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RESEARCH PAPER

Heterosis studies for yield, yield attributes and fibre properties in new hybrids of upland cotton (*Gossypium hirsutum* L.)

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Abstract: A full diallel analysis was undertaken to estimate the magnitude of heterosis in 90 hybrids of cotton (*Gossypium hirsutum* L.) for yield, yield attributes and fibre properties in 103 entries including 10 parents and 3 standard check hybrids (DHH-11, DHH-263 and Ajeet-155 Bt.) at the Agricultual Research Station, Dharwad Farm during *Kharif,* 2020-21. The analysis of variance revealed significant differences among the genotypes for all characters. The mean sum of squares for parents was significant for all the traits except for number of bolls per plant. This study revealed that 32 crosses showed positive significant heterobeltiosis. The best cross GBHV-200 × CPD-1652 showed significant heterosis over all the 3 checks. Four hybrids manifested significant and positive standard heterosis over DHH-11 for seed cotton yield *i.e.* GBHV-200 × CPD-1652 (63.37 %), CPD-1652 × ESS-5 (32.18 %), ESS-12 × GJHV-554 (29.51 %) and GJHV-554 × GBHV-200 (28.51 %).Two most potential hybrids, GBHV-200 × CPD-1652 and CPD-1652 × ESS-5 were identified which exhibited high seed cotton yield, number of bolls per plant, boll weight and number of sympodia and even had significant positive heterosis over the popular Bt. hybrid Ajeet-155 Bt. The two hybrids also had superior fibre qualities with better fibre length and strength than the best fibre check DHH-11.

Key words: Cotton, Diallel, Heterobeltiosis, Heterosis

Introduction

Cotton, the seed-hair fibre crop, popularly known as “White Gold” and the king of natural fibers is one of the leading agricultural crops in the world. It is the primary fibre yielding cash crop cultivated across continents. The word “cotton” is derived from the Arabic word “qutun” meaning fine textile. It has unique spinnable cellulosic textile fibre with 95 per cent cellulose. Cotton has been grown for fibre, food and even fuel for over 6,000 years. The benefits and versatility of cotton are numerous. Cotton provides raw material for various agro based industries like ginning factories, oil mills, textile industries, which provide employment to millions of individuals. Taxonomically, cotton belongs to Malvaceae family and is comprised of four domesticated and cultivated species *viz., Gossypium arboreum*, *Gossypium herbaceum, Gossypium hirsutum* and *Gossypium barbadense. Gossypium arboreum* and *Gossypium herbaceum* are old world cotton and are diploid (2n=26). The New world cotton, *i.e*., *Gossypium hirsutum* and *Gossypium barbadense* are tetraploid (2n=52). The principal species of cultivated cotton, *Gossypium hirsutum* alone contributes around 90 per cent to the total global production. Commercial cultivation of all the 4 cultivated species of cotton takes place only in India. Cotton being an often cross pollinated crop having 5 to 25 per cent cross pollination, is one of the few crops which is amenable to commercial exploitation of heterosis as well as development of varieties.

Heterosis is a well-known phenomenon where F_1 of genetically distant parents show superiority over mid-parent (relative heterosis), better parent (heterobeltiosis) and commercial check (economic or standard heterosis). The exploitation of hybrid vigour has been recognized as a practical tool in providing the breeders a means of increasing yield through an increase of its component traits. Hybrid cotton generally gives higher yield than straight varieties. Although India stands first in area and production of cotton, it has low productivity (487 kg ha^{-1}). The present yield plateau in cotton productivity can be breached by developing superior high yielding hybrids with large values of economic heterosis for which genetically diverse parents with good combining ability must be considered. Griffing’s (1956) Diallel analysis, Method-I, Model - I essentially involves F_1s, reciprocals and their parents. The present study employs a full diallel set to identify the best heterotic crosses for seed cotton yield and other traits among the 90 upland cotton hybrids developed by crossing 10 parents in all possible combinations.

Material and methods

The experiment was carried out at the Agricultural Research Station, Dharwad Farm, which is located in the northern transition zone (Zone-8) of Karnataka during *kharif* 2020. The genetic material was developed through diallel mating among ten genotypes GJHV-554, BS-4-18, RAH-1075, NDLH-2035-5, GBHV-200, GSHV-191, CPD-1652, TSH-325, ESS-5 and ESS-12, which were of diverse origin and were crossed among themselves to produce a full diallel set of 90 intra hirsutum hybrids. The 10 parents and their 90 F_{1s} along with 3 checks were cultivated in row plots having 4.2 m length in a randomized complete block design (RCBD) with 2 replications during *kharif* 2020-21. Observations were recorded on 5 randomly selected plants on plant height (cm), number of nodes on main stem, number of sympodia per plant, number of monopodia per plant, number of bolls per plant, boll weight (g), seed index (g), seed cotton yield (kg/ha), ginning outturn (%), lint index (g) and fibre properties such as fibre length (mm), fibre strength (g/tex) and micronaire (µg/inch) using HVI (High volume instrument). The mean value of five random plants in the derived F_1s and parental lines was employed in statistical analyses for all traits. A RCBD analysis was conducted to evaluate the differences within the set of genotypes used in the study. Then, the data on parents and crosses involved in the diallel mating design were analysed by partitioning the variability into that due to parents, crosses and parents *vs* crosses.

Heterosis was assessed to compare all the derived F_1s obtained from the crosses with their parental lines and checks as per standard method. The heterotic effects were estimated for all the traits. The heterotic effects were measured as deviation of F_1 mean from mid-parent (relative heterosis), better parent (heterobeltiosis) and the standard check (standard heterosis) mean, according to the formula given by Turner (1953) and Hayes *et al*. (1955). Released hybrids DHH-11, DHH-263 and popular Bt. hybrid Ajeet-155 Bt. were considered for calculating standard heterosis for all the characters.

Replicated data obtained from the study was used for heterosis estimation using WINDOSTAT software and MS-Excel programme.

Results and discussion

The data collected from the experimental material was subjected to analysis of variance and results obtained are presented in Table 1. It was revealed from the analysis of variance that there were significant differences among the parental genotypes for ten characters. The mean sum of squares for parents was significant for all the traits except for number of bolls per plant. Parents and hybrids were found to be differing significantly for all traits except for plant height, number of sympodia per plant and number of nodes on main stem per plant. The mean sum of squares with respect to hybrids was found to be significant for all the traits studied. This revealed the presence of considerable differences and variation among the hybrids

The magnitude of variation among the mean values of seed cotton yield of the hybrids ranged from 760.72 kg/ha (TSH-325 × RAH-1075) to 1964.29 kg/ha (GBHV-200 × CPD-1652). For plant height, the magnitude of variation among the hybrids for mean performance was from 56.50 cm (BS-4-18 × NDLH-2035-5) to 119.10 cm (GJHV-554 × GSHV-191). As far as number of monopodia per plant is concerned, it ranged from 0.70 (BS-4-18 × NDLH-2035-5) to 3.00 (RAH-1075 × GJHV-554). The lowest value for the trait, number of sympodia per plant was recorded in the cross BS-4-18 × NDLH-2035-5 (10.00) and the highest in GJHV-554 × GSHV-191 (21.70). The variation of the mean values among crosses ranged from 10.70 (BS-4-18 × NDLH-2035-5) to 24.00 (GJHV-554 × ESS-5) for number of nodes on the main stem per plant. For number of bolls per plant the mean values of the hybrids ranged from 6.90 (CPD-1652 × TSH-325) to 17.30 (GBHV-200 × GSHV-191). The cross RAH-1075 × GJHV-554 showed the lowest boll weight of 3.70 g while the cross, ESS-5 × GSHV-191 exhibited the highest boll weight of 5.14 g. The seed index values among crosses ranged from 7.83 g (GJHV-554 × ESS-12) to 11.21 g (BS-4-18 × GSHV-191). The least ginning outturn, among hybrids, was exhibited by GSHV-191 × BS-4-18 (34.36 %) while the maximum ginning outturn was shown by the cross ESS-5 × ESS-12 (40.92 %). Coming to lint index, among the hybrids, the mean values ranged from 4.78 g (GJHV-554 × ESS-12) to 6.99 g (CPD-1652 × ESS-5). Among the crosses, mean values of fibre length ranged from 23.40 mm (CPD-1652 × NDLH-2035-5) to 31.70 mm (NDLH-2035-5 × ESS-12). As far as fibre strength is concerned, the mean of cross combinations ranged from 23.00 g/tex (CPD-1652 × NDLH-2035-5) to 30.50 g/tex (RAH-1075 × ESS-5). For micronaire, the lowest and the highest values were found to be 4.08 µg/inch (BS-4-18 × ESS-12) and 5.00 µg/inch (TSH-325 × GJHV-554), respectively. The range of heterosis for various traits is furnished in Table 2.

The range of heterosis over better parent for seed cotton yield varied from -34.13 (GJHV-554 × GSHV-191) to 132.36 (RAH-1075 × CPD-1652) per cent. In case of better parent heterosis, 32 crosses showed significance in positive direction. For seed cotton yield, most important aspect of cotton breeding, one hybrid GBHV-200 × CPD-1652 exhibited significant heterotic values over all the 3 check hybrids, whereas 2 most promising hybrid combinations *i.e.* GBHV-200 × CPD-1652 and CPD-1652 × ESS-5 showed significant heterosis over the Bt check hybrid

Table 1. Analysis of variance for yield and yield component characters in cotton (*G. hirsutum* L.)

Sources of variation	df	Plant height (cm)	Number monopodia sympodia	Number of nodes	Number of on main stem	Number of bolls	Boll weight (g)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Seed cotton yield (kg ha^{-1})
Replications	1	152.78	3.21**	0.34	91.66**	1.25	0.008	0.00045	159.60**	9.71**	5241.13
Treatments	99	258.63**	0.53**	11.02**	12.53**	13.27**	0.20**	0.98**	4.91**	0.43**	115259.37**
Parents	9	320.17**	0.49**	12.65**	11.63*	3.06	0.15*	0.97**	7.82**	0.44**	140690.56**
Hybrids	89	254.07**	0.49**	10.86**	12.60**	7.73**	0.17**	0.99**	4.54**	0.42**	84415.12**
Parents *vs* Hybrids	1	110.51	4.86**	10.98	13.69	598.58**	3.63**	0.44**	11.61**	1.42**	2631517.05**
F_1s	44	200.81*	0.55**	6.87**	9.12*	7.36**	0.17**	0.77**	4.65*	0.33**	75757.03**
Reciprocals	44	313.11**	0.41**	14.78**	15.64**	7.45**	0.17**	1.22**	4.36**	0.48**	94374.05**
F_1 *vs* Reciprocals	1	0.26	1.26**	13.45*	32.43*	35.91**	0.40**	0.75**	7.79**	1.47**	27178.60**
Error	99	113.73	0.06**	3.31	5.72	1.84	0.07	0.06	2.03	0.16	28759.57
CV		11.22	17.00	10.78	12.72	13.13	5.82	2.59	3.80	6.90	14.63

Table 2. Range of heterosis for yield, yield attributes and fibre properties in cotton (*G. hirsutum* L.)

Trait	Heterosis range (%) over				
	Mid parent	Better parent	DHH-11	DHH-263	Ajeet-155 Bt.
Plant height	-45.23 to 38.1	-46.19 to 27.24	-43.33 to 20.36	-40.08 to 26.3	-39.31 to 27.93
Number of monopodia per plant	-24.14 to 233.33	-52.94 to 212.5	-22.22 to 233.33	-30 to 200	0 to 328.57
Number of sympodiaper plant	-45.5 to 75.41	-47.09 to 47.59	-31.97 to 47.62	-35.9 to 39.1	-27.54 to 57.25
Number of nodes on main stem/plant	-44.85 to 69.01	-48.06 to 48.15	-31.41 to 53.85	-40.88 to 32.6	-35.15 to 45.45
Number of bolls per plant	22.67 to 254.55	5.56 to 239.22	-38.94 to 53.1	-37.27 to 57.27	-38.39 to 54.46
Boll weight	-3.7 to 30.41	-9.33 to 20.99	-18.05 to 13.73	-19.57 to 11.63	-24.72 to 9.87
Seed cotton yield	-19.24 to 155.81	-34.13 to 132.36	-36.73 to 63.37	-48.01 to 34.26	-37.84 to 60.51
Ginning outturn	-5.84 to 11.37	-8.83 to 7.84	-16.37 to 3.88	-10.25 to 6.88	-7.44 to 10.23
Seed index	-12.36 to 13.59	-19.74 to 10.7	2.15 to 46.34	-12.32 to 25.6	-14.99 to 21.78
Lint index	-12.76 to 24.67	-15.46 to 18.88	-10.49 to 30.9	-13.72 to 26.17	-12.08 to 28.58
Upper Half Mean Length (UHML)	-25.60 to 3.76	-25.71 to 1.69	-16.73 to 12.81	-11.70 to 19.62	-12.69 to 18.28
Fibre strength/Tenacity	-24.22 to 5.17	-25.57 to 4.10	-15.44 to 12.13	-12.88 to 15.53	-11.88 to 16.86
Micronaire	-10.64 to 12.94	-12.50 to 6.52	-2.44 to 21.95	-18.37 to 2.04	0.00 to 25.00

Ajeet-155 Bt. Four crosses, GBHV-200 × CPD-1652, CPD-1652 × ESS-5, ESS-12 × GJHV-554 andGJHV-554 × GBHV-200 showed positive significant heterosis over check DHH-11. Similar reports of superior standard heterosis were made by Naik *et al.* (2020), Pavitra *et al.* (2019), Udaya *et al.* (2020) and Islam *et al.* (2021).

For plant height, the per cent range of heterosis over check DHH-11 varied from -43.33 (BS-4-18 × NDLH-2035-5) to 19.46 (GJHV-554 × GSHV-191). BS-4-18 × NDLH-2035-5 and BS-4-18 × RAH-1075 exhibited negative significant heterosis over mid parent, better parent and all the 3 checks *viz.,* DHH-11, DHH-263 and Ajeet-155 Bt. However, the cross GJHV-554 × GSHV-191 exhibited the highest significant positive heterosis over mid parent and the checks, DHH-263 and Ajeet-155 Bt. Many workers like Pavitra *et al.* (2019), Vavdiya *et al.* (2019), Naik *et al.* (2020), Udaya *et al.* (2020) and Islam *et al.* (2021) have reported both positive and negative heterosis values for plant height.

In case of number of monopodia per plant, seventy-five crosses showed significance over check Ajeet-155 Bt. The range of per cent heterosis over check Ajeet-155 Bt varied from 0.00 (BS-4-18 × NDLH-2035-5 and ESS-5 × BS-4-18) to 328.57 (RAH-1075 × GJHV-554) with none of the crosses showing significant negative heterosis. BS-4-18 × NDLH-2035-5 and ESS-5 × BS-4-18 showed negative heterosis over checks DHH-11, DHH-263 and Ajeet-155 Bt, respectively. However, none of these were significant. ESS-12 × BS-4-18 and 9 other crosses displayed significant negative heterobeltiosis. Results showing similar observations were shown by researchers like Vavdiya *et al.* (2019) and Islam *et al.* (2021). Contrastingly, high number of monopodial branches was reported by Monicashree *et al.* (2017).

In case of heterosis over better parent for number of sympodia per plant, the magnitude of heterosis varied from -47.09 (BS-4-18 × NDLH-2035-5) to 47.59 (GJHV-554 × ESS-5) per cent. Out of 12 significant better parent heterotic crosses, 4 crosses showed positive significance. Supporting evidences with similar results were shown by Memon *et al.* (2017), Monicashree *et al.* (2017) and Islam *et al.* (2021). The cross GJHV-554 × GSHV-191 exhibited significant maximum positive standard heterosis over all the 3 checks. Heterosis over best check DHH-263 for number of sympodia per plant ranged from -35.90 (BS-4-18 × NDLH-2035-5) to 39.10 (GJHV-554 × GSHV-191) per cent. Among 90 crosses, 23, 18 and 38 crosses showed significant positive heterosis over checks DHH-11, DHH-263 and Ajeet-155 Bt., respectively. This was in agreement with Monicashree *et al.* (2017), Bilwal *et al.* (2018) and Vavdiya *et al.* (2019).

The number of nodes on the main stem also has a role in plant type and architecture. It can be associated with plant height and the type of branches arising from these nodes. In case of this trait, the standard heterosis ranged from -31.41 to 53.85 per cent, -40.88 to 32.60 per cent and -35.15 to 45.45 per cent over checks DHH-11, DHH-263 and Ajeet-155 Bt, respectively. Overall, among the three checks, the highest significant positive heterosis was observed in the cross GJHV-554 × ESS-5 and the lowest significant negative heterosis was recorded in the cross BS-4-18 × NDLH-2035-5. Recent reports on heterosis for number of nodes on main stem were not available.

For number of bolls per plant, a total of 73 crosses showed positive heterosis over better parent. The range varied from 5.56 (BS-4-18 × TSH-325) to 239.22 (GBHV-200 × NDLH-2035-5) per cent. Positive heterosis over better parent was also shown by Chaudhary *et al.*(2019) and Islam *et al.* (2021) for this trait. The standard heterosis range over check DHH-11, DHH-263 and Ajeet-155 Bt, was from -38.94 to 53.10, -37.27 to 57.27 and -38.39 to 54.46 per cent, respectively. Five crosses showed significant positive heterosis over all the 3 checks. These results confirmed the results of Bilwal *et al.* (2018) and Reddy *et al.* (2017).

In case of boll weight, a total of 19 crosses had significant better parent heterosis and all were in the positive direction. The range of heterosis over better parent varied from -9.33 (GSHV-191 × ESS-12) to 20.99 (GJHV-554 × GBHV-200) per cent. Cross ESS-5 × GSHV-191 had significant positive heterosis over checks DHH-11, DHH-263 and Ajeet-155 Bt. These results were supported by studies by Monicashree *et al.* (2017), Reddy *et al.* (2017), Bilwal *et al.*(2018), Naik *et al.*(2020) and Rani *et al.*(2020).

For seed index, 41 crosses exhibited significant heterobeltiosis. The range of heterobeltiosis was between -19.74

Table 3. Top three desirable hybrids with mean performance and heterosis across traits in cotton (*G. hirsutum* L.)

Character	Desirable hybrid	Mean	Heterosis				
			H_{mp} (%)	H_{bp}(%)	Standard heterosis (%) over		
					DHH-11	DHH-263	Ajeet-155 Bt.
Plant height (cm)	GJHV-554 × GSHV-191	119.10	27.31 **	27.24 *	19.46	26.30 *	27.93 *
	TSH-325 × GJHV-554	118.70	15.30	5.70	19.06	25.87 *	27.50 *
	ESS-5 × RAH-1075	112.00	38.10 **	15.46	12.34	18.77	20.3
Number of monopodia per plant	BS-4-18 × NDLH-2035-5	0.70	27.27	0.00	-22.22	-30	0
	ESS-5 × BS-4-18	0.70	16.67	-12.5	-22.22	-30	0
	GBHV-200 × BS-4-18	0.80	45.45	14.29	-11.11	-20	14.29
Number of sympodia per plant	GJHV-554 × GSHV-191	21.70	39.55 **	30.72 **	47.62 **	39.10 **	57.25 **
	GJHV-554 × ESS-5	21.40	75.41 **	47.59 **	45.58 **	37.18 **	55.07 **
	ESS-5 × TSH-325	20.90	53.68 **	20.81	42.18 **	33.97 **	51.45 **
Number of nodes on main stem per plant	GJHV-554 × ESS-5	24.00	69.01 **	48.15 **	53.85 **	32.60 *	45.45 **
	GJHV-554 × GSHV-191	23.40	38.05 **	32.20 *	50.00 **	29.28 *	41.82 **
	BS-4-18 × GSHV-191	23.30	29.81 *	28.02 *	49.36 **	28.73 *	41.21 **
Number of bolls per plant	GBHV-200 × NDLH-2035-5	17.30	249.50 **	239.22 **	53.10 **	57.27 **	54.46 **
	GBHV-200 × CPD-1652	15.60	254.55 **	225.00 **	38.05 **	41.82 **	39.29 **
	ESS-12 × NDLH-2035-5	15.50	176.79 **	154.10 **	37.17 **	40.91 **	38.39 **
Boll weight (g)	ESS-5 × GSHV-191	5.14	21.25 **	15.39 **	13.73 *	11.63 *	4.48
	GSHV-191 × ESS-5	4.98	17.59 **	11.91 *	10.30	8.26	1.32
	CPD-1652 × ESS-5	4.97	21.10 **	18.78 **	9.97	7.93	1.02
Seed index (g)	BS-4-18 × GSHV-191	11.21	9.05 **	8.00 **	46.34 **	25.60 **	21.78 **
	GSHV-191 × BS-4-18	11.18	8.75 **	7.71 **	45.95 **	25.27 **	21.46 **
	BS-4-18 × TSH-325	11.10	12.89 **	9.04 **	44.91 **	24.37 **	20.59 **
Ginning outturn (%)	ESS-5 × ESS-12	40.92	5.04	2.8	-0.4	6.88	10.23 **
	ESS-5 × TSH-325	40.52	7.81 *	6.32	-1.38	5.84	9.15 *
	BS-4-18 × GBHV-200	40.30	11.37 **	7.84 *	-1.91	5.26	8.56 *
Lint index (g)	CPD-1652 × ESS-5	6.99	19.39 **	18.07 **	30.90 **	26.17 **	28.58 **
	ESS-5 × GSHV-191	6.59	19.08 **	13.73	23.31 **	18.86 **	21.13 **
	RAH-1075 × CPD-1652	6.57	13.91 *	10.98	23.03 **	18.59 *	20.85 **
Seed cotton yield (kg/ha)	GBHV-200 × CPD-1652	1964.29	155.81 **	113.18 **	63.37 **	34.26 **	60.51 **
	CPD-1652 × ESS-5	1589.29	134.62 **	114.63 **	32.18 *	8.62	29.86 *
	ESS-12 × GJHV-554	1557.15	56.65 **	16.27	29.51 *	6.43	27.24
UHML (mm)	NDLH-2035-5× ESS-12	31.7	3.76	0.63	12.81	19.62	18.28
	BS-4-18 × ESS-12	30.8	1.32	-1.28	9.61	16.23	14.93
	ESS-12 × CPD-1652	30.7	0.66	-2.23	9.25	15.85	14.55
Fibre strength (g/tex)	RAH-1075 × ESS-5	30.5	5.17	4.10	12.13	15.53	16.86
	RAH-1075 × TSH-325	30.1	4.33	2.73	10.66	14.02	15.33
	GSHV-191 × BS-4-18	30.0	-1.48	-2.60	10.29	13.64	14.94
Micronaire (µg/inch)	TSH-325 × GJHV-554	5.0	5.26	4.17	21.95	2.04	25.00
	CPD-1652 × RAH-1075	4.9	6.52	6.52	19.51	0.00	22.50
	CPD-1652 × TSH-325	4.9	4.26	2.08	19.51	0.00	22.50

(ESS-12 × BS-4-18) and 10.70 (CPD-1652 × ESS-5) per cent. The heterosis over standard checks DHH-11, DHH-263 and Ajeet-155 Bt. ranged from 2.15 to 46.34 per cent, -12.32 to 25.60 per cent and -14.99 to 21.78 per cent, respectively. Positive heterosis for seed index was also observed by Reddy *et al.* (2017), Monicashree *et al.* (2017), Bilwal *et al.* (2018) and Naik *et al.* (2019).

In case of ginning outturn, for heterosis over better parent, 7 crosses showed significant heterosis of which only one cross showed significance in the positive direction. The magnitude of heterosis for ginning outturn over better parent ranged from -8.83 (ESS-12 × GBHV-200) to 7.84 (BS-4-18 × GBHV-200) per cent. Maximum standard heterosis over check DHH-11, DHH-263 and Ajeet-155 Bt were -0.40 (ESS-5 × ESS-12) per cent, 6.88 per cent (ESS-5 × ESS-12) and 10.23 (ESS-5 × ESS-12) per cent, respectively. Positive standard heterosis were also exhibited by Monicashree *et al.* (2017), Bilwal *et al.* (2018) and Islam *et al.* (2021).

In case of better parent heterosis for lint index, 3 crosses showed significant positive heterosis with a range -15.46 (ESS-5 × GJHV-554) and 18.88 (NDLH-2035-5 × GSHV-191) per cent. The cross CPD-1652 × ESS-5 exhibited the highest significant positive heterosis over all three checks *viz.*, DHH-11, DHH-263 and Ajeet-155 Bt. Relative heterosis, heterobeltiosis and standard heterosis for lint index were reported previously by Monicashree *et al.* (2017), Reddy *et al.* (2017) and Vavdiya *et al.* (2019).

Fibre length showed mid parent heterosis from -25.60 (CPD-1652 × NDLH-2035-5) to 3.76 per cent (NDLH-2035-5 × ESS-12). The maximum standard heterosis over all the 3 checks was exhibited by the cross NDLH-2035-5 × ESS-12 and the minimum by CPD-1652 × NDLH-2035-5. Positive standard heterosis was observed for most of the crosses. Similar standard heterosis values for fibre length were observed by Monicashree *et al*. (2017), Pavitra *et al*. (2019) and Udaya *et al*. (2020).

Heterobeltiosis for fibre strength ranged from -25.57 (CPD-1652 × NDLH-2035-5) to 4.10 per cent (RAH-1075 × ESS-5). The cross RAH-1075 × ESS-5 was the best for fibre strength. The range of standard heterosis over DHH-11, DHH-263 and Ajeet-155 Bt varied from -15.44 (CPD-1652 × NDLH-2035-5) to 12.13 per cent (RAH-1075 × ESS-5), from -12.88 (CPD-1652 × NDLH-2035-5) to 15.53 per cent (RAH-1075 × ESS-5) and from -11.88 (CPD-1652 × NDLH-2035-5) to 16.86 per cent (RAH-1075 × ESS-5), respectively. Similar results were observed by Ekinci and Basbag (2018), Pavitra *et al*. (2019), Naik *et al*. (2020) and Udaya *et al*. (2020).

The magnitude of mid parent heterosis and better parent heterosis for micronaire ranged from -10.64 (GSHV-191 × GJHV-554) to 12.94 per cent (BS-4-18 × CPD-1652) and -12.50 (TSH-325 × NDLH-2035-5) to 6.52 (CPD-1652 × RAH-1075), respectively. The cross TSH-325 × GJHV-554 was found to have the highest heterotic value over all three checks. Most crosses had moderate micronaire values. The range of standard heterosis over best check varied from -18.37 to 2.04 per cent. High standard heterosis for micronaire was also observed by Reddy *et al*. (2017), Ekinci and Basbag (2018), Pavitra *et al*. (2019), Naik *et al*. (2020) and Udaya *et al*. (2020). Table 3 presents top 3 hybrids, their performance and heterosis for traits.

Conclusion

Among the 90 new *intra hirsutum* cotton hybrids studied, two crosses *viz.,* GBHV-200 × CPD-1652 and CPD-1652 × ESS-5 were found as best hybrids. These hybrids exhibited more number of bolls per plant, more boll weight and higher number of sympodia, all resulting in high seed cotton yield with high heterosis values. Higher magnitude of desirable heterosis was observed in traits like number of sympodia per plant, number of bolls per plant and seed cotton yield. It is notable that the top two best crosses were also significantly higher yielding than the Bt check. These crosses also possessed higher fibre length and strength than the best fibre check DHH-11. Thus, high yielding hybrids along with superior fibre quality were identified. The top 5 hybrids were all superior to the Bt check Ajeet -155 Bt in terms of fibre quality parameters.

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