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Genetic basis of heterosis for seed cotton yield, fibre and biochemical traits in cotton through line $\times$ tester analysis

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Abstract

The present study was undertaken to assess heterosis for seed cotton yield, yield-contributing traits, fibre quality and biochemical characters in upland cotton (*Gossypium hirsutum* L.) using a Line $\times$ Tester design. Four lines, seven testers and their twenty-eight F_1 hybrids, along with the standard check GN.Cot.Hy-18, were evaluated in a Randomized Block Design with three replications during *kharif* 2024. Analysis of variance revealed significant genetic variability for all traits except seed index. Among the hybrids, 76-IH-20 $\times$ GISV-382 exhibited significant heterobeltiosis for seed cotton yield, while BC 68-2 $\times$ GISV-399 and 76-IH-20 $\times$ GISV-382 recorded the highest significant standard heterosis over the check. These hybrids also expressed desirable heterosis for major yield components such as bolls per plant, boll weight and ginning outturn, along with notable heterotic effects for fibre and biochemical traits. The hybrids BC 68-2 $\times$ GISV-399, 76-IH-20 $\times$ GISV-382, 76-IH-20 $\times$ GISV-399 and GSHV-112 $\times$ GISV-399 were identified as promising for exploitation of heterosis in cotton breeding programmes.

Keywords: Cotton, line $\times$ tester, heterosis, heterobeltiosis, standard heterosis

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the most important natural fibre crops globally and plays a vital role in the agricultural and industrial economy of many countries. The genus *Gossypium* (family Malvaceae) comprises nearly fifty species, of which four are cultivated. Among them, *G. hirsutum* (upland cotton) dominates world cotton production due to its wide adaptability, high yield potential and acceptable fibre quality. India is unique in cultivating all four cultivated cotton species and ranks among the leading cotton-producing nations, highlighting the importance of genetic improvement for sustaining productivity and quality.

Seed cotton yield is a complex quantitative trait influenced by several yield-contributing characters such as plant architecture, boll number, boll weight and ginning outturn. In addition to yield, fibre quality traits including fibre length, strength and fineness determine the industrial value of cotton, while biochemical traits such as seed oil, protein, phenol and gossypol content contribute to its nutritional, defensive and economic importance. Improvement of these traits simultaneously is challenging due to their polygenic inheritance and strong environmental influence, necessitating the exploitation of heterosis and an understanding of the underlying genetic mechanisms.

Heterosis or hybrid vigour, expressed as superior performance of F_1 hybrids over their parents, has been widely exploited in cotton to enhance yield and fibre quality. The success of cotton hybrids in India, beginning with the release of Hybrid-4 and subsequent interspecific and intraspecific hybrids, demonstrates the practical utility of heterosis breeding. However, the magnitude and direction of heterosis vary with genetic background and trait, emphasizing the need to study the genetic basis of heterosis to identify superior parents and promising hybrid combinations.

Combining ability analysis provides insight into the nature of gene action governing quantitative traits and helps partition genetic variance into additive and non-additive components. The Line $\times$ Tester mating design is an efficient approach to evaluate heterosis, general combining ability (GCA) and specific combining ability (SCA) simultaneously, thereby facilitating the identification of elite parents and cross combinations. Understanding whether additive or non-

additive gene action predominates is essential for designing effective breeding strategies aimed at heterosis exploitation.

In this context, the present investigation entitled “Genetic Basis of Heterosis for Seed Cotton Yield, Fibre and Biochemical Traits in Cotton through Line × Tester Analysis” was undertaken to assess the extent of heterobeltiosis and standard heterosis, identify superior parental combiners and hybrids, and elucidate the genetic control of yield, fibre and biochemical traits. The findings are expected to contribute valuable information for the development of high-yielding cotton hybrids with improved fibre quality and enhanced biochemical attributes.

Materials and Methods

Experimental site

The present investigation was conducted at the Main Cotton Research Station (MCRS), Navsari Agricultural University, Surat, Gujarat, India, during the *kharif* season of 2024. The experimental site lies in the tropical agro-climatic zone characterized by hot summers, humid monsoon conditions and mild winters. Weather conditions during the cropping season were normal and favourable for cotton cultivation.

Plant material and crossing programme

The experimental material comprised four female lines (G.Cot.10, BC 68-2, 76-IH-20 and GSHV-112) and seven male testers (GISV-382, GISV-385, GISV-389, GISV-395, GISV-399, GISV-318 and GISV-340) of *Gossypium hirsutum* L. These parents were crossed in a Line × Tester mating design, resulting in twenty-eight F₁ hybrids. The commercial hybrid GN.Cot.Hy-18 was included as the standard check. Hybridization was carried out during *kharif* 2023 following the Dock and Moll (1934) ^[1] emasculation and pollination method.

Experimental design and crop management

The parents, F₁ hybrids and standard check were evaluated in a Randomized Block Design (RBD) with three replications during *kharif* 2024. Each entry was grown in a single row plot with a spacing of 120 × 45 cm. All recommended agronomic and plant protection practices were followed to maintain a healthy and uniform crop stand. Observations were recorded on five randomly selected plants per entry in each replication.

Traits recorded

Data were recorded on sixteen agronomic, fibre and biochemical traits, including days to 50% flowering, plant height, monopodia per plant, sympodia per plant, bolls per plant, boll weight, seed index, seed cotton yield per plant, ginning outturn, fibre length, fibre strength, fibre fineness, seed oil content, leaf gossypol content, seed protein content and phenol content. Fibre quality parameters were measured using the High-Volume Instrument (HVI) system, while biochemical traits were estimated using standard laboratory protocols.

Statistical analysis

The replication-wise mean values were subjected to analysis of variance (ANOVA) following the procedures described by Panse and Sukhatme (1978) ^[2] to test the significance of genotypic differences. Heterobeltiosis and standard heterosis were estimated following Fonseca and Patterson (1968) ^[3] and Meredith and Bridge (1972) ^[4], respectively. Combining ability analysis was carried out according to Kempthorne (1957) ^[5] to estimate general combining ability (GCA), specific combining ability (SCA) and the nature of gene action. Significance of GCA and SCA effects was tested using appropriate *t*-tests.

Estimation of Heterosis

It is thought to be more useful and significant to evaluate heterosis in relation to the superior parent and the standard check. Thus, two important criteria were used in this study to assess heterosis: heterosis over the better parent (Heterobeltiosis), as suggested by Fonseca and Patterson (1968) ^[3], and heterosis over the standard check (Standard heterosis), as described by Meredith and Bridge (1972) ^[4]. Following are the formulae used to calculate these parameters as well as the significance tests for them.

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis (\%)} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\overline{F_1}$ = Mean performance of F₁

$\overline{BP}$ = Mean value of better parent of respective cross combination

$\overline{SC}$ = Mean performance of standard check hybrid (GR-19)

Results and Discussion

Analysis of Variance

The analysis of variance (ANOVA) revealed highly significant differences among genotypes for all the traits studied, except seed index, indicating the presence of substantial genetic variability among the experimental material (Table 1). Significant variation among parents was observed for most characters, while hybrids exhibited highly significant differences for all traits except seed index, reflecting wide genetic divergence among hybrid combinations. The parents vs. hybrids comparison was significant for the majority of traits, confirming the expression of heterosis, particularly for seed cotton yield per plant and its associated yield components. These results demonstrate that the genetic material employed in the present study was sufficiently diverse and appropriate for heterosis evaluation and genetic improvement.

Table 1: Analysis of variance (mean squares) for different characters in cotton

Sr. No	Sources of variation	d.f.	Days to 50 percent flowering	Plant height (cm)	Monopodia per plant	Sympodia per plant	Bolls per plant	Boll weight (g)	Seed Index (g)	Seed cotton yield per plant (g)
1	Replications	2	0.3084	236.5368*	0.021	29.8151**	21.7483*	0.1484	1.075*	90.4938
2	Genotypes	39	39.0425**	306.3179**	0.9302**	4.8672**	34.488**	0.2347**	0.2126	172.2342**
	(a) Parents	10	115.297**	361.2875**	0.8892**	4.1013	12.7275*	0.2735**	0.2212	175.7803**
	(i) Females	3	92.75**	214.8756*	1.8044**	0.6178	33.8133**	0.1332	0.1319	115.1667
	(ii) Males	6	143.873**	390.633**	0.5187**	5.266	4.2965	0.35**	0.2698	218.7143**
	(iii) Females vs Males	1	11.4816*	624.4504**	0.3664**	7.5638	0.0561	0.2355	0.1972	100.0173
	(b) Hybrids	27	11.4497**	286.9683**	0.9959**	5.3167**	42.053**	0.2061**	0.2244	156.8849**
	(c) Parents vs Hybrids	1	59.802**	387.5131*	0.0098	3.7682	64.8735**	0.847**	0.0147	718.1033**
	(d) Check vs Hybrids	1	2.6273	254.0628	0.4971**	1.0469	24.5162*	0	0.0037	0.1186
3	Error	78	2.1374	74.1111	0.0125	2.4417	5.3036	0.0957	0.2588	66.8356
Sr. No	Sources of variation	d.f.	Ginning outturn (%)	Fibre strenght (g/tex)	Fibre length (mm)	Fibre fineness (mv)	Seed oil content (%)	Leaf Gossypol content (%)	Seed protein content (%)	Phenol conent (mg/g)
1	Replications	2	1.0391	0.1851	0.2732	0.0208	0.2626	0.0019	0.5153	0
2	Genotypes	39	7.1505**	6.2593**	5.6555**	0.769**	33.6208**	0.2652**	46.707**	0.0446**
	(a) Parents	10	8.2672**	13.0629**	9.902**	0.6109**	29.5092**	0.1859**	51.4364**	0.0516**
	(i) Females	3	8.3222**	9.1**	10.7097**	1.1075**	12.935**	0.2216**	70.0506**	0.0369**
	(ii) Males	6	8.3327**	17.1926**	9.3126**	0.33**	16.586**	0.1941**	45.7433**	0.0527**
	(iii) Females vs Males	1	7.7093*	0.1729	11.0151**	0.8066**	156.771**	0.0295**	29.7522**	0.0894**
	(b) Hybrids	27	4.9289**	3.9574**	4.4529**	0.6647**	35.5238**	0.2832**	37.3456**	0.0443**
	(c) Parents vs Hybrids	1	45.3308**	0.042	1.0759	0.4009*	19.9879**	0.8391**	274.5467**	0.0117**
	(d) Check vs Hybrids	1	23.6256**	6.6307**	0.1482	5.7742**	42.1608**	0.0034	10.7233**	0.0169**
3	Error	78	1.5816	0.6992	0.5089	0.091	0.6827	0.0018	0.6257	0.0002

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively

Mean Performance of Parents and Hybrids

Mean performance is a crucial criterion for identifying superior parents and hybrids. The mean performance of parents and hybrids for different agronomic, fibre and biochemical traits is presented in Table 2. None of the parents exhibited consistently superior performance for all traits. Among the female parents, GSHV-112 showed promising performance for seed cotton yield, boll weight, ginning outturn and fibre quality traits, while BC 68-2 performed well for seed cotton yield and biochemical traits. Among the male parents, GISV-399 and GISV-389 recorded higher mean values for yield components and fibre quality traits, whereas GISV-382 showed earliness and higher seed oil content.

Among the hybrids, BC 68-2 × GISV-399, 76-IH-20 × GISV-382, 76-IH-20 × GISV-399 and GSHV-112 × GISV-399 recorded superior per se performance for seed cotton yield per plant. These hybrids also exhibited desirable mean values for key yield-contributing traits such as bolls per plant, boll weight and ginning outturn. For fibre quality, BC 68-2 × GISV-395 showed higher fibre strength, BC 68-2 × GISV-318 recorded longer fibre length and 76-IH-20 × GISV-399 exhibited favourable fibre fineness. In biochemical traits, G.Cot.10 × GISV-389 showed higher seed oil content, 76-IH-20 × GISV-395 recorded higher seed protein content and 76-IH-20 × GISV-399 exhibited higher phenol content.

Heterosis

The magnitude of heterosis provides a basis for genetic diversity of the parents and a guide to the choice of parents in developing superior F_1 's so as to exploit hybrid vigour. In addition, if heterosis is due to epistatic gene action, particularly of additive ×

additive type, it would be possible to fix alleles at the interacting loci to preserve the heterotic effect. The heterotic hybrids can also produce desirable transgressive segregant in advanced generations. The aim of estimation of heterosis in the present study was to find out the superior combination of parents giving high degree of useful heterosis for yield and its contributing characters and for future use in development of hybrids.

In the present investigation, several crosses exhibited conspicuous heterotic response over better parent and standard check for different traits. The magnitude of heterosis varied from cross to cross for all the characters studied. The conspicuous heterotic response in certain crosses and low in others, revealed the nature of gene actions, which varied according to the genetic makeup of the parents. The estimation of heterosis over better parent (heterobeltiosis) and over standard check (standard heterosis) for different character is presented in Table 3. GN.Cot.Hy-18, a cotton hybrid variety released from NAU, Surat was used as a standard hybrid to estimates standard heterosis.

1. Days to 50% flowering

Heterobeltiosis for days to 50% flowering ranged from -21.08% to 14.01%, indicating substantial variation among hybrids. Only three crosses, G.Cot.10 × GISV-382 (-21.08%), GISV-350 × G.Cot.10 (-10.56%) and GISV-368 × G.Cot.10 (-19.61%), exhibited significant negative heterobeltiosis, suggesting superiority for earliness. Standard heterosis over GN.Cot.Hy-18 varied from -8.00% to 2.29%, with seven hybrids showing significant negative effects. These findings are consistent with earlier reports demonstrating desirable heterosis for earliness in cotton (Sawarkar *et al.*, 2015; Chhavikant *et al.*, 2017; Gohil *et al.*

al., 2017; Monicashree *et al.*, 2017; Murthy *et al.*, 2017; Pavitra *et al.*, 2019; Rani *et al.*, 2020; Vaid *et al.*, 2022a; Parmar *et al.*, 2023; Deshmukh *et al.*, 2024; Sharma *et al.*, 2025)^[6-16].

2. Plant height (cm)

Heterobeltiosis for plant height ranged from -14.31% to 20.02%, with four hybrids exhibiting significant positive heterobeltiosis, indicating superiority for increased plant stature. Standard heterosis over the check varied from -13.50% to 23.96%, and ten hybrids showed significant positive effects. The highest standard heterosis was recorded in GSHV-112 × GISV-385 (23.96%), followed by GSHV-112 × GISV-399 (23.03%) and GSHV-112 × GISV-395 (21.11%). These results corroborate earlier findings reporting desirable heterosis for plant height in cotton (Khokhar *et al.*, 2018; Vennila *et al.*, 2022; Deshmukh *et al.*, 2024; Wahid *et al.*, 2024; Sharma *et al.*, 2025)^[15-19].

3. Monopodia per plant

Positive heterosis for monopodia per plant is desirable as monopodia contribute to plant architecture and photosynthetic efficiency. Heterobeltiosis ranged from -85.29% to 209.09%, with seven hybrids exhibiting significant positive heterobeltiosis. Standard heterosis varied from -70.14% to 238.80%, and eighteen out of twenty-eight hybrids showed significant positive heterosis over the standard check. Similar magnitudes of positive heterosis for monopodia per plant have been reported earlier (Chhavikant *et al.*, 2017;^[7] Richika *et al.*, 2021;^[20] Kanasagra *et al.*, 2022)^[21].

4. Sympodia per plant

Positive heterosis for sympodia per plant is desirable as sympodia are directly associated with yield formation. Heterobeltiosis ranged from -21.71% to 25.62%, with only three hybrids showing significant positive heterobeltiosis. Standard heterosis varied from -23.08% to 11.11%; however, none of the hybrids exhibited significant positive heterosis over the standard check. These results are in partial agreement with earlier studies reporting positive heterosis for sympodia per plant (Srinivas and Bhadru, 2015;^[22] Chhavikant *et al.*, 2017;^[7] Gnanasekaran and Thiyaagu, 2019;^[23] Vennila *et al.*, 2022;^[18] Richika *et al.*, 2021;^[20] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024)^[15].

5. Bolls per plant

Number of bolls per plant is a major yield determinant in cotton. Heterobeltiosis for bolls per plant ranged from -31.96% to 33.77%, with five hybrids exhibiting significant positive heterobeltiosis. The highest desirable heterobeltiosis was recorded in GSHV-112 × GISV-382 (33.77%), followed by G.Cot.10 × GISV-382 (25.61%), BC 68-2 × GISV-399 (24.47%), GSHV-112 × GISV-395 (17.66%) and GSHV-112 × GISV-399 (16.36%). Standard heterosis ranged from -19.02% to 48.41%, with thirteen hybrids showing significant positive effects. These findings are in agreement with earlier reports (Sawarkar *et al.*, 2015;^[6] Srinivas and Bhadru, 2015;^[22] Pavitra *et al.*, 2019;^[11] Richika *et al.*, 2021;^[20] Parmar *et al.*, 2023;^[14]

Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

6. Boll weight (g)

Boll weight, an important component of seed cotton yield, showed heterobeltiosis ranging from -8.19% to 21.08%, with only two hybrids exhibiting significant positive heterobeltiosis. Standard heterosis varied from -12.25% to 16.94%, and only one hybrid recorded significant positive heterosis over the standard check. The limited expression of heterosis for boll weight observed in the present study is in accordance with earlier findings (Sawarkar *et al.*, 2015;^[6] Pavitra *et al.*, 2019;^[11] Richika *et al.*, 2021;^[20] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

7. Seed index (g)

Seed index (100-seed weight) exhibited limited heterotic expression among the hybrids. Heterobeltiosis ranged from -7.41% to 7.69%; however, none of the hybrids showed significant positive heterobeltiosis in the desirable direction. Standard heterosis varied from -5.77% to 7.69%, and again no hybrid exhibited significant positive standard heterosis over the check. These results indicate restricted scope for heterosis breeding for seed index in cotton and are in agreement with earlier reports (Chhavikant *et al.*, 2017;^[7] Gohil *et al.*, 2017;^[8] Murthy *et al.*, 2017;^[10] Tigga *et al.*, 2017;^[24] Pavitra *et al.*, 2019;^[11] Vaid *et al.*, 2022b)^[25].

8. Seed cotton yield per plant (g)

Seed cotton yield per plant, the most important economic trait, exhibited heterobeltiosis ranging from -8.19% to 24.63%. Only one hybrid, 76-IH-20 × GISV-382 (24.63%), showed significant positive heterobeltiosis. Standard heterosis varied from -12.48% to 16.81%, with two hybrids recording significant positive effects, namely BC 68-2 × GISV-399 (16.81%) and 76-IH-20 × GISV-382 (15.77%). The expression of useful heterosis for seed cotton yield observed in the present study is in agreement with earlier reports (Sawarkar *et al.*, 2015;^[6] Srinivas and Bhadru, 2015;^[22] Chhavikant *et al.*, 2017;^[7] Pavitra *et al.*, 2019;^[11] Richika *et al.*, 2021;^[20] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

9. Ginning outturn (%)

Ginning outturn, a composite trait influenced by lint and seed weight, showed heterobeltiosis ranging from -5.18% to 8.18%, with two hybrids exhibiting significant positive heterobeltiosis, namely G.Cot.10 × GISV-385 (8.18%) and GSHV-112 × GISV-318 (6.62%). Standard heterosis ranged from 2.17% to 19.20%, and twenty hybrids recorded significant positive standard heterosis. The highest standard heterosis was observed in GSHV-112 × GISV-395 (19.20%), followed by GSHV-112 × GISV-318 (14.76%), GSHV-112 × GISV-382 (13.73%) and GSHV-112 × GISV-399 (13.11%). These results corroborate earlier findings on heterosis for ginning outturn in cotton (Murthy *et al.*, 2017;^[10] Tigga *et al.*, 2017;^[24] Thiyaagu *et al.*, 2019;^[25] Richika *et al.*, 2021;^[20] Vaid *et al.*, 2022a;^[13] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

Table 2: Mean values of cotton genotypes for sixteen characters in cotton

Sr. No.	Genotypes	Days to 50 percent flowering	Plant height (cm)	Monopodia per plant	Sympodia per plant	Bolls per plant	Boll weight (g)	Seed Index (g)	Seed cotton yield per plant (g)
Hybrids									
1	G.Cot.10×GISV-382	53.67	119.03	1.53	16.47	30.73	3.52	8.17	88.00
2	G.Cot.10×GISV-385	57.67	111.33	1.73	13.60	27.47	3.68	8.83	92.33
3	G.Cot.10×GISV-389	57.67	103.87	0.33	16.27	23.40	3.69	8.67	92.33
4	G.Cot.10×GISV-395	57.67	104.07	1.27	16.53	23.07	3.51	8.50	87.83
5	G.Cot.10×GISV-399	57.33	118.33	1.73	14.27	25.93	3.91	8.50	97.67
6	G.Cot.10×GISV-318	53.67	112.80	0.93	17.00	25.13	3.38	8.67	84.50
7	G.Cot.10×GISV-340	54.67	113.47	0.87	15.53	25.07	3.51	8.67	87.83
8	BC 68-2×GISV -382	54.67	98.80	1.27	15.13	23.73	3.91	8.50	97.67
9	BC 68-2×GISV -385	55.67	111.73	1.47	14.13	26.93	3.89	8.33	97.33
10	BC 68-2×GISV -389	58.67	103.93	1.27	15.80	22.60	3.91	9.00	97.83
11	BC 68-2×GISV -395	58.00	100.60	0.67	14.27	19.87	4.01	8.83	100.17
12	BC 68-2×GISV -399	59.00	99.40	0.47	14.40	31.53	4.49	8.67	112.33
13	BC 68-2×GISV -318	58.67	99.27	0.73	13.87	21.47	3.94	8.50	98.50
14	BC 68-2×GISV -340	59.67	87.13	0.27	12.00	23.20	3.82	9.00	95.50
15	76-IH-20×GISV -382	58.67	115.20	0.20	14.80	27.73	4.33	9.00	111.33
16	76-IH-20×GISV -385	57.33	108.67	0.27	14.60	20.73	4.01	9.33	100.17
17	76-IH-20×GISV -389	53.67	111.87	1.33	13.47	24.80	3.77	8.50	94.33
18	76-IH-20×GISV -395	59.67	115.87	0.73	17.10	27.73	4.07	8.67	105.67
19	76-IH-20×GISV -399	55.67	117.67	0.73	17.33	30.07	4.22	8.50	108.00
20	76-IH-20×GISV -318	56.00	95.20	0.27	12.53	18.73	3.69	8.50	92.33
21	76-IH-20×GISV -340	58.67	96.00	1.27	13.87	24.67	3.37	8.67	84.17
22	GSHV-112×GISV - 382	59.00	113.00	1.33	15.00	34.33	3.84	8.50	96.00
23	GSHV-112×GISV - 385	57.33	124.87	1.53	14.53	26.93	3.69	8.67	92.17
24	GSHV-112×GISV - 389	59.67	120.93	1.47	16.07	28.39	3.71	8.67	92.67
25	GSHV-112×GISV - 395	59.67	122.00	2.27	15.67	30.20	3.91	8.17	97.67
26	GSHV-112×GISV - 399	58.00	123.93	2.27	14.80	29.87	4.05	8.17	104.83
27	GSHV-112×GISV - 318	57.00	114.67	1.13	15.07	28.80	3.75	8.50	93.83
28	GSHV-112×GISV - 340	59.67	119.13	0.93	15.87	26.07	3.81	9.00	95.33
Lines									
29	G.Cot.10	68.00	92.20	2.27	13.40	24.47	3.60	8.67	86.83
30	BC 68 -2	57.00	93.80	0.73	13.80	19.67	3.85	9.00	96.17
31	76-IH-20	56.00	107.13	1.27	14.33	27.53	3.57	8.67	89.33
Continue...									
32	GSHV-112	58.00	108.07	0.53	14.33	25.67	4.01	8.50	100.33
Testers									
33	GISV -382	68.00	111.60	0.87	13.80	24.40	3.57	8.50	89.17
34	GISV -385	53.67	121.60	1.00	15.33	24.73	3.54	8.33	88.50
35	GISV -389	52.33	120.67	1.33	17.20	22.73	3.88	9.17	97.00
36	GISV -395	54.00	117.40	1.13	16.07	22.80	3.83	8.67	95.67
37	GISV -399	53.67	103.73	0.73	14.67	25.33	3.98	8.33	99.50
38	GISV -318	60.00	96.00	0.27	13.53	25.47	3.13	8.33	78.33
39	GISV -340	68.00	94.40	1.53	14.13	25.47	3.15	8.50	78.67
Check									
40	G.Cot.Hy-18	58.33	100.73	0.67	15.60	23.13	3.84	8.67	96.17
Mean									
Parents mean		58.97	106.05	1.06	14.60	24.39	3.65	8.61	90.86
Lines mean		59.75	100.30	1.20	13.97	24.33	3.76	8.71	93.17
Testers mean		58.52	109.34	0.98	14.96	24.42	3.58	8.55	89.55
Hybrids mean		57.38	110.10	1.08	15.00	26.04	3.83	8.63	96.37
General mean		57.84	108.75	1.07	14.90	25.51	3.78	8.63	94.85
Range									
Lines	Min.	56.00	92.20	0.53	13.40	19.67	3.57	8.50	86.83
	Max.	68.00	108.07	2.27	14.33	27.53	4.01	9.00	100.33
Testers	Min.	52.33	94.40	0.27	13.53	22.73	3.13	8.33	78.33
	Max.	68.00	121.60	1.53	17.20	25.47	3.98	9.17	99.50
Parents	Min.	52.33	92.20	0.27	13.40	19.67	3.13	8.33	78.33
	Max.	68.00	121.60	2.27	17.20	27.53	4.01	9.17	100.33
Hybrids	Min.	53.67	87.13	0.20	12.00	18.73	3.37	8.17	84.17
	Max.	59.67	124.87	2.27	17.33	34.33	4.49	9.33	112.33
S. E. ±		0.84	4.97	0.06	0.90	1.33	0.18	0.29	4.72
C. D. at 5%		2.38	13.99	0.18	2.54	3.74	0.50	0.83	13.29
C. V. %		2.53	7.92	10.48	10.48	9.03	8.18	5.90	8.62

Sr. No.	Genotypes	Ginning outturn (%)	Fibre strenght (g/tex)	Fibre length (mm)	Fibre fineness (mv)	Seed oil content (%)	Leaf Gossypol content (%)	Seed protein content (%)	Phenol conent (mg/g)
Hybrids									
1	G.Cot.10×GISV-382	35.13	27.63	25.00	5.00	19.00	0.86	15.90	0.54
2	G.Cot.10×GISV-385	34.83	28.07	25.03	4.50	22.19	0.86	24.29	0.58
3	G.Cot.10×GISV-389	33.20	29.90	25.60	5.20	27.31	0.74	22.51	0.58
4	G.Cot.10×GISV-395	35.40	28.40	24.60	5.50	26.78	1.23	24.93	0.39
5	G.Cot.10×GISV-399	36.53	27.97	25.23	4.43	24.13	0.95	25.28	0.45
6	G.Cot.10×GISV-318	34.43	28.85	25.43	4.80	24.46	1.48	21.72	0.54
7	G.Cot.10×GISV-340	33.00	27.17	24.17	5.83	23.58	1.09	24.64	0.39
8	BC 68-2×GISV -382	34.83	28.80	26.90	5.10	15.01	0.63	22.41	0.51
9	BC 68-2×GISV -385	33.00	28.73	27.20	4.50	17.21	1.14	20.30	0.54
10	BC 68-2×GISV -389	33.90	30.16	27.83	4.90	17.83	1.25	22.33	0.66
11	BC 68-2×GISV -395	35.97	31.80	28.40	4.70	24.88	1.21	20.38	0.67
12	BC 68-2×GISV -399	34.90	30.30	27.50	4.50	17.45	1.49	24.69	0.64
13	BC 68-2×GISV -318	34.10	29.93	28.43	4.90	23.65	1.38	23.41	0.73
14	BC 68-2×GISV -340	34.33	28.70	27.43	4.80	25.55	0.73	17.20	0.74
15	76-IH-20×GISV -382	33.87	28.70	27.27	4.30	25.16	0.51	24.36	0.73
16	76-IH-20×GISV -385	35.07	28.20	26.13	4.30	23.28	1.28	23.89	0.53
17	76-IH-20×GISV -389	34.10	30.17	27.70	4.50	18.10	0.96	18.94	0.75
18	76-IH-20×GISV -395	34.77	29.50	27.40	4.47	23.73	1.23	25.41	0.74
19	76-IH-20×GISV -399	35.47	27.30	25.10	4.00	19.13	1.31	24.48	0.78
20	76-IH-20×GISV -318	35.50	28.10	27.00	4.70	18.40	1.23	24.90	0.76
21	76-IH-20×GISV -340	35.93	27.20	24.97	4.30	26.05	0.81	21.07	0.40
22	GSHV-112×GISV - 382	36.73	28.43	26.03	4.50	24.27	1.83	24.46	0.53
23	GSHV-112×GISV - 385	35.77	29.50	26.50	4.40	26.21	1.27	12.67	0.61
24	GSHV-112×GISV - 389	35.30	29.00	25.50	5.83	20.60	1.01	23.44	0.65
25	GSHV-112×GISV - 395	38.50	26.90	25.50	4.90	20.13	1.07	17.11	0.55
26	GSHV-112×GISV - 399	36.53	27.60	26.37	5.33	24.27	0.72	24.42	0.56
27	GSHV-112×GISV - 318	37.07	29.27	27.30	5.10	25.50	0.99	17.76	0.73
28	GSHV-112×GISV - 340	36.20	27.90	25.07	5.43	24.30	0.59	15.49	0.43
Lines									
29	G.Cot.10	31.40	28.13	24.13	5.00	18.80	0.69	14.19	0.49
30	BC 68 -2	32.03	30.03	28.10	4.60	20.18	1.01	16.86	0.63
Continue...									
31	76-IH-20	34.33	26.43	27.03	4.70	19.90	0.53	13.27	0.74
32	GSHV-112	34.77	30.07	28.17	3.60	15.65	1.11	23.95	0.71
Testers									
33	GISV -382	33.97	29.53	27.37	5.00	25.50	0.58	17.78	0.41
34	GISV -385	32.20	29.17	24.77	4.20	23.45	0.63	21.52	0.73
35	GISV -389	33.13	32.27	27.60	5.00	25.18	0.90	20.84	0.65
36	GISV -395	36.67	29.70	26.30	5.00	18.43	1.33	13.31	0.63
37	GISV -399	35.80	24.52	22.43	5.10	22.33	0.87	17.21	0.45
38	GISV -318	34.63	29.27	25.97	4.50	23.45	0.96	17.20	0.40
39	GISV -340	32.57	27.27	25.17	4.80	23.80	1.04	25.44	0.47
Check									
40	G.Cot.Hy-18	32.30	30.23	26.53	3.40	18.62	1.03	23.65	0.52
Mean									
Parents mean		33.77	28.76	26.09	4.68	21.52	0.88	18.32	0.57
Lines mean		33.13	28.67	26.86	4.48	18.63	0.84	17.07	0.64
Testers mean		34.14	28.82	25.66	4.80	23.16	0.90	19.04	0.54
Hybrids mean		35.16	28.72	26.31	4.81	22.44	1.07	21.73	0.60
General mean		34.70	28.77	26.25	4.74	22.09	1.01	20.84	0.59
Range									
Lines	Min.	31.40	26.43	24.13	3.60	15.65	0.53	13.27	0.49
	Max.	34.77	30.07	28.17	5.00	20.18	1.11	23.95	0.74
Testers	Min.	32.20	24.52	22.43	4.20	18.43	0.58	13.31	0.40
	Max.	36.67	32.27	27.60	5.10	25.50	1.33	25.44	0.73
Parents	Min.	31.40	24.52	22.43	3.60	15.65	0.53	13.27	0.40
	Max.	36.67	32.27	28.17	5.10	25.50	1.33	25.44	0.74
Hybrids	Min.	33.00	26.90	24.17	4.00	15.01	0.51	12.67	0.39
	Max.	38.50	31.80	28.43	5.83	27.31	1.83	25.41	0.78
S. E. ±		0.73	0.48	0.41	0.17	0.48	0.02	0.46	0.01
C. D. at 5%		2.04	1.36	1.16	0.49	1.34	0.07	1.29	0.02
C. V.%		3.62	2.91	2.72	6.36	3.74	4.23	3.80	2.46

Table 3: Estimates of per cent heterosis over better parent (BP) and standard check (SC) for different characters in cotton

Sr. No	Genotype	Days to 50% flowering		Plant height (cm)		Monopodia per plant		Sympodia per plant		Bolls per plant		Boll weight (g)	
		Heterosis over		Heterosis over		Heterosis over		Heterosis over		Heterosis over		Heterosis over	
		BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
1	G.Cot.10×GISV-382	-21.08**	-8**	6.66	18.17*	-32.35**	130**	19.32*	5.56	25.61**	32.85**	-2.13	-8.25
2	G.Cot.10×GISV-385	7.45**	-1.14	-8.44	10.52	-23.53**	160**	-11.3	-12.82	11.05	18.73*	2.3	-4.1
3	G.Cot.10×GISV-389	10.19**	-1.14	-13.92*	3.11	-85.29**	-50**	-5.43	4.27	-4.36	1.15	-4.81	-3.74
4	G.Cot.10×GISV-395	6.79**	-1.14	-11.36	3.31	-44.12**	90**	2.9	5.98	-5.72	-0.29	-8.19	-8.43
5	G.Cot.10×GISV-399	6.83**	-1.71	14.07*	17.47*	-23.53**	160**	-2.73	-8.55	2.37	12.1	-1.84	1.82
6	G.Cot.10×GISV-318	-10.56**	-8**	17.5*	11.98	-58.82**	40**	25.62**	8.97	-1.31	8.65	-6.02	-11.9
7	G.Cot.10×GISV-340	-19.61**	-6.29**	20.2**	12.64	-61.76**	30*	9.91	-0.43	-1.57	8.36	-2.32	-8.43
8	BC 68-2×GISV -382	-4.09	-6.29**	-11.47	-1.92	46.15**	90**	9.66	-2.99	-2.73	2.59	1.56	1.82
9	BC 68-2×GISV -385	3.73	-4.57*	-8.11	10.92	46.67**	120**	-7.83	-9.4	8.89	16.43*	1.21	1.48
10	BC 68-2×GISV -389	12.1**	0.57	-13.87*	3.18	-5	90**	-8.14	1.28	-0.59	-2.31	0.86	2
11	BC 68-2×GISV -395	7.41**	-0.57	-14.31*	-0.13	-41.18**	0	-11.2	-8.55	-12.87	-14.12	4.16	4.43
12	BC 68-2×GISV -399	9.94**	1.14	-4.18	-1.32	-36.36**	-30*	-1.82	-7.69	24.47**	36.31**	12.73*	16.94*
13	BC 68-2×GISV -318	2.92	0.57	3.4	-1.46	0	10	0.48	-11.11	-15.71*	-7.2	2.43	2.69
14	BC 68-2×GISV -340	4.68*	2.29	-7.7	-13.5	-82.61**	-60**	-15.09	-23.08**	-8.9	0.29	-0.8	-0.54
15	76-IH-20×GISV -382	4.76*	0.57	3.23	14.36*	-84.21**	-70**	3.26	-5.13	0.73	19.88*	21.08**	12.77
16	76-IH-20×GISV -385	6.83**	-1.71	-10.64	7.88	-78.95**	-60**	-4.78	-6.41	-24.7**	-10.37	12.13	4.43
17	76-IH-20×GISV -389	2.55	-8**	-7.29	11.05	0	100**	-21.71**	-13.68	-9.93	7.2	-2.75	-1.65
18	76-IH-20×GISV -395	10.49**	2.29	-1.31	15.02*	-42.11**	10	6.43	9.62	0.73	19.88*	6.27	5.99
19	76-IH-20×GISV -399	3.73	-4.57*	9.83	16.81*	-42.11**	10	18.18*	11.11	9.2	29.97**	6.03	9.99
20	76-IH-20×GISV -318	0	-4	-11.14	-5.49	-78.95**	-60**	-12.56	-19.66*	-31.96**	-19.02*	3.36	-3.74
21	76-IH-20×GISV -340	4.76*	0.57	-10.39	-4.7	-17.39**	90**	-3.26	-11.11	-10.41	6.63	-5.78	-12.25
22	GSHV-112×GISV -382	1.72	1.14	1.25	12.18	53.85**	100**	4.65	-3.85	33.77**	48.41**	-4.32	0.09
23	GSHV-112×GISV -385	6.83**	-1.71	2.69	23.96**	53.33**	130**	-5.22	-6.84	4.94	16.43*	-8.14	-3.91
24	GSHV-112×GISV -389	14.01**	2.29	0.22	20.05**	10	120**	-6.59	2.99	10.62	22.74**	-7.64	-3.39
25	GSHV-112×GISV -395	10.49**	2.29	3.92	21.11**	100**	240**	-2.49	0.43	17.66*	30.55**	-2.66	1.82
26	GSHV-112×GISV -399	8.07**	-0.57	14.68*	23.03**	209.09**	240**	0.91	-5.13	16.36*	29.11**	0.83	5.47
27	GSHV-112×GISV -318	-1.72	-2.29	6.11	13.83	112.5**	70**	5.12	-3.42	12.21	24.5**	-6.48	-2.17
28	GSHV-112×GISV -340	2.87	2.29	10.24	18.27*	-39.13**	40**	10.7	1.71	1.56	12.68	-4.98	-0.61
Range	Min.	-21.08	-8	-14.31	-13.5	-85.29	-70	-21.71	-23.08	-31.96	-19.02	-8.19	-12.25
	Max.	14.01	2.29	20.2	23.96	209.09	240	25.62	11.11	33.77	48.41	15.67	10.17
No. of significant crosses	Positive	16	0	4	10	7	18	3	0	5	13	2	1
	Negative	3	7	3	0	17	6	1	2	3	1	0	0
	Total Crosses	19	7	7	10	24	24	4	2	8	14	2	0

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively

Table 3: Continue...

Sr. No	Genotype	Seed Index (g)		Seed cotton yield per plant (g)		Ginning outturn (%)		Fibre strength (g/tex)		Fibre length (mm)		Fibre fineness (mv)	
		Heterosis over		Heterosis over		Heterosis over		Heterosis over		Heterosis over		Heterosis over	
		BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
1	G.Cot.10×GISV-382	-5.77	-5.77	-1.31	-8.49	3.43	8.77**	-6.44**	-8.61**	-8.65**	-5.78*	0	47.06**
2	G.Cot.10×GISV-385	1.92	1.92	4.33	-3.99	8.18*	7.84*	-3.77	-7.17**	1.08	-5.65*	-10*	32.35**
3	G.Cot.10×GISV-389	-5.45	0	-4.81	-3.99	0.2	2.79	-7.33**	-1.1	-7.25**	-3.52	4	52.94**
4	G.Cot.10×GISV-395	-1.92	-1.92	-8.19	-8.67	-3.45	9.6**	-4.38	-6.06**	-6.46**	-7.29**	10*	61.76**
5	G.Cot.10×GISV-399	-1.92	-1.92	-1.84	1.56	2.05	13.11**	-0.59	-7.5**	4.56	-4.9*	-13.07**	30.39**
6	G.Cot.10×GISV-318	0	0	-2.69	-12.13	-0.58	6.6*	-1.43	-4.58*	-2.05	-4.15	-4	41.18**
7	G.Cot.10×GISV-340	0	0	1.15	-8.67	1.33	2.17	-3.44	-10.14**	-3.97	-8.92**	16.67**	71.57**
8	BC 68-2×GISV -382	-5.56	-1.92	1.56	1.56	2.55	7.84*	-4.11	-4.74*	-4.27*	1.38	2	50**
9	BC 68-2×GISV -385	-7.41	-3.85	1.21	1.21	2.48	2.17	-4.33	-4.96*	-3.2	2.51	-2.17	32.35**
10	BC 68-2×GISV -389	-1.82	3.85	0.86	1.73	2.31	4.95	-6.54**	-0.26	-0.95	4.9*	-2	44.12**
11	BC 68-2×GISV -395	-1.85	1.92	4.16	4.16	-1.91	11.35**	5.88*	5.18*	1.07	7.04**	-6	38.24**
12	BC 68-2×GISV -399	-3.7	0	12.9	16.81*	-2.51	8.05*	0.89	0.22	-2.14	3.64	-11.76*	32.35**
13	BC 68-2×GISV -318	-5.56	-1.92	2.43	2.43	-1.54	5.57	-0.33	-0.99	1.19	7.16**	6.52	44.12**
14	BC 68-2×GISV -340	0	3.85	-0.69	-0.69	5.42	6.3	-4.44	-5.07*	-2.37	3.39	0	41.18**
15	76-IH-20×GISV -382	3.85	3.85	24.63**	15.77*	-1.36	4.85	-2.82	-5.07*	-0.37	2.76	-14**	26.47**
16	76-IH-20×GISV -385	7.69	7.69	12.13	4.16	2.14	8.57**	-3.31	-6.73**	-3.33	-1.51	-8.51	26.47**
17	76-IH-20×GISV -389	-7.27	-1.92	-2.75	-1.91	-0.68	5.57	-6.51**	-0.22	0.36	4.4*	-10*	32.35**
18	76-IH-20×GISV -395	0	0	10.45	9.88	-5.18	7.64*	-0.67	-2.43	1.36	3.27	-10.67*	31.37**
19	76-IH-20×GISV -399	-1.92	-1.92	8.54	12.31	-0.93	9.8**	3.28	-9.7**	-7.15**	-5.4*	-21.57**	17.65*
20	76-IH-20×GISV -318	-1.92	-1.92	3.36	-3.99	2.5	9.91**	-3.99	-7.06**	-0.12	1.76	0	38.24**
21	76-IH-20×GISV -340	0	0	-5.78	-12.48	4.66	11.25**	-0.24	-10.03**	-7.64**	-5.9**	-10.42*	26.47**
22	GSHV-112×GISV -382	0	-1.92	-4.32	-0.17	5.66	13.73**	-5.43*	-5.95*	-7.57**	-1.88	-10*	32.35**
23	GSHV-112×GISV -385	1.96	0	-8.14	-4.16	2.88	10.73**	-1.88	-2.43	-5.92**	-0.13	4.76	29.41**
24	GSHV-112×GISV -389	-5.45	0	-7.64	-3.64	1.53	9.29**	-10.12**	-4.08	-9.47**	-3.89	16.67**	71.57**
25	GSHV-112×GISV -395	-5.77	-5.77	-2.66	1.56	5	19.2**	-10.53**	-11.03**	-9.47**	-3.89	-2	44.12**
26	GSHV-112×GISV -399	-3.92	-5.77	4.49	9.01	2.05	13.11**	-8.2**	-8.71**	-6.39**	-0.63	4.58	56.86**
27	GSHV-112×GISV -318	0	-1.92	-6.48	-2.43	6.62*	14.76**	-2.66	-3.2	-3.08	2.89	13.33*	50**
28	GSHV-112×GISV -340	5.88	3.85	-4.98	-0.87	4.12	12.07**	-7.21**	-7.72**	-11.01**	-5.53*	13.19*	59.8**
Range	Min.	-7.41	-5.77	-8.19	-12.48	-5.18	2.17	-10.53	-11.03	-11.01	-8.92	-21.57	17.65

	Max.	7.69	7.69	24.63	16.81	8.18	19.2	5.88	5.18	4.56	7.16	16.67	71.57
No. of significant crosses	Positive	0	0	1	2	2	20	1	1	0	4	5	28
	Negative	0	0	0	0	0	0	9	18	12	8	9	0
	Total Crosses	0	0	1	2	2	20	10	19	12	12	14	28

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively

Table 3: Continue...

Sr. No	Genotype	Seed oil content (%)		Leaf gossypol content (%)		Seed protein content (%)		Phenol content (mg/g)	
		Heterosis over		Heterosis over		Heterosis over		Heterosis over	
		BP	SC	BP	SC	BP	SC	BP	SC
1	G.Cot.10×GISV-382	-25.5**	2.02	48.65**	-16.95**	-10.59**	-32.79**	30.4**	3.52
2	G.Cot.10×GISV-385	-5.35	19.2**	38.16**	-16.11**	12.89**	2.71	17.95**	11.47**
3	G.Cot.10×GISV-389	8.46**	46.69**	7.06	-28.35**	8.03*	-4.84	18.96**	12.42**
4	G.Cot.10×GISV-395	42.45**	43.82**	77.77**	18.97**	75.72**	5.42	-21.69**	-25.99**
5	G.Cot.10×GISV-399	8.04**	29.59**	37.37**	-8.06*	46.92**	6.88*	-0.37	-13.83**
6	G.Cot.10×GISV-318	4.32	31.38**	115.03**	43.91**	26.28**	-8.17**	33.13**	3.24
7	G.Cot.10×GISV-340	-0.91	26.66**	57.57**	5.45	-3.15	4.17	-15.82**	-24.39**
8	BC 68-2×GISV -382	-41.12**	-19.37**	9.38	-38.89**	26.01**	-5.27	23.46**	-1.99
9	BC 68-2×GISV -385	-26.6**	-7.55*	81.45**	10.17**	-5.67	-14.18**	-14.64**	3.86
10	BC 68-2×GISV -389	-29.19**	-4.22	38.83**	20.79**	7.16*	-5.6*	3.55	26**
11	BC 68-2×GISV -395	23.27**	33.62**	19.64**	17.71**	20.84**	-13.86**	7.4**	29.1**
12	BC 68-2×GISV -399	-21.87**	-6.28	70.97**	44.23**	43.49**	4.39	42.65**	23.37**
13	BC 68-2×GISV -318	0.85	27.01**	43.39**	33.54**	36.12**	-1.01	81.87**	41.03**
14	BC 68-2×GISV -340	7.35*	37.22**	-27.75**	-28.92**	-32.39**	-27.28**	58.56**	42.42**
15	76-IH-20×GISV -382	-1.32	35.14**	-3.57	-50.15**	37**	2.99	77.87**	41.21**
16	76-IH-20×GISV -385	-0.72	25.03**	140.33**	24.24**	11.02**	1.01	-28.36**	1
17	76-IH-20×GISV -389	-28.11**	-2.77	80.49**	-6.69*	-9.1**	-19.92**	14.34**	43.39**
18	76-IH-20×GISV -395	19.25**	27.44**	130.18**	19**	90.89**	7.43**	18.85**	42.86**
19	76-IH-20×GISV -399	-14.33**	2.76	145.37**	26.85**	42.29**	3.52	72.54**	49.22**
20	76-IH-20×GISV -318	-21.54**	-1.18	130.39**	19.11**	44.78**	5.28	88.05**	45.82**
21	76-IH-20×GISV -340	9.45**	39.9**	52.77**	-21.02**	-17.18**	-10.92**	-13.54**	-22.34**
22	GSHV-112×GISV -382	-4.84	30.33**	217.42**	77.34**	2.15	3.43	27.83**	1.48
23	GSHV-112×GISV -385	11.76**	40.74**	102.08**	22.7**	-47.09**	-46.43**	-13.72**	16.98**
24	GSHV-112×GISV -389	-18.2**	10.63**	12.15**	-2.42	-2.12	-0.9	0.13	25.58**
25	GSHV-112×GISV -395	9.22*	8.13*	-4.13	3.49	-28.56**	-27.67**	-11.57**	6.29**
26	GSHV-112×GISV -399	8.66**	30.33**	-16.87**	-29.87**	1.98	3.25	23.94**	7.19**
27	GSHV-112×GISV -318	8.74**	36.95**	2.79	-4.27	-25.84**	-24.91**	80.47**	39.94**
28	GSHV-112×GISV -340	2.1	30.5**	-43.1**	-42.58**	-39.1**	-34.5**	-8.84**	-18.11**
Range	Min.	-41.12	-19.37	-43.1	-50.15	-47.09	-46.43	-28.36	-25.99
	Max.	42.45	46.69	217.42	77.34	90.89	7.43	88.05	49.22
No. of significant crosses	Positive	11	20	20	13	15	2	17	17
	Negative	9	2	3	11	8	12	8	5
	Total Crosses	20	22	23	24	23	14	25	22

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively

1. Fibre strength (g tex⁻¹)

Fibre strength, a polygenically controlled and environmentally influenced trait, showed limited expression of heterosis. Heterobeltiosis ranged from -10.53% to 5.88%, with only one hybrid (BC 68-2 × GISV-395) exhibiting significant positive heterobeltiosis. Standard heterosis varied from -11.03% to 5.18%, and again only one hybrid showed significant positive heterosis in the desirable direction. These findings are consistent with earlier reports indicating low heterotic response for fibre strength (Murthy *et al.*, 2017;^[10] Pavitra *et al.*, 2019;^[11] Vaghela *et al.*, 2022;^[26] Vaid *et al.*, 2022a;^[13] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

2. Fibre length (mm)

Fibre length, one of the most critical fibre quality traits, exhibited no significant heterobeltiosis, with values ranging from -11.01% to 4.56%. Standard heterosis ranged from -8.92% to 7.16%, and a few hybrids expressed moderate positive standard heterosis, with the highest recorded in BC 68-2 × GISV-318 (7.16%), followed by BC 68-2 × GISV-395 (7.04%), BC 68-2 × GISV-389 (4.90%) and 76-IH-20 × GISV-

389 (4.40%). Similar trends of limited heterosis for fibre length have been reported earlier (Murthy *et al.*, 2017;^[10] Pavitra *et al.*, 2019;^[11] Vaghela *et al.*, 2022;^[26] Vaid *et al.*, 2022a;^[13] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

3. Fibre fineness (micronaire value)

Fibre fineness, expressed as micronaire value, showed heterobeltiosis ranging from -21.50% to 16.67%, with the highest desirable negative heterobeltiosis observed in 76-IH-20 × GISV-399 (-21.50%). Standard heterosis varied widely from 17.65% to 71.57%; however, none of the hybrids exhibited significant negative standard heterosis within the desirable micronaire range. These results align with previous reports indicating limited scope for improving fibre fineness through heterosis breeding (Murthy *et al.*, 2017;^[10] Thiyagu *et al.*, 2019; Vaghela *et al.*, 2022;^[26] Vaid *et al.*, 2022a;^[13] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

4. Seed oil content (%)

Cotton seed oil is an important by-product contributing to the dual utility of cotton as a fibre and oilseed crop. Heterobeltiosis

for seed oil content ranged from -41.12% to 42.45%, with eleven hybrids exhibiting significant positive heterobeltiosis. The highest values were recorded in G.Cot.10 × GISV-395 (42.45%), BC 68-2 × GISV-395 (23.27%) and 76-IH-20 × GISV-395 (19.25%). Standard heterosis varied from -19.37% to 46.69%, and twenty hybrids showed significant positive heterosis, with G.Cot.10 × GISV-389 (46.69%), G.Cot.10 × GISV-395 (43.82%) and GSHV-112 × GISV-385 (40.74%) being superior. These results are in agreement with earlier reports (Vekariya *et al.*, 2017;^[27] Vaghela *et al.*, 2022;^[26] Vaid *et al.*, 2022b;^[25] Parmar *et al.*, 2023)^[14].

5. Leaf gossypol content (%)

Gossypol, a phenolic compound conferring insect resistance, showed wide variation among hybrids. Heterobeltiosis ranged from -43.10% to 217.42%, with twenty hybrids exhibiting significant positive heterobeltiosis. Standard heterosis ranged from -50.15% to 77.34%, and thirteen hybrids showed significant positive heterosis over the standard check. The most desirable standard heterosis was observed in GSHV-112 × GISV-382 (77.34%), followed by BC 68-2 × GISV-399 (44.23%) and G.Cot.10 × GISV-318 (43.91%). Similar trends have been reported earlier (Vekariya *et al.*, 2017;^[27] Vaghela *et al.*, 2022;^[26] Vaid *et al.*, 2022a;^[13] Parmar *et al.*, 2023)^[14].

6. Seed protein content (%)

Seed protein content, an emerging trait of nutritional importance, exhibited heterobeltiosis ranging from -47.09% to 90.89%, with fifteen hybrids showing significant positive heterobeltiosis. The highest heterobeltiosis was recorded in 76-IH-20 × GISV-395 (90.89%), followed by G.Cot.10 × GISV-399 (46.92%) and 76-IH-20 × GISV-318 (44.78%). Standard heterosis ranged from -46.43% to 7.43%, with only two hybrids expressing significant positive heterosis, namely 76-IH-20 × GISV-395 (7.43%) and G.Cot.10 × GISV-399 (6.88%). These observations are in accordance with earlier findings (Vekariya *et al.*, 2017;^[27] Vaid *et al.*, 2022a;^[13] Parmar *et al.*, 2023;^[14] Deshmukh *et al.*, 2024;^[15] Sharma *et al.*, 2025)^[16].

7. Phenol content (mg g⁻¹)

Phenol content, associated with plant defense mechanisms, showed heterobeltiosis ranging from -28.36% to 88.05%, with seventeen hybrids exhibiting significant positive heterobeltiosis. Standard heterosis also showed significant positive effects in seventeen hybrids, ranging from -25.99% to 49.22%. These results support earlier reports highlighting heterotic expression for phenol content in cotton (Vaghela *et al.*, 2022;^[26] Parmar *et al.*, 2023)^[14].

Conclusion

A line × tester analysis was conducted in upland cotton to assess heterosis, combining ability, and gene action for seed cotton yield, yield components, fibre quality, and biochemical traits. Significant genetic variability was observed among parents and hybrids for most characters, validating the suitability of the experimental material. Several parents showed superior per se performance for specific traits, while no single hybrid was superior for all traits. The hybrid BC 68-2 × GISV-399 recorded the highest seed cotton yield and boll weight, whereas BC 68-2 × GISV-399 and 76-IH-20 × GISV-399 expressed significant positive standard heterosis for yield over the commercial check. High-yielding hybrids also exhibited favourable heterosis for key yield-contributing traits. Combining ability analysis revealed significant GCA and SCA variances,^[16] indicating the

involvement of both additive and non-additive gene actions, with predominance of non-additive effects for most traits. Hybrids showing high heterosis generally involved at least one good general combiner. The results suggest that heterosis breeding is an effective strategy for improving seed cotton yield and associated traits in cotton and provide valuable parental combinations for future breeding programmes

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