × KALYANPUR LONG GREEN (20.60%) SBC/DRB-201-2 × KALYANPUR LONG GREEN (17.95%)

DFSF- Days to first staminate flower anthesis, **DFPF**- Days to first pistillate flower anthesis, **NFSF-** Node number to first staminate flower appearance, **NFPF-** Node number to first pistillate flower appearance, **NPBP**- Number of primary branches per plant, **VL**- Vine length (m), **DFFH-** Days to first fruit harvest, **FL-** Fruit length (cm), **FC-** Fruit circumference (cm), **FW-** Fruit weight (kg), **NFPP-** Number of fruits per plant, **FYPP-** Fruit yield per plant (kg), **TSS-** Total soluble solids (%), **ASC**- Ascorbic acid, **TS-** Total Sugar, **DM-** Dry Matter

to 12.10% in VRBG-67 × Kalyanpur Long Green. The highest desirable negative heterosis was observed in SBC/DRB-201-2 × PUSA NAVEEN (-23.62%), followed by SBC/DRB-201-2 × KASHI GANGA (-13.57%), SBC/DRB-201-1 × PUSA NAVEEN (-12.00%), SBC/DRB-206-1 × KALYANPUR LONG GREEN (-9.88%). In SBC/DRB-201-2 × Pusa Naveen, the SC heterosis was –14.60%, while in SBC/DRB-206-1 × Kashi Ganga, it was 8.43%. The maximum negative standard heterosis was observed in SBC/DRB-201-2 × PUSA NAVEEN (-14.60%), followed by SBC/DRB-201-1 × PUSA NAVEEN (-13.48%), SBC/DRB-206-1 × KALYANPUR LONG GREEN (-12.92%). Node number to first staminate flower appearance BP heterosis varied from -47.66% in SBC/DRB-201-2 × Kalyanpur Long Green to 39.03% in VRBG-67 × Pusa Naveen. The highest negative heterosis was recorded by SBC/DRB-201-2 × KALYANPUR LONG GREEN (-47.66%), followed by VRBG-67 × KASHI GANGA (-41.45%) and NDBG-18 × KALYANPUR LONG GREEN (-41.28%). In SBC/DRB-201-2 Kalyanpur Long Green, the standard check heterosis was 47.66%, while in SBC/DRB-75 Pusa Naveen, it was 54.73%. The highest negative standard heterosis was exhibited by VRBG-67 × KASHI GANGA (-40.58%), followed by SBC/DRB-201-2 × KALYANPUR LONG GREEN (-40.47%), SBC/DRB-206-1 × PUSA NAVEEN (-38.11%). These findings were in accordance with the reports of Dubey *et al.* (2003), Singh *et al.* (2024) and Virendra *et al.* (2026).

For node number to first pistillate flower appearance, heterosis over better parent (BP) varied from –31.23% in SBC/DRB-75 × Kalyanpur Long Green to 12.83% in VRBG-67 × Pusa Naveen. The highest negative heterosis was observed in SBC/DRB-75 × KALYANPUR LONG GREEN (-31.23%), followed by NDBG-18 × PUSA NAVEEN (-25.51%), SBC/DRB-125-1 × PUSA NAVEEN (-24.54%), SBC/DRB-201-2 × PUSA NAVEEN (-23.13%), while heterosis over the standard check heterosis (SC) was 31.25%, while in SBC/DRB-201-1 Kalyanpur Long Green, it was 4.94%. The highest negative standard heterosis was observed in SBC/DRB-75 × KALYANPUR LONG GREEN (-31.25%), followed by SBC/DRB-125-1 × PUSA NAVEEN (-30.35%), SBC/DRB-75 × PUSA NAVEEN (-27.66%). Number of primary branches per plant, BP heterosis varied from -43.98% in BGP-6 × Kalyanpur Long Green to 41.82% in SBC/DRB-201-3 × Pusa Naveen. The highest positive heterosis was observed in SBC/DRB-201-3 × PUSA NAVEEN (41.82%), followed by SBC/DRB-75 × KASHI GANGA (20.74%), SBC/DRB-206-1 × PUSA NAVEEN (19.75%). In BGP-6 × Kalyanpur Long Green, the SC heterosis was –42.30%, while in SBC/DRB-201-3 × Pusa Naveen, it was 12.00%. Significant positive standard heterosis was observed only in SBC/DRB-201-3 × PUSA NAVEEN (12.00%) and SBC/DRB-201-1 × PUSA NAVEEN (4.10%). For vine length (m), BP heterosis ranged from -24.56% in SBC/DRB-125-1 × Pusa Naveen to 34.98% in SBC/DRB-125-1 × Kashi Ganga. The highest positive heterosis was recorded by VRBG-67 × PUSA NAVEEN (14.36%), followed by NDBG-18 × PUSA NAVEEN (9.59%), SBC/DRB-125-1 × PUSA NAVEEN (8.09%). Standard check heterosis varied from -40.35% in SBC/DRB-125-1 Pusa Naveen to 16.51% in VRBG-67 Pusa Naveen. The highest significant positive standard heterosis was exhibited by SBC/DRB-75 × KASHI GANGA (19.00%), followed by SBC/DRB-201-1 × KASHI GANGA (17.36%), BGP-6 × KASHI GANGA (17.36%). These results were in agreement with reports of Yadav *et al.* (2011), Singh *et al.* (2012) and Janaranjani *et al.* (2016).

For days to first fruit harvest, heterosis over the better-parent (BP) heterosis varied from –11.54% in NDBG-18 × Kalyanpur Long Green to 5.29% in BGP-6 × Kalyanpur Long Green. The highest significant negative heterosis was recorded by NDBG-18 × KALYANPUR LONG GREEN (-11.54%), followed by VRBG-67 × PUSA NAVEEN (-8.74%), SBC/DRB-201-3 × PUSA NAVEEN (-7.73%). Standard-check (SC) heterosis varied from -9.80% in NDBG-18 × Kalyanpur Long Green to 7.35% in BGP-6 × Kalyanpur Long Green. The highest significant negative standard heterosis was recorded by NDBG-18 × KALYANPUR LONG GREEN (-9.80%), followed by VRBG-67 × PUSA NAVEEN (-7.84%), SBC/DRB-201-3 × PUSA NAVEEN (-6.37%). For fruit length (cm), BP heterosis ranged from -32.30% in VRBG-67 × Kashi Ganga to 16.03% in SBC/DRB-206-1 × Pusa Naveen. The highest significant positive heterosis was recorded by SBC/DRB-206-1 × PUSA NAVEEN (16.03%), followed by VRBG-21 × PUSA NAVEEN (15.56%), SBC/DRB-125-1 × PUSA NAVEEN (10.81%). The SC heterosis varied from -11.75% in VRBG-67 × Kashi Ganga to 29.27% in SBC/DRB-201-3 × Kalyanpur Long Green. The highest significant positive standard heterosis was exhibited by SBC/DRB-201-3 × KALYANPUR LONG GREEN (29.27%), followed by SBC/DRB-206-1 × PUSA NAVEEN (28.91%), SBC/DRB-201-1 × KALYANPUR LONG GREEN (28.52%). Fruit circumference (cm), BP heterosis ranged from -24.76% in SBC/DRB-201-1 × Kashi Ganga to 54.19% in SBC/DRB-75 × Kalyanpur Long Green. The highest significant positive heterosis

was observed in VRBG-21 × KALYANPUR LONG GREEN (54.19%), followed by SBC/DRB-75 × KALYANPUR LONG GREEN (53.49%), SBC/DRB-125-1 × PUSA NAVEEN (45.11%). Standard-check heterosis varied from -24.32% in SBC/DRB-201-3 × Pusa Naveen to 38.00% in SBC/DRB-125-1 × Kashi Ganga. The highest significant positive standard heterosis was exhibited by SBC/DRB-125-1 × KASHI GANGA (38.00%), followed by VRBG-21 × KALYANPUR LONG GREEN (36.88%), SBC/DRB-75 × KALYANPUR LONG GREEN (36.26%). This similar observation reported by Quamruzzaman *et al.* (2009) and Koulagi (2018) in bottle gourd crop.

Fruit weight (kg) heterosis over better-parent (BP) heterosis ranged from -32.73% in SBC/DRB-201-2 × Kalyanpur Long Green to 34.97% in SBC/DRB-201-1 × Kashi Ganga. The highest significant positive heterosis was exhibited by SBC/DRB-201-1 × KASHI GANGA (34.97%), followed by SBC/DRB-75 × PUSA NAVEEN (31.30%), VRBG-21 × KASHI GANGA (21.94%). Standard-check (SC) heterosis varied from -15.46% in SBC/DRB-125-1 × Kashi Ganga to 32.65% in SBC/DRB-201-1 × Kashi Ganga. The highest significant standard heterosis was observed in SBC/DRB-201-1 × KASHI GANGA (32.65%), followed by SBC/DRB-206-1 × KASHI GANGA (23.02%), VRBG-21 × KALYANPUR LONG GREEN (21.99%), SBC/DRB-75 × PUSA NAVEEN (18.21%). Number of fruits per plant, the BP heterosis ranged from -27.23% in NDBG-18 × Kashi Ganga to 25.11% in VRBG-21 × Kashi Ganga. The highest significant positive heterosis was observed in VRBG-21 × KASHI GANGA (25.11%), followed by NDBG-18 × PUSA NAVEEN (14.66%), SBC/DRB-201-1 × KASHI GANGA (14.75%). The SC heterosis varied from -39.33% in NDBG-18 × Kashi Ganga to 16.55% in SBC/DRB-201-2 × Kalyanpur Long Green. The highest significant positive standard heterosis was recorded in VRBG-67 × KALYANPUR LONG GREEN (29.16%), followed by NDBG-18 × PUSA NAVEEN (26.65%), SBC/DRB-201-2 × KALYANPUR LONG GREEN (16.55%). In terms of fruit yield per plant (kg), BP heterosis ranged from -50.04% in BGP-6 × Kalyanpur Long Green to 52.60% in VRBG-21 × Kashi Ganga. Significant positive heterosis was exhibited by hybrids, namely VRBG-21 × PUSA NAVEEN (33.18%), VRBG-21 × KASHI GANGA (52.60%), VRBG-67 × KASHI GANGA (15.72%). Standard-check heterosis varied from -11.22% in SBC/DRB-201-1 × Kashi Ganga to 49.25% in VRBG-21 × Kalyanpur Long Green. The highest standard heterosis was recorded by VRBG-21 × KALYANPUR LONG GREEN (49.25%), followed by VRBG-67 × KASHI GANGA (47.84%), SBC/DRB-206-1 × PUSA NAVEEN (47.37%). Heterosis over the better parent for the total soluble solids ranged from -42.16% in SBC/DRB-201-1 × Pusa Naveen to 24.67% in VRBG-67 × Pusa Naveen. Highest significant positive value was observed in VRBG-67 × PUSA NAVEEN (24.67%), followed by VRBG-21 × PUSA NAVEEN (19.58%), SBC/DRB-75 × KALYANPUR LONG GREEN (19.26%), BGP-6 × PUSA NAVEEN (16.73%). Standard-check heterosis varied from -24.70% in VRBG-67 × Kashi Ganga and NDBG-18 × Pusa Naveen to 30.40% in SBC/DRB-75 × Kalyanpur Long Green. Significant positive heterosis was highest in SBC/DRB-75 × KALYANPUR LONG GREEN (30.40%), followed by BGP-6 × KALYANPUR LONG GREEN (24.78%), VRBG-21 × PUSA NAVEEN (20.90%). The present findings are comparable with Gautam *et al.* (2017), Doloi *et al*. (2018), Malviya *et al*. (2017), who reported heterobeltiosis for yield and quality characters in bottle gourd.

Heterosis over better parent (MP) for ascorbic acid (mg/100 g fresh fruit) varied from –20.63% in SBC/DRB-125-1 × Kalyanpur Long Green to 7.51% in SBC/DRB-206-1 × Kalyanpur Long Green. Highest significant positive heterosis was recorded in SBC/DRB-206-1 × KALYANPUR LONG GREEN (7.51%), followed by SBC/DRB-75 × KASHI GANGA (6.93%), NDBG-18 × KALYANPUR LONG GREEN (5.64%). In SBC/DRB-125-1 × Kalyanpur Long Green, the standard-check (SC) heterosis was -16.44%, while in SBC/DRB-206-1 × Kalyanpur Long Green, it was 13.19%. highest significant positive heterosis was observed in SBC/DRB-206-1 × KALYANPUR LONG GREEN (13.19%), followed by VRBG-21 × PUSA NAVEEN (12.23%), NDBG-18 × KALYANPUR LONG GREEN (11.23%). Total sugar over the better parent heterosis varied from -27.31% in SBC/DRB-206-1 × Kashi Ganga to 3.72% in SBC/DRB-125-1 × Kashi Ganga. SBC/DRB-125-1 × KASHI GANGA (3.72%) expressed the highest significant positive heterosis, followed by SBC/DRB-206-1 × KALYANPUR LONG GREEN (1.37%) and SBC/DRB-206-1 × PUSA NAVEEN (0.00). In VRBG-21 × Kalyanpur Long Green, the SC heterosis was -19.90%, while in SBC/DRB-125-1 × Kashi Ganga, it was 14.30%. the highest significant positive heterosis was observed in SBC/DRB-125-1 × KASHI GANGA (14.30%), followed by SBC/DRB-206-1 × KALYANPUR LONG GREEN (10.20%), SBC/DRB-206-1 × PUSA NAVEEN (10.20%). For the dry matter over the better parent heterosis varied from -35.42% in VRBG-21 × Kalyanpur Long Green to 23.59% in BGP-6 × Kalyanpur Long

Table 2 : Genetic components of variation.

Traits	σ^2GCA (Cov H.S. Avg)	σ^2SCA	σ^2GCA/σ^2SCA	σ^2A (Additive Variance)
Days to first male flowering	-0.2296	10.0471	-0.0229	-0.9186
Days to first female flowering	-1.9003	14.5141	-0.1309	-7.6014
Node number to first male flower	-0.6336	4.3750	-0.1448	-2.5344
Node number to first female plant	-0.1926	3.7720	-0.0511	-0.7705
No. of primary branches/plant	-0.1953	2.1114	-0.0925	-0.7810
Vine length (cm)	-0.0344	0.4843	-0.0711	-0.1378
Days to first female harvest	0.6481	4.7996	0.1350	2.5924
Fruit length (cm)	0.6538	13.4855	0.0485	2.6152
Fruit circumference (cm)	-0.0317	1.8932	-0.0167	-0.1267
Fruit weight (kg)	-0.0007	0.0129	-0.0567	-0.0029
No. of fruits per plant	-0.0105	-0.0072	1.4638	-0.0421
Fruit yield per plant (kg)	-0.0892	0.6437	-0.1385	-0.3567
Ascorbic acid (mg/100g)	-0.0379	0.4369	-0.0868	-0.1517
Total sugar (%)	0.0021	0.3326	0.0063	0.0083
Dry matter (%)	-0.0075	0.0580	-0.1299	-0.0301

Green. Significant positive heterosis was recorded by BGP-6 × KALYANPUR LONG GREEN (23.59%), followed by SBC/DRB-75 × KASHI GANGA (19.49%), NDBG-18 × KALYANPUR LONG GREEN (15.92%). In SBC/DRB-206-1 × Kashi Ganga, standard-check heterosis was –30.50%, while in SBC/DRB-75 × Kashi Ganga, it was 21.04%. Significant positive heterosis was observed in SBC/DRB-75 × KASHI GANGA (21.04%), followed by BGP-6 × KALYANPUR LONG GREEN (20.60%), SBC/DRB-201-2 × KALYANPUR LONG GREEN (17.95%). The results agree particularly well with Jha *et al.* (2016), Bhatt *et al.* (2023) and Rambabu *et al.* (2021), who demonstrated significant heterosis and combining ability for dry matter, ascorbic acid and total sugar in bottle gourd.

Components of variation

The estimates of σ^2gca and σ^2sca variances for the eighteen characters studied in bottle gourd are presented in Table 2. Estimates of sca variance (σ^2s) were higher than gca variance (σ^2g) for all the characters studied - namely days to first staminate flower appearance, days to first pistillate flower appearance, node number to first staminate flower appearance, node number to first pistillate flower appearance, number of primary branches per plant, vine length, days to first female flower harvest, fruit length, fruit circumference, fruit weight, number of fruits per plant, fruit yield per plant, total soluble solids, ascorbic acid, total sugar content and dry matter content. No character recorded a higher σ^2g than σ^2s, indicating that specific combining ability variance consistently outweighed general combining ability variance across the entire set of growth, earliness, yield and quality traits evaluated.

The value of sca variance was positive for all the characters except number of fruits per plant, which recorded a negative σ^2s (-0.0072), suggesting a value not significantly different from zero for this trait alone. Positive sca variance was thus exhibited by days to first staminate flower appearance, days to first pistillate flower appearance, node number to first staminate flower appearance, node number to first pistillate flower appearance, number of primary branches per plant, vine length, days to first female flower harvest, fruit length, fruit circumference, fruit weight, fruit yield per plant, total soluble solids, ascorbic acid, total sugar content and dry matter content. GCA variance, on the other hand, was negative for the majority of characters, days to first staminate flower appearance, days to first pistillate flower appearance, node number to first staminate flower appearance, node number to first pistillate flower appearance, number of primary branches per plant, vine length, fruit circumference, fruit weight, number of fruits per plant, fruit yield per plant and total soluble solids - while positive and comparatively small gca variance was recorded only for days to first female flower harvest (0.6481), fruit length (0.6538) and total sugar (0.0021). The predominance of negative or near-zero σ^2g together with consistently higher and largely positive ó²s confirms that non-additive gene action governed the inheritance of nearly all the characters studied. This view aligns with the findings of Rani *et al.* (2017), Harshita *et al.* (2024), Patel *et al.* (2023), Keshari and Singh (2024), who performed a line tester study in bottle gourd and concluded that non-additive gene action predominated since SCA variation was larger than GCA variance for every

character examined.

Conclusion

Heterotic expression of yield and contributing traits in bottle gourd, with significant diversity among the examined crosses. SBC/DRB-201-1 × Kashi Ganga had the highest positive heterobeltiosis in fruit weight, followed by SBC/DRB-75 × Pusa Naveen. VRBG-21 × Kashi Ganga produced the most fruits per plant, followed by NDBG-18 × Pusa Naveen and SBC/DRB-201-1 × Kashi Ganga. VRBG-21 × Kashi Ganga had the highest heterobeltiosis for fruit yield per plant, followed by VRBG-21 × Pusa Naveen. VRBG-21 × Kalyanpur Long Green showed the greatest standard heterosis rate. SCA variation was greater than GCA variance for yield traits, indicating that non-additive gene action predominated. Thus, these crosses have significant potential for heterosis breeding and yield improvement in bottle gourd.

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