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Estimation of Heterobeltiosis and Standard Heterosis for Morphological, Biochemical and Quality Traits in Upland Cotton (*Gossypium hirsutum* L.)

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ABSTRACT: Heterosis study is very helpful genetic parameters for identification of potential crosses for genetic improvement of cotton. The present study was undertaken by ten parents (7 lines and 3 testers) and their twenty-one resultant crosses with a check G. Cot. Hy-10 was evaluated in a randomized block design with three replications in line × tester manner during kharif 2022 at Main Cotton Research Station, Navsari Agricultural University, Surat. The heterobeltiosis for seed cotton yield per plant ranged from -24.80 to 99.55 per cent, while the standard heterosis ranged from -18.50 to 54.60 per cent. The highest value of heterobeltiosis and standard heterosis were observed for cross BGDS 1063 × G. Cot-10 BG II. For seed cotton yield per plant top five crosses *viz*., BGDS 1063 × G. Cot-10 BG II, DELTA 15 × G. Cot-16 BG II, GISV 218 × G. Cot-10 BG II, SCS 106 × BC-68-2 BG II and GJHV 374 × BC-68-2 BG II recorded positive and significant heterobeltiosis and standard heterosis. These five crosses also exhibited significant heterobeltiosis and standard heterosis for yields contributing character like bolls per plant, boll weight, ginning outturn, seed index, fiber strength, phenol content, protein content, oil content and gossypol content. In case of fiber parameters, the maximum value of standard heterosis was observed by the cross ARBC 1351 × G. Cot-10 BG II for ginning outturn and GJHV 374 × G. Cot-10 BG II for fiber strength. For biochemical parameters, cross GISV 218 × G. Cot-10 BG II, cross GISV 218 × G. Cot-16 BG II and cross SCS 1061 × BC-68 2 BG II recorded significant standard heterosis in desired direction for oil content, protein content and phenol content, respectively. On the basis of *per se* performance, heterobeltiosis and standard heterosis cross combination BGDS 1063 × G. Cot-10 BG II was found to be the most promising for seed cotton yield and some of its component traits. So, this cross fully be exploited through pedigree method to obtain higher yielding transgressive segregants.

Keywords: Cotton, Line × Tester, Heterosis, Heterobeltiosis, standard heterosis.

INTRODUCTION

Cotton is immensely an important crop for the sustainable economy of India and livelihood of the Indian cotton farming community. The cotton genus *Gossypium* of the *Malvaceae* family occurs naturally throughout the tropics and subtropics and consists of about 50 species that form a monophyletic group. Out of the 50 species, only four species are cultivated species and the remaining 46 are wild species. Most commercially cultivated cotton is derived from two species, G. hirsutum, contributes 90 per cent of the world production and *G. barbadense* taking eight per cent of world production. Two other species, *G. arboreum* and *G. herbaceum* are indigenous to Asia and Africa, respectively and are popularly referred to as desi cotton in India. Worldwide, cotton is grown over an area of 33.48 Mha with the productivity of 787 kg per ha (Anon., 2022). Cotton is a perennial shrub that is grown on black soils of the world. It has a large flower that makes hand emasculation and pollination very easy. To increase the productivity and to produce the best quality fiber, plant breeders have a responsibility to upgrade the crop in every regards. Line × tester analysis (Kempthorne, 1957) provides a systemic approach for the identification of superior parents and crosses. An additional advantage of line × tester analysis is that it provides an overall genetic picture of the experimental material in a single generation.

MATERIALS AND METHODS

The experimental material consisted of ten parents (7 lines and 3 testers) and their twenty-one resultant crosses with a check G. Cot. Hy-10 was evaluated in a randomized block design with three replications during kharif 2022 at Main Cotton Research Station, Navsari Agricultural University, Surat. The hybrid (F_1) seeds were produced by Dock and Moll (1934) method. The present investigation was carried out to study heterosis in the inheritance of the morphological, biochemical and quality traits of cotton *viz*., days to 50% flowering, sympodia per plant, bolls per plant, boll weight (g), seed cotton yield per plant (g), ginning out turn (%), seed index (g), fiber length (mm), fiber strength (g/tex), fiber fineness (mv), protein content (%), oil content (%), gossypol content (%) and phenol content (%). The observations were recorded from randomly selected 5 plants from each genotype in each replication. The mean performance of parents, as well as hybrids, were subjected to statistical analysis. Analysis of variance was carried out to test the significance for each character as per the methodology suggested by Panse and Sukhatme (1985). Heterobeltiosis (BH) was calculated using the method given by Fonseca and Patterson (1968) and standard heterosis by Meredith and Bridge (1972).

RESULTS AND DISCUSSION

Analysis of variance depicting mean sum of squares for fourteen quantitative traits is presented in Table 1. The analysis of variance revealed significant differences among the genotypes for all characters. This confirmed that the material was appropriate for the research. Parents, hybrids, parents *vs* hybrids and check *vs* hybrids were used to divide the genotypic variance. Differences between parents were highly significant for all characters studied except for days to 50% flowering and gossypol content (%) whereas, hybrids were highly significant for all characters. Differences related to parents *vs* hybrids were found to be significant for all of the parameters studied except for days to 50% flowering, fiber fineness (mv) and gossypol content (%). Differences related to check *vs* hybrids were found to be significant for ginning outturn, fiber fineness (mv), oil content (%) and phenol content (%). The differences between the lines as female parents were also highly significant for all the characters except for days to 50% flowering and gossypol content (%). Significant variability also existed among the testers as male parents except for days to 50% flowering, boll weight (g), fiber length (mm), fiber strength (g/tex) and gossypol content (%). The differences between the lines vs testers were also significant for all the characters except days to 50% flowering, boll weight (g), fiber length (mm), fiber strength (g/tex), protein content (%) and gossypol content (%).

Concerning heterosis over better parent and standard check, out of 21 hybrids, hybrids exhibited significant heterosis in the desired direction for days to 50% flowering (2,1), sympodia per plant (4,8), bolls per plant (9,10), boll weight (4,1), seed cotton yield per plant (13,8), ginning outturn (2,14), seed index (9,6), fiber length (4,0), fiber strength (9,4), fiber fineness (6,9), oil content (7,13), gossypol content (5,0), protein content (12,13) and phenol content (3,12).

Plant Height. According to better parent heterosis, none of the hybrids showed significant and positive heterobeltiosis. While, as per the standard heterosis, best performing positively significant hybrids were GISV-323 × ARBC-1351 (19.16%), GJHV-566 × GSHV-213 (18.64%) and GJHV-566 × H 401/2014 (16.17%). Similar findings have also been reported by Ashokkumar and Ravikesavan (2013); Chhavikant *et al.* (2017); Gohil *et al*. (2017); Vavdiya *et al.* (2019); Richika *et al.* (2021); Vadodariya *et al*. (2022); for standard heterosis only.

Days to 50% Flowering. As earliness in flowering is more suitable in escaping insect and pest attack as well as moisture stress, early parents were deemed to be a superior parent for days to 50% flowering. A heterobeltiosis for days to 50 % flowering character ranged from -5.42 per cent (GISV 218 × BC-68-2 BG II) to 6.15 per cent (BGDS 1063 × G. Cot-10 BG II). For this feature, spectrum of standard heterosis ranged from -6.53 per cent (ARBC 1351 × G. Cot-16 BG II) to 6.03 per cent (SCS 1061 × G. Cot-10 BG II). Out of 21 hybrids, hybrid ARBC 1351 × G. Cot-16 BG II (-6.53 %) displayed significant and negative standard heterosis for this trait. Similar findings have also been reported by Chhavikant *et al.* (2017); Gohil *et al.* (2017); Murthy *et al.* (2017); Rani *et al.* (2020).

Sympodia per Plant. This is the most important character which contributes significantly to yield. The heterobeltiosis for this feature ranged from -38.07 per cent (BS 27 × G. Cot-16 BG II) to 42.46 per cent (BGDS 1063 × G. Cot-10 BG II). Standard heterosis for this trait ranged from -14.21 per cent (BS 27 × G. Cot-16 BG II) to 41.71 per cent (BGDS 1063 × G. Cot-10 BG II). Over the standard check, BGDS 1063 × G. Cot-10 BG II (41.71 %), ARBC 1351 × G. Cot-10 BG II (31.58 %) and GISV 218 × BC-68-2 BG II (28.42 %) were the top three hybrid which showed significant and positive heterosis. Chhavikant *et al.* (2017); Gohil *et al.* (2017); Murthy *et al.* (2017); Vavdiya *et al.* (2019); Gawande *et al.* (2021) who reported significant and positive heterosis for sympodia per plant.

Bolls per Plant. The number of bolls generated per plant showed the strongest relationship with yield and genotypic selection for mature bolls, which led to increased output. For bolls per plant, heterobeltiosis ranged from -22.22 per cent (BS 27 × G. Cot-16 BG II) to 119.05 per cent (BGDS 1063 × G. Cot-10 BG II). Magnitude of standard heterosis was varied from -20.35 per cent (SCS 1061 × G. Cot-16 BG II) to 62.83 per cent (BGDS 1063 × G. Cot-10 BG II). Among the 21 hybrids, BGDS 1063 × G. Cot-10 BG II (62.83 %), GISV 218 × G. Cot-10 BG II (39.82 %), ARBC 1351 × G. Cot-10 BG II (38.05 %), GJHV 374 × G. Cot-16 BG II (29.20 %), SCS 1061 × G. Cot-10 BG II (24.78 %), GJHV 374 × BC-68-2 BG II (24.78 %), DELTA 15 × G. Cot-16 BG II (20.35 %), BS 27 × G. Cot-10 BG II (19.47 %), GISV 218 × BC-68-2 BG II (17.70 %) and GJHV 374 × G. Cot-10 BG II (16.81 %) exhibited significant and positive standard heterosis. Similar results also reported by Chhavikant *et al.* (2017); Gohil *et al.* (2017); Murthy *et al.* (2017); Vavdiya *et al.* (2019); Rani *et al.* (2020); Richika *et al.* (2021).

BOLL WEIGHT (g). The cross combinations had better parent heterosis ranging from -14.60 per cent (ARBC 1351 × G. Cot-10 BG II) to 27.27 per cent (SCS 1061 × G. Cot-16 BG II). Similar way magnitude of standard heterosis ranged from -11.47 per cent (ARBC 1351 × G. Cot-10 BG II) to 20.18 per cent (BS

27 × BC-68-2 BG II). One hybrid BS 27 × BC-68-2 BG II (20.18 %) depicted positive and significant standard heterosis. A positive and significant heterosis for boll weight were also reported by Chhavikant *et al.* (2017); Gohil *et al.* (2017); Rani *et al.* (2020); Gawande *et al.* (2021); Richika *et al.* (2021).

SEED cotton yield per plant. For this important economic trait, heterobeltiosis ranged from -24.80 per cent (BS 27 × G. Cot-16 BG II) to 99.55 per cent (BGDS 1063 × G. Cot-10 BG II). Thirteen hybrids out of 21 demonstrated significant and positive heterobeltiosis over the superior parent. With respect to standard heterosis, it ranged from -18.50 per cent (BS 27 × G. Cot-16 BG II) to 54.60 per cent (BGDS 1063 × G. Cot-10 BG II). BGDS 1063 × G. Cot-10 BG II (54.60 %), DELTA 15 × G. Cot-16 BG II (38.25 %), GISV 218 × G. Cot-10 BG II (36.94 %), SCS 1061 × BC-68-2 BG II (29.67 %), GJHV 374 × BC-68 2 BG II (25.87 %), ARBC 1351 × G. Cot-10 BG II (23.98 %), GJHV 374 × G. Cot-16 BG II (23.28 %) and SCS 1061 × G. Cot-10 BG II (20.16 %) were the hybrids that showed considerable and positive standard heterosis among twenty-one crosses. Similar results were also reported by Chhavikant *et al.* (2017); Gohil *et al.* (2017); Murthy *et al.* (2017); Richika *et al.* (2021).

Top five crosses, for per se performance including standard heterosis and better parent heterosis for seed cotton yield, as well as the yield attributing traits that registered significant and desirable standard heterosis for the cross were summarized in Table 5.

GINNING OUTTURN (%). For ginning outturn, heterobeltiosis ranged from -16.50 per cent (ARBC 1351 × BC-68-2 BG II) to 6.72 per cent (GJHV 374 × G. Cot-10 BG II). The standard heterosis ranged from -2.75 per cent (ARBC 1351 × BC-68-2 BG II) to 16.08 per cent (ARBC 1351 × G. Cot-10 BG II). Out of 21 cross combinations, ARBC 1351 × G. Cot-10 BG II (16.08 %) exhibited the highest desirable standard heterosis followed by BS 27 × G. Cot-10 BG II (14.16 %) and SCS 1061 × BC-68-2 BG II (12.22 %). Similar results were also reported by Murthy *et al.* (2017); Thiyagu *et al.* (2019); Richika *et al.* (2021); Vanapariya *et al.* (2022).

Seed Index (g). Nine hybrids out of 21 demonstrated significant and positive heterobeltiosis for seed index, which affects seed cotton output directly. Heterobeltiosis varied from -28.83 per cent (GISV 218 × G. Cot-10 BG II) to 42.36 per cent (BGDS 1063 × G. Cot-16 BG II). The standard heterosis ranged from -19.35 per cent (GISV 218 × G. Cot-10 BG II) to 31.45 per cent (BGDS 1063 × G. Cot-16 BG II). The top three hybrids, BGDS 1063 × G. Cot-16 BG II (31.45 %), BS 27 × G. Cot-10 BG II (9.68 %) and SCS 1061 × G. Cot-16 BG II (8.87 %), showed considerable and positive standard heterosis in the desired direction among the 21 hybrids. A similar type of results were also obtained by Chhavikant *et al.* (2017); Gohil *et al.* (2017); Murthy *et al.* (2017); Pavitra *et al.* (2019).

Fiber Length (mm). The extent of heterobeltiosis ranged from -7.83 per cent (DELTA 15 × BC-68-2 BG II) to 14.07 per cent (SCS 1061 × G. Cot-10 BG II). Standard heterosis ranged from -9.02 per cent (GJHV 374 × BC-68-2 BG II) to 4.20 percent (SCS 1061 × G. Cot-10 BG II). The cross SCS 1061 × G. Cot-10 BG II (4.20 %) had the greatest standard heterosis value followed by BS 27 × G. Cot-16 BG II (1.48 %) and BGDS 1063 × G. Cot-16 BG II (1.24 %). Murthy *et al.* (2017); Pavitra *et al.* (2019); Max *et al.* (2021) also recorded similar results.

Fiber Strength (g/tex). The heterobeltiosis varied between -3.03 per cent (ARBC 1351 × BC-68-2 BG II) to 9.81 per cent (GJHV 374 × G. Cot-10 BG II). The standard heterosis lies between -3.94 per cent (BGDS 1063 × BC-68-2 BG II) and 4.67 per cent (GJHV 374 × G. Cot-10 BG II). Four hybrids GJHV 374 × G. Cot-10 BG II (4.67 %) followed by BGDS 1063 × G. Cot-16 BG II (3.81 %), DELTA 15 × G. Cot-16 BG II (3.81 %) and ARBC 1351 × G. Cot-10 BG II (3.69 %) showed significant and positive value in the desirable direction. Murthy *et al.* (2017); Pavitra *et al.* (2019); Max *et al.* (2021) also recorded similar type of results.

FIBER FINENESS (mv). The air permeability of compressed cotton fiber is measured using the micronaire value. Cotton that feels soft and silky is deemed fine. The micronaire values between 3.5 and 4.5 are more desirable than higher or lower values. Heterobeltiosis for this trait varied from -12.50 per cent (SCS 1061 × G. Cot-16 BG II) to 27.96 per cent (GJHV 374 × BC-68-2 BG II). The heterosis over standard check ranged from -10.78 per cent (SCS 1061 × G. Cot-16 BG II) to 28.43 per cent (BS 27 × G. Cot-10 BG II). None of the hybrids possesses significant and negative standard heterosis value for fiber fineness. Similar results have been reported by Murthy *et al.* (2017).

Oil Content (%). Cotton seed oil is now commonly used for human consumption. Heterobeltiosis ranged from -40.91 per cent (BGDS 1063 × G. Cot-16 BG II) to 43.92 per cent (GJHV 374 × BC-68-2 BG II). Standard heterosis for oil content ranged from -21.13 per cent (BGDS 1063 × G. Cot-16 BG II) to 44.95 per cent (GISV 218 × G. Cot-10 BG II). Thirteen hybrids out of the 21 hybrids exhibited positive and significant value for this feature. Among them, the top three were GISV 218 × G. Cot-10 BG II (44.95 per cent), BS 27 × G. Cot-10 BG II (43.87 per cent) and GJHV 374 × BC-68-2 BG II (39.93 per cent).

Gossypol Content (%). Pigment glands in cotton stems, leaves, seeds and flower buds produce gossypol, a phenolic substance. Acute clinical manifestations of gossypol poisoning may be caused by a high concentration of free gossypol. So, selection has generated cotton variants that lack the glands that produce gossypol, but these kinds are less productive and more susceptible to insect attack. For this characteristic, the standard heterosis ranged from -7.72 per cent (DELTA 15 × BC-68-2 BG II) to 5.73 per cent (SCS 1061 × G. Cot-10 BG II). The cross DELTA 15 × BC-68-2 BG II (-7.72 %) had the greatest desirable standard heterosis, followed by cross DELTA 15 × G. Cot-16 BG II (-7.25 %). Vekariya *et al.* (2017); Vanapariya *et al.* (2022) also recorded similar results.

Protein Content (%). Protein derived from cotton seeds is a novel for human consumption these days, hence research into the protein content is critical. Out of the 21 crosses, twelve were positive significant for heterobeltiosis. A standard heterosis varied from -16.39

per cent (BS 27 × BC-68-2 BG II) to 37.76 per cent (GISV 218 × G. Cot-16 BG II) for protein content. Among 21 hybrids top hybrids, *viz*., GISV 218 × G. Cot-16 BG II (37.76 %), DELTA 15 × G. Cot-10 BG II (35.59 %), BGDS 1063 × G. Cot-16 BG II (18.93 %) recorded positive and significant standard heterosis. Vekariya *et al.* (2017) also recorded similar results.

Phenol Content (%). Three crosses had significant and positive heterosis over the better parent, with phenol content ranging from -42.36 per cent (GJHV 374 × BC-68-2 BG II) to 10.14 per cent (SCS 1061 × BC-68-2 BG II). Standard heterosis was positive in twelve of the crosses. The standard heterosis ranged from -26.39 per cent (BS 27 × G. Cot-10 BG II) to 48.64 per cent (SCS 1061 × BC-68-2 BG II). The cross SCS 1061 × BC-68-2 BG II had the highest standard heterosis (48.64 %) followed by DELTA 15 × BC-68-2 BG II (47.04 %) and GJHV 374 × G. Cot-16 BG II (43.18 %).

Table 1: Analysis of variance for experimental design for different traits in cotton.

Source of variation	Df	Days to 50% flowering	Sympodia per plant	Bolls per plant	Boll weight (g)	Seed cotton yield per plant (g)	Ginning outturn (%)	Seed index (g)
Replications	02	10.04	03.54	52.63*	0.13	1577.90**	01.21	00.11
Treatments	31	09.88**	10.88**	273.08**	0.28**	3512.61**	9.60**	03.21**
Parents	09	04.68	11.09**	177.47**	0.27*	2213.68**	16.70**	04.29**
Lines	06	04.63	06.24*	180.10**	0.33*	2662.39**	15.73**	04.22**
Testers	02	07.11	25.86**	128.78**	0.12	1022.01*	19.72**	03.20**
Lines vs Testers	01	00.10	10.69*	259.07**	0.18	1904.72**	16.48**	06.90**
Hybrids	20	12.59**	10.71**	178.98**	0.29**	1757.87**	06.09**	02.35**
Parents vs Hybrids	01	07.55	18.88**	3283.57**	0.60*	53783.34**	07.54**	13.77**
Check vs Hybrids	01	04.76	04.43	05.25	00.01	27.00	18.00**	00.20
Error	62	03.31	02.17	15.03	0.11	268.08	01.01	00.05

* and ** indicates significance at 5% and 1% levels of probability, respectively.

Tabel 1 continue…

Source of variation	df	Fiber length (mm)	Fiber strength (g/tex)	Fiber fineness (mv)	Protein content (%)	Oil content (%)	Gossypol content (%)	Phenol content (%)
Replications	02	00.03	00.80	00.17	00.13	00.84	0.001	0.001
Treatments	31	03.01**	03.17**	00.50**	16.80**	36.06**	0.002**	0.047**
Parents	09	04.38**	04.06**	01.02**	03.03**	25.89**	0.001	0.046**
Lines	06	05.79**	06.01**	00.91**	03.07**	24.67**	0.001	0.046**
Testers	02	01.55	00.02	01.47**	03.56**	36.06**	0.001	0.008**
Lines vs Testers	01	01.63	00.44	00.78**	01.78	12.81**	0.001	0.122**
Hybrids	20	02.27**	01.46**	00.30**	22.22**	41.98**	0.002**	0.051**
Parents vs Hybrids	01	06.29**	32.45**	00.00	47.39**	19.53**	0.000	0.003*
Check vs Hybrids	01	02.13	00.95	00.35*	01.63	24.80**	0.001	0.018*
Error	62	00.59	00.34	00.06	00.50	00.45	0.001	0.001

* and ** indicates significance at 5% and 1% levels of probability, respectively.

Table 2: Per cent heterobeltiosis (H_1) and standard heterosis (H_2) for days to 50% flowering, sympodia per plant, bolls per plant and boll weight (g) in cotton.

Sr. No.	Crosses	Days to 50% flowering		Sympodia per plant		Bolls per plant		Boll weight(g)	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
1	BGDS 1063 × G. Cot-10 BG II	6.15**	4.02	42.46**	41.71**	119.05**	62.83**	-9.33	-6.42
2	ARBC 1351 × G. Cot-10 BG II	0.49	3.02	-10.57	6.84	60.82**	38.05**	-14.60*	-11.47
3	GISV 218 × G. Cot-10 BG II	2.96	5.03*	-0.53	-1.05	92.68**	39.82**	-2.76	-3.21
4	BS 27 × G. Cot-10 BG II	3.96	5.53*	-12.30	-0.53	15.38	19.47*	-13.60	-9.63
5	SCS 1061 × G. Cot-10 BG II	4.46*	6.03**	-4.23	-4.74	31.78**	24.78**	-0.96	-5.05
6	DELTA 15 × G. Cot-10 BG II	3.43	6.03**	18.04	20.53*	58.54**	15.04	-7.18	-11.01
7	GJHV 374 × G. Cot-10 BG II	4.02	4.02	17.99	17.37	60.98**	16.81*	4.78	0.46
8	BGDS 1063 × G. Cot-16 BG II	4.62*	2.51	-28.19**	-0.53	7.83	9.73	-5.78	-2.75
9	ARBC 1351 × G. Cot-16 BG II	-5.10*	-6.53**	-5.02	31.58**	6.09	7.96	-3.10	0.46
10	GISV 218 × G. Cot-16 BG II	3.57	2.01	-14.51*	18.42	7.83	9.73	2.30	1.83
11	BS 27 × G. Cot-16 BG II	4.59*	3.02	-38.07**	-14.21	-22.22**	-19.47*	-4.39	0.00
12	SCS 1061 × G. Cot-16 BG II	5.10*	3.52	-37.31**	-13.16	-21.74*	-20.35*	27.27**	9.17
13	DELTA 15 × G. Cot-16 BG II	5.61*	4.02	-14.89*	17.89	18.26*	20.35*	24.50**	14.22
14	GJHV 374 × G. Cot-16	1.53	0.00	-13.37	20.00*	26.96**	29.20**	0.48	-4.59

	BG II								
15	BGDS 1063 × BC-68-2 BG II	2.56	0.50	26.49**	23.16*	11.11	15.04	-5.33	-2.29
16	ARBC 1351 × BC-68-2 BG II	0.49	3.02	2.86	22.89*	-17.95*	-15.04	-6.64	-3.21
17	GISV 218 × BC-68-2 BG II	-5.42*	-3.52	31.18**	28.42**	13.68	17.70*	-5.99	-6.42
18	BS 27 × BC-68-2 BG II	-2.48	-1.01	-12.76	-1.05	-20.51*	-17.70*	14.91*	20.18**
19	SCS 1061 × BC-68-2 BG II	0.99	2.51	6.70	4.74	8.55	12.39	20.87**	14.22
20	DELTA 15 × BC-68-2 BG II	-1.47	1.01	17.01	19.47*	8.55	12.39	13.11	6.88
21	GJHV 374 × BC-68-2 BG II	2.01	2.01	21.62*	18.42	20.51*	24.78**	4.35	-0.92
SEm ±		1.49		1.20		3.17		0.27	
CD @ 5%		0.91		0.74		1.94		0.16	
Range		-5.42 to 6.15	-6.53 to 6.03	-38.07 to 42.46	-14.21 to 41.71	-22.22 to 119.05	-20.35 to 62.83	-14.6 to 27.27	-11.47 to 20.18

Table 3: Per cent heterobeltiosis (H_1) and standard heterosis (H_2) for Seed cotton yield per plant (g), ginning percentage (%), seed index (g), fiber length (mm) and fiber strength (g/tex) in cotton.

Sr. No.	Crosses	Seed cotton yield per plant (g)		Ginning outturn (%)		Seed index (g)		Fiber length (mm)		Fiber strength (g/tex)	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
1	BGDS 1063 × G. Cot-10 BG II	99.55**	54.60**	-8.68**	6.61*	-18.86**	-8.06**	0.13	-4.57	2.41	-0.62
2	ARBC 1351 × G. Cot-10 BG II	38.46**	23.98*	3.62	16.08**	-22.42**	-12.1**	-4.27	-2.97	-1.86	3.69*
3	GISV 218 × G. Cot-10 BG II	94.82**	36.94**	2.13	9.29**	-28.83**	-19.35**	3.11	-5.81*	6.71**	1.72
4	BS 27 × G. Cot-10 BG II	0.42	8.84	-1.47	14.16**	-3.20	9.68**	1.79	-1.85	2.24	0.98
5	SCS 1061 × G. Cot-10 BG II	67.93**	20.16*	3.33	9.99**	-10.68**	1.21	14.07**	4.20	6.97**	1.97
6	DELTA 15 × G. Cot-10 BG II	47.83**	3.91	6.65*	10.52**	-12.46**	-0.81	-7.23**	-4.82*	3.62*	2.09
7	GJHV 374 × G. Cot-10 BG II	69.23**	18.95	6.72*	10.58**	-12.46**	-0.81	-1.53	-4.57	9.81**	4.67*
8	BGDS 1063 × G. Cot-16 BG II	23.36*	8.65	-14.71**	1.89	42.36**	31.45**	6.23*	1.24	6.97**	3.81*
9	ARBC 1351 × G. Cot-16 BG II	21.29	8.60	-7.97**	9.95**	-4.30	-1.21	-0.12	1.24	-2.91	2.58
10	GISV 218 × G. Cot-16 BG II	28.62*	13.29	-7.91**	10.03**	2.22	-7.26**	4.06	-1.85	7.23**	2.21
11	BS 27 × G. Cot-16 BG II	-24.80**	-18.50	-8.02**	9.89**	14.47**	5.24*	5.26*	1.48	1.62	0.37
12	SCS 1061 × G. Cot-16 BG II	0.75	-11.27	-11.07**	6.25*	20**	8.87**	7.08**	0.99	7.35**	2.34
13	DELTA 15 × G. Cot-16 BG II	56.96**	38.25**	-10.22**	7.26**	7.36**	0.00	-4.82*	-2.35	5.37**	3.81*
14	GJHV 374 × G. Cot-16 BG II	39.96**	23.28*	-8.31**	9.54**	0.89	-8.47**	-0.13	-3.21	2.97	-1.85
15	BGDS 1063 × BC-68-2 BG II	15.76	12.89	-14.18**	0.20	12.17**	4.03	4.48	0.99	-1.01	-3.94*
16	ARBC 1351 × BC-68-2 BG II	-16.13	-18.21	-16.50**	-2.75	-10.94**	-8.06**	-5.73*	-4.45	-3.03	2.46
17	GISV 218 × BC-68-2 BG II	15.12	12.26	-11.21**	3.42	-6.09*	-12.90**	-2.81	-6.06*	1.54	-2.71
18	BS 27 × BC-68-2 BG II	-9.28	-1.68	-10.58**	4.15	16.96**	8.47**	0.97	-2.40	1.00	-0.25
19	SCS 1061 × BC-68-2 BG II	32.97**	29.67**	-3.66	12.22**	11.74**	3.63	-0.13	-3.46	5.01**	0.62
20	DELTA 15 × BC-68-2 BG II	21.53*	18.52	-11.03**	3.62	6.49*	-0.81	-7.83**	-5.44*	-1.37	-2.83
21	GJHV 374 × BC-68-2 BG II	29.07**	25.87*	-10.71**	4.00	16.09**	7.66**	-6.12*	-9.02**	0.64	-3.57*
SEm ±		13.37		0.82		0.19		0.63		0.48	
CD @ 5%		8.18		0.50		0.12		0.39		0.29	
Range		-24.80 to 99.55	-18.50 to 54.60	-16.50 to 6.72	-2.75 to 16.08	-28.83 to 42.36	-19.35 to 31.45	-7.83 to 14.07	-9.02 to 4.20	-3.03 to 9.81	-3.94 to 4.67

* and ** indicates significance at 5% and 1% levels of probability, respectively.

Table 4: Per cent heterobeltiosis (H_1) and standard heterosis (H_2) for fiber fineness (mv), protein content (%), oil content (%), gossypol content (%) and phenol content (%) in cotton.

Sr. No.	Crosses	fiber fineness (mv)		Protein content (%)		Oil content (%)		Gossypol content (%)		Phenol content (%)	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
1	BGDS 1063 × G. Cot-10 BG II	1.63	22.55**	14.87**	8.37*	-15.38**	3.85	7.26*	2.62	-26.16**	3.70
2	ARBC 1351 × G. Cot-10 BG II	-6.90	5.88	23.41**	16.43**	-5.61*	18.89**	1.86	-2.54	-10.77**	11.77**
3	GISV 218 × G. Cot-10 BG II	7.07	3.92	11.15**	8.82**	13.38**	44.95**	5.46	0.90	-9.42**	11.44**
4	BS 27 × G. Cot-10 BG II	-4.38	28.43**	17.91**	11.24**	17.22**	43.87**	4.20	-0.30	-39.22**	-26.39**
5	SCS 1061 × G. Cot-10 BG II	3.85	5.88	9.58**	11.96**	5.62*	29.64**	10.51**	5.73	-28.72**	-13.68**
6	DELTA 15 × G. Cot-10 BG II	21.28**	11.76	32.20**	35.59**	5.62*	29.64**	7.65*	3.00	-16.36**	1.29
7	GJHV 374 × G. Cot-10 BG II	25.81**	14.71*	9.82**	14.37**	1.75	24.89**	5.19	0.65	-37.90**	-24.79**
8	BGDS 1063 × G. Cot-16 BG II	6.31	15.69*	18.05**	18.93**	-40.91**	-21.13**	-4.60	-4.07	-27.19**	2.26
9	ARBC 1351 × G. Cot-16 BG II	5.41	14.71*	11.17**	12.00**	-32.06**	-9.31**	0.29	0.85	-27.66**	1.45
10	GISV 218 × G. Cot-16 BG II	7.07	3.92	36.73**	37.76**	-29.58**	-6.00*	-1.01	-2.96	-6.65*	30.93**
11	BS 27 × G. Cot-16 BG II	0.90	9.80	9.96**	10.78**	0.13	33.66**	0.27	-0.29	-7.79**	29.33**
12	SCS 1061 × G. Cot-16 BG II	-12.5*	-10.78	15.35**	17.86**	-29.78**	-6.27*	0.38	0.94	-11.69**	23.86**
13	DELTA 15 × G. Cot-16 BG II	5.32	-2.94	4.99	7.68*	-4.83*	27.04**	-5.76	-7.25*	0.71	41.25**
14	GJHV 374 × G. Cot-16 BG II	21.51**	10.78	0.12	4.27	2.82	37.24**	9.01*	4.67	2.09	43.18**
15	BGDS 1063 × BC-68-2 BG II	11.43	14.71*	-16.32**	-11.02**	12.37**	33.39**	-1.27	-4.02	-0.36	39.94**
16	ARBC 1351 × BC-68-2 BG II	-7.62	-4.90	-10.51**	-4.85	-0.71	25.07**	7.57*	4.58	-26.13**	-0.31
17	GISV 218 × BC-68-2 BG II	24.24**	20.59**	-19.51**	-14.42**	-25.35**	-4.57	1.09	-1.72	4.90	41.58**
18	BS 27 × BC-68-2 BG II	8.57	11.76	-21.36**	-16.39**	26.24**	27.48**	2.20	-0.64	5.62*	42.54**
19	SCS 1061 × BC-68-2 BG II	10.58	12.75*	-15.98**	-10.66**	-5.29	0.98	-3.63	-6.31	10.14**	48.64**
20	DELTA 15 × BC-68-2 BG II	15.96*	6.86	-10.73**	-5.08	-7.54**	-1.16	-5.08	-7.72*	8.95**	47.04**
21	GJHV 374 × BC-68-2 BG II	27.96**	16.67**	-15.56**	-10.22**	43.92**	39.93**	5.40	1.20	-42.36**	-22.22**
SEm ±		0.20		0.58		0.55		0.02		0.02	
CD @ 5%		0.12		0.35		0.34		0.01		0.01	
Range		-12.50 to 27.96	-10.78 to 28.43	-21.36 to 36.73	-16.39 to 37.76	-40.91 to 43.92	-21.13 to 44.95	-5.76 to 10.51	-7.72 to 5.73	-42.36 to 10.14	-26.39 to 48.64

Table 5: Best heterotic crosses and their performance for seed cotton yield and related parameters in cotton.

Best crosses ($P_1 \times P_2$)	Mean yield/ plant (g)	Better parent heterosis (%)	Standard heterosis (%)	Significant standard heterosis of other yield attributing traits in desired direction
BGDS 1063 × G. Cot-10 BG II	206.39	99.55**	54.6**	Sympodia per plant, Bolls per plant, Ginning outturn, Protein content
DELTA 15 × G. Cot-16 BG II	184.56	56.96**	38.25**	Bolls per plant, Ginning outturn, fiber strength, Phenol content, Protein content, Oil content, Gossypol content
GISV 218 × G. Cot-10 BG II	182.81	94.82**	36.94**	Bolls per plant, Ginning outturn, Protein content, Oil content, Phenol content
SCS 106 × BC-68-2 BG II	173.10	32.97**	29.67**	Ginning outturn, Phenol content
GJHV 374 × BC-68-2 BG II	168.03	29.07**	25.87*	Bolls per plant, Seed index, Oil content

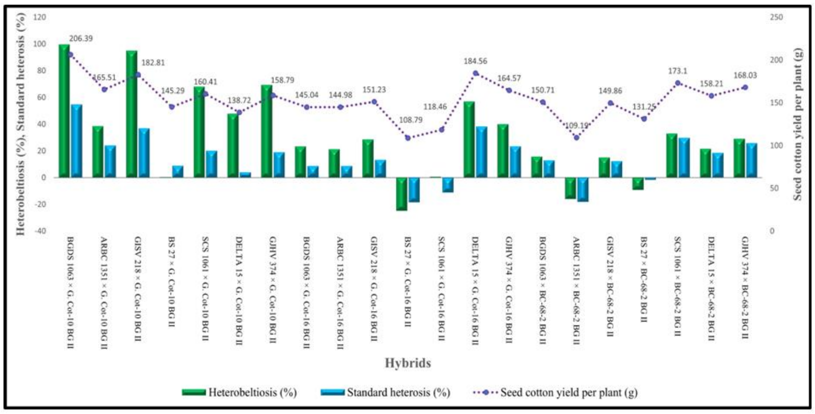

Fig. 1. Seed cotton yield per plant(g), heterobeltiosis (%) and standard heterosis (%) of 21 hybrids.

CONCLUSIONS

The current analysis revealed significant amounts of both desired heterobeltiosis and standard heterosis for various traits. These imply the potential for cotton improvement through heterosis breeding. Top-ranking crosses based on per se performance and standard heterosis were nearly identical, although heterobeltiosis resulted in a slight difference. Since better parent heterosis is less reliable, ranking based on standard heterosis is more reliable.

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FUTURE SCOPE

Out of 21 crosses, top five crosses *viz*., BGDS 1063 × G. Cot-10 BG II, DELTA 15 × G. Cot-16 BG II, GISV 218 × G. Cot-10 BG II, SCS 1061 × BC-68-2 BG II and GJHV 374 × BC 68-2 BG II recorded positive and significant standard heterosis for seed cotton yield per plant. Therefore, such cross combinations may be recommended for commercial cultivation as hybrids or further production of more desirable recombinants and superior varieties.

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Conflict of Interest. None.

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