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Prakashsinh Rathava
Department of Genetics and Plant Breeding, N. M. College of Agriculture, N. A. U., Navsari, Gujarat, India

SR Patel
Department of Genetics and Plant Breeding, College of Agriculture, N. A. U., Bharuch, Gujarat, India

DM Patel
Main Cotton Research station, N. A. U., Surat, Gujarat, India

HN Patel
Department of Genetics and Plant Breeding, College of Agriculture, N. A. U., Bharuch, Gujarat, India

Dinisha A
Department of Genetics and Plant Breeding, College of Agriculture, N. A. U., Bharuch, Gujarat, India

SS Patil
Department of Genetics and Plant Breeding, College of Agriculture, N. A. U., Bharuch, Gujarat, India

Correspondence
Prakashsinh Rathava
Department of Genetics and Plant Breeding, N. M. College of Agriculture, N. A. U., Navsari, Gujarat, India

Heterosis studies for seed cotton yield and other traits in tetraploid cotton (*Gossypium hirsutum* L.)

Prakashsinh Rathava, SR Patel, DM Patel, HN Patel, Dinisha A and SS Patil

Abstract
A line x tester analysis was undertaken to estimates the magnitude of heterosis in thirty-two hybrids of cotton (*Gossypium hirsutum* L.) for yield and its components characters in 45 entries including (32 hybrids along with 12 parents and 1 standard check hybrid G. Cot. Hy. 14). The analysis of variance revealed significant differences among the genotypes for all the characters. The mean squares due to genotypes were significant for all the characters except ginning percentage. Significant mean squares were observed among parents for all the characters indicate existence of sufficient variability among the parents except for ginning percentage. Studies revealed that Seven hybrids GSHV 172 x BGDS 1033 (35.11 %), GSHV 172 x CPD 1501 (23.62 %), GSHV 172 x TCH 1824 (44.96 %), GSHV 172 x Suraj (21.67 %), GSHV 172 x RAH 1069 (24.51 %), GSHV 185 x RAH 1069 (24.39 %) and GISV 310 x TCH 1716 (28.72 %) showed significant heterobeltiosis effect. Nine hybrids manifested significant and positive standard heterosis *i.e.* GSHV 172 x BGDS 1033 (29.27 %), GSHV 172 x CPD 1501 (27.83 %), GSHV 172 x TCH 1824 (30.69 %), GSHV 172 x RAH 1069 (37.64 %), GSHV 173 x TCH 1824 (19.94 %), GSHV 173 x CCH 15-1 (19.78 %), GSHV 173 x RAH 1069 (47.03 %), GSHV 185 x RAH 1069 (37.51 %) and GISV 310 x TCH 1716 (20.38 %). Where ever cross combinations involving either GSHV 172 & GSHV 185 as female parent recorded significant positive heterosis for most of the yield contributing characters. Thus, the female parents GSHV 172 & GSHV 185 can be used within breeding programmes aimed for heterosis breeding after proper evaluation within multi-location trials.

Keywords: Cotton, line x tester, *Gossypium*, heterosis, seed cotton yield

Introduction
Cotton *(Gossypium hirsutum* L.) is the king of fibre and an important cash crop of India which exercise profound influence on economics and social affairs. Although cotton in India is grown chiefly for its fiber but it also gained additional economic importance as a major contributor of edible oil, proteins and other byproducts. Cotton is the most important raw material for Indian textile industry, which makes up 70 per cent of its raw material needs. It is one of the largest contributing sectors of India's export. The world-wide trade of textiles and clothing has boosted the GDP of India to a great extent. The textile industry is claimed to be biggest revenue earner in India in term of foreign exchange and also biggest employer in the country, providing employment to over 119 million people either directly or indirectly. There are four cultivated species of cotton *viz. Gossypium arboreum, Gossypium herbaceum, Gossypium hirsutum* and *Gossypium barbadense*. Among which *Gossypium hirsutum* is the predominant species which alone contributes about 90% to the global production. India is the only country in the world where all the four cultivated species are grown on commercial scale. Cotton is one of the few crops which are accessible to the development of genotypes as varieties and at the same time amenable for commercial exploitation of heterosis. Heterosis is the phenomenon in which the F_1 of two genetically dissimilar parents show increased vigour for various characters over the mid parent (relative heterosis) or better parent (heterobeltiosis) or the standard check (standard heterosis). The objective of any plant breeding programme is to evolve varieties with traits of interest coupled with high yield. The yield plateau in cotton productivity can be broken by identifying suitable high yielding hybrids exhibiting high economic heterosis. To develop potential hybrids in cotton, it is necessary to exploit economic heterosis by means of genetic divergence and good combing ability of parents, which can lead to higher production and productivity. In the present study, line x tester analysis has been used to exploit the best heterotic crosses for seed cotton yield and other traits among thirty-two upland cotton hybrids developed by crossing four female parents (lines) with eight male parents (testers) in a line x tester mating design.

Material and Methods
Forty-five specific crosses were undertaken during kharif 2016-2017 by using 12 parents of

G. hirsutum viz., GSHV 172, GSHV 173, GSHV 185, GISV 310, BGDS 1033, CPD 1501, TCH 1716, TCH 1824, CCH 15-1, Suraj, RAH 1069 and TCH 321 with diverse origin. These hybrids along with one standard check G. COT. Hy. -14 were grown in randomized block design with 3 replications at MCRS Surat, Navsari Agricultural University. Observations were recorded on five randomly selected plants for days to 50 % flowering, plant height (cm), number of sympodia per plant, number of bolls per plant, boll weight (g), seed cotton yield per plant (g), ginning out turn (%), seed index (g) and lint index (g) and lint yield per plant (g). The useful heterosis (heterosis over best check) was estimated as per standard method.

Results and Discussion

The phenomenon of heterosis has proved to be the most important genetic tool in boosting the yield of self as well as cross pollinated crops and is considered as the most important breakthrough in the field of crop improvement. Heterosis may be positive or negative, depending on the magnitude of the hybrid mean value. The primary objective of heterosis breeding is to achieve a quantum jump in yield of crop plants. The data collected from the experimental material was subjected to analysis of variance and results obtained had been presented in Table 1. The analysis of variance revealed significant differences among the genotypes for all the characters. The mean squares due to genotypes were significant for all the characters except ginning percentage. Significant mean squares were observed among parents for all the characters indicate existence of sufficient variability among the parents except for ginning percentage (Table 1.2). This indicated that the material selected for the present investigation was quite appropriate for further genetical analysis as considerable amount of variability existed in the experimental material under study's. Perusal of data in table revealed that high heterosis was observed for almost all the traits. Range of mean values among the cross combination for seed cotton yield varied from 58.08 g (GSHV 173 x BGDS 1033) to 102.17 g (GSHV 173 x RAH 1069). The mean values for hybrids for days to 50% flowering varied from 43.62 days (GSHV 173 x CCH 15-1) to 59.71 days (GSHV 172 x TCH 1824) (Table 1.3). For plant height, crosses GSHV 185 x BGDS 1033 showed highest plant height of 175.15 while cross GISV 310 x CPD 1501 revealed the lowest plant height of 129.07 cm (Table 1.1). For average bolls/plant, the range of mean values among the hybrids was observed lowest in 15.92 (GSHV 185 x CPD 1501) and highest in 36.24 (GSHV 172 x BGDS 1033). The cross GSHV 172 x BGDS 1033 exhibited lowest average boll weight of 2.80 g while the cross, GSHV 173 x TCH 1824 recorded highest average boll weight 4.41 g (Table 1.2). As far as number of sympods is concerned, it ranged from 12.94 (GSHV 172 x BGDS 1033) to 29.96 (GSHV 173 x RAH 1069) (Table 1.2). Lint yield per plant ranged from 17.67 g (GSHV 173 x CPD 1501) to 35.27 g (GSHV 172 x RAH 1069). The highest value for this trait was recorded by the cross combination GSHV 173 x CPD 1501 (35.27 g), which was followed by GSHV 185 x RAH 1069 (34.73 g), GSHV 173 x RAH 1069 (32.60 g) (Table 1.4). Maximum ginning percentage among hybrids was exhibited by GSHV 173 x TCH 321 (40.79 %) followed by GISV 310 x BGDS 1033 (38.61 %) and GISV 310 x CCH 15-1 (36.11 %) as against of check G. Cot. Hy-14 (35.75 %) (Table 1.4). For seed index lowest value was observed for cross combination GISV 310 x TCH 321 (7.60 g) and highest value was observed for cross combination GSHV 172 x TCH 1824 (12.07 g) (Table 1.4). Mean value of lint index varied from 3.90 g (GISV 310 x TCH 321) to 7.23 g (GSHV 173 x TCH 321) (Table 1.5). For seed cotton yield, important aspect of cotton breeding, nine hybrids exhibited significant heterotic values. Most promising hybrids for seed cotton yield *i.e*, GSHV 172 x BGDS 1033 (29.27 %), GSHV 172 x CPD 1501 (27.83 %), GSHV 172 x TCH 1824 (30.69 %), GSHV 172 x RAH 1069 (37.64 %), GSHV 173 x TCH 1824 (19.94 %), GSHV 173 x CCH 15-1 (19.78 %), GSHV 173 x RAH 1069 (47.03 %), GSHV 185 x RAH 1069 (37.51 %) and GISV 310 x TCH 1716 (20.38 %). Most of these high heterotic cross combinations involve either GSHV 172 & GSHV 185 as female parent. Thus, these nine high heterotic hybrids along with the female parents GSHV 172 and GSHV 185 can be used to exploit high heterotic values for seed cotton yield. Sharma *et al.* (2016) [15], Arbad *et al.* (2017) [2], Chhavikant *et al.* (2017) [3], Dhamyanthi and Rathinavel (2017) [4], Lingaraja *et al.* (2017) [9] and Gohil *et al.* (2017) [6] also reported significant positive heterosis was observed for seed cotton yield. For days to 50% flowering maximum desirable standard heterosis were observed for the hybrid GSHV 173 x CCH 15-1 (-26.26 %) followed by GSHV 185 x TCH 1824 (-15.07 %), GSHV 185 x Suraj (-15.07 %) and GSHV 185 x RAH 1069 (-15.07 %). The result is akin to the findings of Ganapathy and Nadarajan (2008), Dukre *et al.* (2009), Patel *et al.* (2010) and Arbad *et al.* (2017) [2]. As far as plant height is concerned high heterosis were shown by 27.63 per cent (GSHV 173 x CPD 1501) followed by GSHV 173 x CPD 1501 (27.63 %), GSHV 185 x BGDS 1033 (22.95 %) and GSHV 185 x TCH 321 (20.61 %). Whereas maximum heterosis in negative direction was shown by the cross GISV 310 x CPD 1501 (-9.40 %). These finding was in accordance with the results obtained by Sharma *et al.* (2016) [15], Gohil *et al.* (2017) [6], Solanki *et al.* (2014) [16], Chhavikant *et al.* (2017) [3], Arbad *et al.* (2017) [2] and Devidas *et al.* (2017). Maximum heterosis for boll number was shown by crosses 53.69 per cent (GSHV 172 x BGDS 1033). Heterosis for this trait was also reported by earlier workers Tuteja *et al.* (2014) [19], Sawarkar *et al.* (2015) [14], Ghevariya *et al.* (2016) [5], Sonawane *et al.* (2015) [17], Solanki *et al.* (2014) [16], Kannan and Saravanan (2015) [7], Sharma *et al.* (2016) [15], Arbad *et al.* (2017) [2], Chhavikant *et al.* (2017) [3]. and Lingaraja *et al.* (2017) [9]. For number of sympods, hybrids viz., 78.42 per cent (GSHV 173 x CPD 1501), GSHV 173 x RAH 1069 (67.08 %), GISV 310 x BGDS 1033 (64.75 %), GSHV 173 x Suraj (54.38 %) and GSHV 173 x TCH 1716 (46.55 %) hybrids exhibited significant and positive standard heterosis. Similar finding was reported by Nakum *et al.* (2014) [11], Patel *et al.* (2015), Kannan and Saravanan (2015) [7], Sharma *et al.* (2016) [15] Chhavikant *et al.* (2017) [3] and Devidas *et al.* (2017).

The hybrid GSHV 172 x RAH 1069 (49.01 %) recorded the highest heterosis for lint yield per plant over standard check followed by GSHV 185 x RAH 1069 (46.76 %), GSHV 173 x RAH 1069, GSHV 173 x RAH 1069 (37.75 %) and GSHV 172 x TCH 1824 (36.76 %). The study of Pole *et al.* (2008) and Khan *et al.* (2009) [8] assembles with present study. The spectrum of variation for standard heterosis was varied from -16.31 (GSHV 310 x TCH 321) to 55.15 (GSHV 173 x TCH 321) percent over G. Cot. Hy.14fot lint index. Three hybrids recorded significantly positive heterosis over G. Cot. Hy. 14 for lint index. These crosses are 173 x TCH 321 (55.15 %), GISV 310 x CCH 15-1 (29.76 %) and GSHV 172 x TCH 321 (26.11 %). The present findings were in close association with results reported by Pole *et al.* (2008) and Khan *et al.* (2009)

[8]. For boll weight hybrids 20.82 per cent (GSHV 173 x TCH 1824), GSHV 173 x CPD 1501 (11.14 %), GSHV 173 x TCH 1824 (20.82 %), GSHV 173 x CCH 15-1 (15.80 %), GSHV 185 x CPD 1501 (13.06 %), GSHV 185 x RAH 1069 (9.95 %), GSHV 185 x TCH 321 (11.78 %) and GISV 310 x RAH 1069 (15.16 %) showed high heterosis. Similar finding was reported by Tuteja *et al*. (2014) [19], Pushpam *et al*. (2015) [13], Kanan and sarvanan (2015), Sharma *et al.* (2016) [15], Arbad *et al.* (2017) [2] and Chhavikant *et al.* (2017) [3]. Among all the characters studied, the lowest heterotic values were found for ginning out turn. The value of standard heterosis was ranged from -13.84 per cent (GSHV 185 x TCH 1716) to 14.09 per cent (GSHV 173 x TCH 321). Out of 32 crosses, none of the crosses had significant standard heterotic effect in positive direction. For seed index hybrid GSHV 172 x TCH 1824 (20.67 %) showed the maximum heterotic effect. Out of 32 crosses, one hybrid showed significant and positive standard heterosis *i.e*. GSHV 172 x TCH 1824 (20.67 %). Heterosis for this trait was also reported by the earlier workers Nakum *et al.* (2014) [11], Sawarkar *et al.* (2015) [14], Munir *et al.* (2016) [10] and pundir *et al.* (2017) [12]. The cross with maximum heterotic effect for lint index was GSHV 173 x TCH 321 (55.15 percent). Similar result was reported by Patel *et al.* (2014), Pushpam *et al.* (2015) [13], Nirania *et al.* (2014) [3], Chhavikant *et al.* (2017) [3] and Lingaraja *et al.* (2017) [9].

Table 1.1: Magnitude of heterosis over better parent (BP) and over standard check for days to 50% flowering and plant height (cm) in tetraploid cotton (*G. hirsutum* L.)

Sr. No.	Crosses	Days to 50% flowering		Plant height (cm)	
		BP	SC	BP	SC
1	GSHV 172 x BGDS 1033	14.05 **	-1.54	-13.31 **	-2.19
2	GSHV 172 x CPD 1501	-2.09	-2.03	-5.47	4.96
3	GSHV 172 x TCH 1716	-0.82	-0.82	-3.05	7.64
4	GSHV 172 x TCH 1824	2.46	0.96	1.04	16.87 **
5	GSHV 172 x CCH 15-1	-1.26	-2.01	0.10	11.14 *
6	GSHV 172 x Suraj	-0.82	-0.76	-9.69 *	0.27
7	GSHV 172 x RAH 1069	-0.32	-1.85	3.43	14.83 **
8	GSHV 172 x TCH 321	1.23	-0.80	6.67	18.44 **
9	GSHV 173 x BGDS 1033	0.00	-13.67 **	-1.10	11.59 *
10	GSHV 173 x CPD 1501	1.92	0.05	25.47 **	27.63 **
11	GSHV 173 x TCH 1716	0.00	-1.84	4.56	13.69 **
12	GSHV 173 x TCH 1824	0.38	-1.47	1.89	17.85 **
13	GSHV 173 x CCH 15-1	-24.88 **	-26.26 **	3.55	12.65 **
14	GSHV 173 x Suraj	2.19	0.31	-2.02	2.23
15	GSHV 173 x RAH 1069	1.04	-0.82	6.78	8.62
16	GSHV 173 x TCH 321	0.17	-1.84	7.81	12.36 **
17	GSHV 185 x BGDS 1033	14.90 **	-0.8	8.97 *	22.95 **
18	GSHV 185 x CPD 1501	-0.38	-1.84	1.85	7.92
19	GSHV 185 x TCH 1716	1.80	0.31	0.84	9.64 *
20	GSHV 185 x TCH 1824	-13.80 **	-15.07 **	-5.78	8.98
21	GSHV 185 x CCH 15-1	0.37	-1.1	-10.07 *	-2.17
22	GSHV 185 x Suraj	-13.80 **	-15.07 **	-0.95	4.95
23	GSHV 185 x RAH 1069	-13.74 **	-15.07 **	-8.70	-3.26
24	GSHV 185 x TCH 321	2.17	0.12	13.82 **	20.61 **
25	GISV 310 x BGDS 1033	29.80 **	-2.05	-2.64	9.85 *
26	GISV 310 x CPD 1501	30.18 **	-1.76	-19.51 **	-9.40 *
27	GISV 310 x TCH 1716	31.46 **	-0.80	1.89	14.68 **
28	GISV 310 x TCH 1824	30.08 **	-1.84	-1.39	14.06 **
29	GISV 310 x CCH 15-1	32.93 **	0.31	-3.54	8.58
30	GISV 310 x Suraj	29.86 **	-2.01	6.68	20.08 **
31	GISV 310 x RAH 1069	31.44 **	-0.82	4.25	17.34 **
32	GISV 310 x TCH 321	31.46 **	-0.80	-3.16	9.00
	S.Ed ±	2.39	2.39	6.57	6.57
	CD .05	4.78	4.78	13.15	13.15
	CD .01	6.36	6.36	17.48	17.48

*, ** Significant at 5% and 1% levels, respectively

Table 1.2: Magnitude of heterosis over better parent (BP) and over standard check for days to Sympodia per plant and Balls per plant in tetraploid cotton (*G. hirsutum* L.)

Sr. No.	Crosses	Sympodia per plant		Balls per plant	
		BP	SC	BP	SC
1	GSHV 172 x BGDS 1033	-44.46 **	-27.83 **	64.11 **	53.69 **
2	GSHV 172 x CPD 1501	-10.4	16.42	-2.75	-8.00
3	GSHV 172 x TCH 1716	-25.00 **	-2.55	-8.53	-14.33 *
4	GSHV 172 x TCH 1824	-4.02	24.71 **	23.70 **	15.85 *
5	GSHV 172 x CCH 15-1	-14.95 *	10.50	-14.46	-19.89 **
6	GSHV 172 x Suraj	-29.62 **	-8.55	24.21 **	16.33 *
7	GSHV 172 x RAH 1069	-25.34 **	-2.99	0.71	11.55
8	GSHV 172 x TCH 321	-7.01	20.82 *	2.81	-3.72
9	GSHV 173 x BGDS 1033	-9.53	8.51	-46.65 **	-29.32 **

10	GSHV 173 x CPD 1501	83.11 **	78.42 **	-47.91 **	-30.99 **
11	GSHV 173 x TCH 1716	14.26 *	46.55 **	-38.68 **	-18.76 **
12	GSHV 173 x TCH 1824	23.77 **	44.62 **	-30.73 **	-8.23
13	GSHV 173 x CCH 15-1	31.12 **	30.88 **	-31.41 **	-9.13
14	GSHV 173 x Suraj	48.87 **	54.38 **	-21.23 **	4.35
15	GSHV 173 x RAH 1069	35.00 **	67.08 **	-11.38 *	17.40 *
16	GSHV 173 x TCH 321	11.61	-3.33	-25.58 **	-1.40
17	GSHV 185 x BGDS 1033	-25.34 **	25.82 **	-16.44 *	-21.80 **
18	GSHV 185 x CPD 1501	-32.00 **	14.59	-28.63 **	-32.49 **
19	GSHV 185 x TCH 1716	-34.15 **	10.97	5.68	-1.10
20	GSHV 185 x TCH 1824	-29.27 **	19.20 *	-16.28 *	-21.66 **
21	GSHV 185 x CCH 15-1	-31.24 **	15.88	-18.49 *	-23.72 **
22	GSHV 185 x Suraj	-46.05 **	-9.07	-17.78 *	-23.06 **
23	GSHV 185 x RAH 1069	-33.66 **	11.81	2.65	13.70 *
24	GSHV 185 x TCH 321	-29.48 **	18.85 *	-15.89 *	-21.29 **
25	GISV 310 x BGDS 1033	37.35 **	64.75 **	16.62 *	-2.62
26	GISV 310 x CPD 1501	-16.34 *	-5.74	-8.68	-13.61
27	GISV 310 x TCH 1716	12.05	43.71 **	6.53	-11.04
28	GISV 310 x TCH 1824	10.31	28.89 **	-3.57	-19.48 **
29	GISV 310 x CCH 15-1	16.22 *	30.94 **	11.53	-6.87
30	GISV 310 x Suraj	0.92	13.7	4.84	-12.45
31	GISV 310 x RAH 1069	-9.10	12.49	-30.06 **	-22.53 **
32	GISV 310 x TCH 321	-31.67 **	-23.02 **	4.57	-12.68
	S.Ed ±	1.52	1.52	1.61	1.61
	CD .05	3.04	3.04	3.21	3.21
	CD .01	4.04	4.04	4.26	4.26

*, ** significant at 5% and 1% levels, respectively

Table 1.3: Magnitude of heterosis over better parent (BP) and over standard check for Ball weight (g) and Seed cotton yield per plant (g) in tetraploid cotton (*G. hirsutum* L.)

Sr. No.	Crosses	Ball weight (g)		Seed cotton yield per plant (g)	
		BP	SC	BP	SC
1	GSHV 172 x BGDS 1033	-33.09 **	-23.20 **	35.11 **	29.27 **
2	GSHV 172 x CPD 1501	-4.68	7.95 *	23.62 **	27.83 **
3	GSHV 172 x TCH 1716	8.27 *	9.95 *	-1.47	-11.18
4	GSHV 172 x TCH 1824	-7.09	-3.11	44.96 **	30.69 **
5	GSHV 172 x CCH 15-1	16.42 **	8.77 *	-14.89	-23.27 *
6	GSHV 172 x Suraj	-9.78 *	-4.84	21.67 *	9.68
7	GSHV 172 x RAH 1069	6.15	7.21	24.51 **	37.64 **
8	GSHV 172 x TCH 321	6.19	0.27	1.13	-8.83
9	GSHV 173 x BGDS 1033	-4.69	9.41 *	-37.57 **	-16.42
10	GSHV 173 x CPD 1501	-1.85	11.14 **	-46.43 **	-28.29 **
11	GSHV 173 x TCH 1716	-20.14 **	-18.90 **	-34.91 **	-12.85
12	GSHV 173 x TCH 1824	15.85 **	20.82 **	-10.41	19.94 *
13	GSHV 173 x CCH 15-1	20.08 **	15.80 **	-10.53	19.78 *
14	GSHV 173 x Suraj	-15.76 **	-11.14 **	-17.35 *	10.65
15	GSHV 173 x RAH 1069	-6.78	-5.84	9.82	47.03 **
16	GSHV 173 x TCH 321	-14.20 **	-17.26 **	-32.83 **	-10.08
17	GSHV 185 x BGDS 1033	-14.03 **	6.30	-27.14 **	-19.65 *
18	GSHV 185 x CPD 1501	-8.57 **	13.06 **	-7.77	1.71
19	GSHV 185 x TCH 1716	-23.26 **	-5.11	2.32	12.83
20	GSHV 185 x TCH 1824	-19.28 **	-0.18	-28.31 **	-20.95 *
21	GSHV 185 x CCH 15-1	-12.92 **	7.67	-19.71 *	-11.46
22	GSHV 185 x Suraj	-13.52 **	6.94	-23.68 **	-15.84
23	GSHV 185 x RAH 1069	-11.08 **	9.95 *	24.39 **	37.51 **
24	GSHV 185 x TCH 321	-9.60 **	11.78 **	-15.5	-6.82
25	GISV 310 x BGDS 1033	-14.16 **	-1.46	2.96	-7.16
26	GISV 310 x CPD 1501	-15.16 **	-3.93	-11.51	-8.49
27	GISV 310 x TCH 1716	5.04	6.67	28.72 **	20.38 *
28	GISV 310 x TCH 1824	-1.49	2.74	-4.13	-10.35
29	GISV 310 x CCH 15-1	-7.43	-13.52 **	5.39	-1.45
30	GISV 310 x Suraj	0.95	6.48	7.88	0.89
31	GISV 310 x RAH 1069	14.01 **	15.16 **	-10.18	-0.71
32	GISV 310 x TCH 321	-0.68	-6.21	-1.1	-7.52
	S.Ed ±	0.14	0.14	6.09	6.09
	CD .05	0.28	0.28	12.18	12.18
	CD .01	0.37	0.37	16.19	16.19

*, ** significant at 5% and 1% levels, respectively

Table 1.4: Magnitude of heterosis over better parent (BP) and over standard check for Lint yield per plant (g) and Ginning percentage in tetraploid cotton (*G. hirsutum* L.)

Sr. No.	Crosses	Lint yield per plant (g)		Ginning percentage	
		BP	SC	BP	SC
1	GSHV 172 x BGDS 1033	29.20 **	29.01 **	-0.38	-2.53
2	GSHV 172 x CPD 1501	30.99 **	33.94 **	-1.5	-3.62
3	GSHV 172 x TCH 1716	-2.52	-12.96	-8.58	-3.89
4	GSHV 172 x TCH 1824	53.15 **	36.76 **	-1.71	-3.82
5	GSHV 172 x CCH 15-1	-4.42	-14.65	-14.05 *	-0.04
6	GSHV 172 x Suraj	17.67	5.07	-7.18	-4.12
7	GSHV 172 x RAH 1069	39.21 **	49.01 **	1.6	-0.59
8	GSHV 172 x TCH 321	7.57	-3.94	-1.57	-3.69
9	GSHV 173 x BGDS 1033	-30.36 **	-12.11	-0.8	-5.3
10	GSHV 173 x CPD 1501	-40.85 **	-25.35 **	-5.08	-7.14
11	GSHV 173 x TCH 1716	-31.58 **	-13.66	-13.21	-8.75
12	GSHV 173 x TCH 1824	-5.58	19.15 *	-3.7	-8.72
13	GSHV 173 x CCH 15-1	-3.13	22.25 **	-19.73 **	-6.65
14	GSHV 173 x Suraj	-11.72	11.41	-11.06	-8.12
15	GSHV 173 x RAH 1069	9.15	37.75 **	-4.41	-8.75
16	GSHV 173 x TCH 321	-12.39	10.56	18.55 *	14.09
17	GSHV 185 x BGDS 1033	-23.76 **	-17.75 *	8.41	3.88
18	GSHV 185 x CPD 1501	-3.79	3.80	-4.38	-6.46
19	GSHV 185 x TCH 1716	-11.23	-4.23	-18.05 *	-13.84
20	GSHV 185 x TCH 1824	-23.63 **	-17.61 *	1.02	-3.20
21	GSHV 185 x CCH 15-1	-12.92	-6.06	-16.28 *	-2.63
22	GSHV 185 x Suraj	-26.11 **	-20.28 *	-10.26	-7.30
23	GSHV 185 x RAH 1069	36.03 **	46.76 **	1.89	-2.37
24	GSHV 185 x TCH 321	-13.45	-6.62	-2.52	-6.19
25	GISV 310 x BGDS 1033	-3.42	3.52	2.35	7.99
26	GISV 310 x CPD 1501	-10.12	-3.66	-7.17	-2.05
27	GISV 310 x TCH 1716	11.7	19.72 *	-8.86	-3.84
28	GISV 310 x TCH 1824	-22.08 **	-16.48 *	-16.36 *	-11.75
29	GISV 310 x CCH 15-1	0.53	7.75	-13.15	1.01
30	GISV 310 x Suraj	-4.07	2.82	-9.46	-4.47
31	GISV 310 x RAH 1069	-6.96	-0.28	-13.49	-8.72
32	GISV 310 x TCH 321	-10.12	-3.66	-9.37	-4.37
	S.Ed ±	1.90	1.90	2.91	2.91
	CD .05	3.80	3.80	5.82	5.82
	CD .01	5.05	5.05	7.74	7.74

*, ** significant at 5% and 1% levels, respectively

Table 1.5: Magnitude of heterosis over better parent (BP) and over standard check for Seed index (g) and Lint index (g) in tetraploid cotton (*G. hirsutum* L.)

Sr. No.	Crosses	Seed index (g)		Lint index (g)	
		BP	SC	BP	SC
1	GSHV 172 x BGDS 1033	-15.84 *	-15.00 *	-0.42	2.36
2	GSHV 172 x CPD 1501	7.53	0.00	15.34	10.23
3	GSHV 172 x TCH 1716	2.15	-5.00	0.43	0.14
4	GSHV 172 x TCH 1824	29.75 **	20.67 **	28.10 *	25.54
5	GSHV 172 x CCH 15-1	-5.00	-5.00	-0.69	13.73
6	GSHV 172 x Suraj	-0.33	0.33	7.75	9.44
7	GSHV 172 x RAH 1069	-1.90	3.00	7.49	12.88
8	GSHV 172 x TCH 321	11.00	11.00	10.33	26.11 *
9	GSHV 173 x BGDS 1033	-9.56	10.33	21.16	24.54
10	GSHV 173 x CPD 1501	-26.50 **	-10.33	-5.36	-3.93
11	GSHV 173 x TCH 1716	-15.30 *	3.33	3.88	5.44
12	GSHV 173 x TCH 1824	-13.93 *	5.00	-0.35	1.14
13	GSHV 173 x CCH 15-1	-8.47	11.67	0.87	15.52
14	GSHV 173 x Suraj	-14.21 *	4.67	7.68	9.37
15	GSHV 173 x RAH 1069	-9.84	10.00	-1.29	3.65
16	GSHV 173 x TCH 321	-17.21 **	1.00	35.73 **	55.15 **
17	GSHV 185 x BGDS 1033	-2.90	0.33	15.03	18.24
18	GSHV 185 x CPD 1501	1.61	5.00	15.37	17.60
19	GSHV 185 x TCH 1716	1.61	5.00	-8.7	-6.94
20	GSHV 185 x TCH 1824	-3.23	0.00	4.98	7.01
21	GSHV 185 x CCH 15-1	1.61	5.00	2.06	16.88
22	GSHV 185 x Suraj	1.61	5.00	10.74	12.88
23	GSHV 185 x RAH 1069	0.32	5.33	3.81	9.01

24	GSHV 185 x TCH 321	-2.90	0.33	-10.01	2.86
25	GISV 310 x BGDS 1033	-15.84 *	-15.00 *	5.61	13.02
26	GISV 310 x CPD 1501	5.17	-5.00	9.09	16.74
27	GISV 310 x TCH 1716	5.17	-5.00	6.48	13.95
28	GISV 310 x TCH 1824	5.93	-4.67	-15.51	-9.59
29	GISV 310 x CCH 15-1	3.00	3.00	13.30	29.76 *
30	GISV 310 x Suraj	0.33	1.00	8.62	16.24
31	GISV 310 x RAH 1069	-13.02	-8.67	-11.83	-5.65
32	GISV 310 x TCH 321	-24.00 **	-24.00 **	-26.78 *	-16.31
	S.E (d) ±	0.73	0.73	0.60	0.60
	CD .05	1.46	1.46	1.20	1.20
	CD .01	1.95	1.95	1.60	1.60

*, ** significant at 5% and 1% levels, respectively

Table 2.1: Analysis of variance (mean sum of squares) for experiment for various characters in tetraploid cotton (*G. hirsutum* L.)

Source of variation	d.f.	Days to 50% flowering	Plant height (cm)	No. of sympodia per plant	No. of bolls per plant	Boll Weight (g)	Seed cotton yield / plant (g)
Replicates	2	0.33	197.80	22.23 **	42.42 **	0.03	134.26
Treatments	43	45.05 **	380.76 **	58.04 **	71.21 **	0.47 **	861.89 **
Parents	11	60.73 **	259.22 **	52.33 **	110.23 **	0.53 **	1306.53 **
Parents (Line)	3	145.08 **	148.93	113.90 **	78.19 **	1.26 **	578.84 **
Parents (Testers)	7	24.17 *	333.47 **	24.54 **	85.11 **	0.24 **	1143.88 **
Parents (L vs T)	1	63.67 **	70.34	62.16 **	382.16 **	0.31 **	4628.18 **
Parents vs Crosses	1	0.54	832.08 **	26.98 **	166.50 **	0.00	4450.79 **
Crosses	31	40.93 **	409.33 **	61.06 **	54.29 **	0.46 **	588.35 **
Line Effect	3	62.37	218.26	190.48 *	134.92	0.27	498.34
Tester Effect	7	22.13	236.32	26.97	46.70	0.29	826.33
Line * Tester Eff.	21	44.13 **	494.30 **	53.93 **	45.30 **	0.55 **	521.88 **
Error	86	8.61	64.93	3.48	3.87	0.03	55.72

*, ** Significant at 5 % and 1 % levels, respectively

Table 2.2: Contd…

Source of variation	d.f.	Lint yield/ plant (g)	Ginning percentage	Seed index (g)	Lint index (g)
Replicates	2	77.65 **	129.36 **	1.24	3.30 **
Treatments	43	101.65 **	14.20	2.43 **	1.03 **
Parents	11	142.79 **	21.07	2.80 **	0.34
Parents (Line)	3	38.15 **	22.22	7.35 **	0.14
Parents (Testers)	7	130.57 **	21.23	1.07	0.46
Parents (L vs T)	1	542.30 **	16.53	1.23	0.05
Parents vs Crosses	1	619.39 **	33.39	0.99	3.89 **
Crosses	31	70.35 **	11.14	2.34 **	1.18 **
Line Effect	3	81.38	3.48	6.76 *	0.45
Tester Effect	7	92.04	15.64	1.57	0.88
Line * Tester Eff.	21	61.55 **	10.74	1.97 **	1.39 **
Error	86	5.43	12.74	0.81	0.55

*, ** Significant at 5 % and 1 % levels, respectively

Conclusion

In the light of current investigation, it is clear that, a substantial degree of heterosis over standard checks G. Cot. Hy. 14 was for almost all the traits. However maximum extent of heterosis is recorded for traits like seed cotton yield GSHV 173 x RAH 1069 (47.03 %), boll number GSHV 172 x BGDS 1033 (53.69 %) and number of sympods, GSHV 173 x CPD 1501 (78.42 %).Most promising hybrids for seed cotton yield *i.e*, GSHV 172 x BGDS 1033 (29.27 %), GSHV 172 x CPD 1501 (27.83 %), GSHV 172 x TCH 1824 (30.69 %), GSHV 172 x RAH 1069 (37.64 %), GSHV 173 x TCH 1824 (19.94 %), GSHV 173 x CCH 15-1 (19.78 %), GSHV 173 x RAH 1069 (47.03 %), GSHV 185 x RAH 1069 (37.51 %) and GISV 310 x TCH 1716 (20.38 %). Most of these high heterotic cross combinations involve either GSHV 172 & GSHV 185 as female parent. Thus, these nine high heterotic hybrids along with the female parents GSHV 172 and GSHV 185 can be used to exploit high heterotic values for seed cotton yield. Thus, the female parents GSHV 172 & GSHV 185 along with the above nine highly heterotic hybrids exhibiting heterosis for seed cotton yield and significant heterosis for other attributing traits, can be used within breeding programmes aimed for heterosis breeding after proper evaluation within multi-location trials.

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