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Heterotic analysis of GMS based hybrids of seed cotton yield and fibre quality traits in cotton (*Gossypium hirsutum* L.)

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Abstract
The present investigation was undertaken with the objectives to study the extent of heterosis over better parent (Heterobeltiosis) and standard check (Standard heterosis) GN.Cot.Hy-14. Three lines were crossed with eight testers to obtain 24 hybrids in Line x Tester design. Studies revealed that for trait seed cotton yield per plant out of 24 crosses, seven hybrid manifested significant and positive standard heterosis. The maximum standard heterosis was depicted by S-D-2 x TCH 1716 (17.63 %) which was followed by G(T)-84 x TCH 1716 (15.58 %) and GMS Gregg x TCH 1716 (15.03 %). Among all the fibre quality characters, the cross combinations S-D-2 x BGDS 1033 (5.32 %) and S-D-2 x TCH 321 (3.11 %) displayed highly significant standard heterosis over check GN.Cot.Hy-14 for ginning outturn respectively. The magnitude of standard heterosis over check GN.Cot.Hy-14 was high in the cross combinations GMS Gregg x TCH1716 (4.35 %) for 2.5 per cent span length, (-2.38 %) GMS Gregg x TCH 1716, GMS Gregg x CCH 15-1 and G(T)-84 x CPD 1501 for fibre fineness and GMS Gregg x RAH 1069 (8.61 %), G(T)-84 x CPD 1501 (2.32 %) and GMS Gregg x TCH 1824 (1.66 %) for fibre strength.

Keywords: genetic male sterile, heterosis, line x tester design, *Gossypium hirsutum*

Introduction
Cotton is one of the major fibre crop which is mainly cultivated for its fibre and hence, quality of lint is important in cotton. Cotton, which has been reputed as the king of fibre, is one of the momentous and an important cash crop exercising a profound influence on economics and social affairs of the world. Any other fibre crop cannot be compared with cotton for its fibre quality. India is pioneer country in the world for commercial exploitation of heterosis in cotton. Hybrids have played a significant role to attain self sufficiency of cotton production in India. Cotton production in India got momentum with the release of world’s first cotton hybrid hybrid 4 by late Dr. C. T. Patel (1971) at Main Cotton Research Station, GAU, Surat followed by the release of various high yielding hybrids during early and late seventies.
For development of superior and heterotic hybrids in cotton, it is essential to utilize large number of available germplasm. 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 heterosis breeding programme, the selection of crosses on basis of heterosis is very important in producing superior hybrids.

Material and Methods
The present investigation was undertaken to study heterotic effect for seed cotton yield, its component traits and fibre quality traits in cotton (*Gossypium hirsutum* L.). Twenty four cross combinations derived by crossing three lines with eight testers in line x tester mating design. The experiment material consisted of 24 crosses eleven parents along with one standard check

(GN.Cot.Hy-14). The experiment was conducted at Main Cotton Research Station, Athwa Farm, Navsari Agricultural University, Surat during *Kharif* 2017. The mean values of all the treatments for the characters under study were worked out. Standard error and critical difference at 1 and 5 per cent level of significance were calculated by using the formula. The magnitude of heterosis was estimated for all the characters under study over better parent and standard check.

Results and Discussion

The analysis of variance showed significant differences for yield and fibre characters studied. The mean sum of squares for the treatments was highly significant for all the characters studied. The analysis of variance for all the characters is presented in Table 1. The heterosis over better parent and standard check are presented in Table 2. Best heterotic crosses for seed cotton yield per plant have been listed in Table 3.

The range for important economic character *i.e* seed cotton yield per plant was from -0.35 (S-D-2 x CPD 1501) to 24.74 per cent (S-D-2 x CCH 15-1). Eight hybrids showed significant and positive heterobeltiotic effect *viz.*, S-D-2 x CCH 15-1 (24.74 %) which was followed by G(T)-84 x CCH 15-1 (21.72 %), G(T)-84 x TCH 321 (17.79 %), GMS Gregg x TCH 321 (17.41 %), S-D-2 x TCH 321 (17.02 %), S-D-2 x BGDS 1033 (15.83 %), GMS Gregg x CCH 15-1 (15.38 %) and G(T)-84 x BGDS 1033 (14.09 %). The range for standard heterosis was from 5.01 [G(T)-84 x CCH 15-1] to 17.63 per cent (S-D-2 x TCH 1716). Out of 24 crosses, seven hybrid manifested significant and positive standard heterosis. The maximum standard heterosis was depicted by S-D-2 x TCH 1716 (17.63 %) which was followed by G(T)-84 x TCH 1716 (15.58 %), GMS Gregg x TCH 1716 (15.03 %), G(T)-84 x TCH 321 (12.99 %), GMS Gregg x TCH 321 (12.62 %), S-D-2 x TCH 321 (12.24 %) and S-D-2 x CCH 15-1 (12.21 %). Several workers *viz.*, Monicashree *et al*. (2017) [11], Dhamyanthi and Rathinavel (2017) [6], Adsare *et al*. (2017) [1], Balakrishna *et al*. (2017) [2], Patel *et al*. (2015) [13], Tuteja and Agrawal (2014) [17], Deshmukh *et al*. (2014) [5] and Jyotiba *et al*. (2010) [8] reported significant heterosis in positive direction for seed cotton yield per plant.

A perusal of data for ginning out turn revealed that heterobeltiosis was ranged from -10.42 (GMS Gregg x Suraj) to 5.66 per cent (RAH 1069). Out of 24 crosses, only one of the cross GMS Gregg x RAH 1069 (5.66 %) had significant heterobeltiotic effect in positive direction. The value of standard heterosis was ranged from -13.18 (GMS Gregg x TCH 1716) to 5.32 per cent (S-D-2 x BGDS 1033). Out of 24 crosses, two crosses S-D-2 x BGDS 1033 (5.32 %) and S-D-2 x TCH 321 (3.11 %) showed significant standard heterotic effect in positive direction. Chinchane *et al*. (2018) [4], Lingaraja *et al*. (2017) [10], Chhavikant *et al*. (2017) [3], Kannan and Saravanan (2016) [9], Srinivas and Bhadru (2015) [15], Tuteja *et al*. (2013) [16] and Jyotiba *et al*. (2010) [8].

For the character 2.5 per cent span length, the value of heterosis over better parent varied from -7.89 [G(T)-84 x TCH 1716] to 4.33 per cent [G(T)-84 x TCH 1824]. Six hybrids *viz.*, G(T)-84 x TCH 1824 (4.33 %) which was followed by GMS Gregg x CCH 15-1 (4.27 %), GMS Gregg x BGDS 1033 (4.14 %), S-D-2 x BGDS 1033 (3.56 %), S-D-2 x TCH 321 (2.85 %) and S-D-2 x CCH 15-1 (2.85 %) showed significant and positive heterobeltiotic effect. The estimates of standard heterosis over the check GN.Cot.Hy-14 varied from -12.04 [G(T)-84 x BGDS 1033] to 4.35 per cent (GMS Gregg x TCH 1716) per cent among the 24 hybrids. Out of 24 hybrids, only one hybrid GMS Gregg x TCH 1716 (4.35 %) showed significant and positive standard heterotic effect. Chinchane *et al*. (2018) [4], Lingaraja *et al*. (2017) [10], Sharma *et al*. (2016) [14], Srinivas and Bhadru (2015) [15], Tuteja and Agrawal (2014) [17], Deshmukh *et al*. (2014) [5], Geddam *et al*. (2013) [7], Tuteja *et al*. (2011a) [18] also reported similar results.

The estimates of heterobeltiosis for fiber fineness was varied from -18.00 (GMS Gregg x CCH 15-1) to 30.56 per cent [G(T)-84 x TCH 1716]. Among twenty four hybrids, ten hybrids depicted significant and negative heterobeltiosis. The cross GMS Gregg x CCH 15-1 recorded the highest value (-18.00 %) which was followed by G(T)-84 x CPD 1501 (-8.89 %) and S-D-2 x BGDS 1033 (-8.51 %). The estimates for standard heterosis varied from -2.38 [GMS Gregg x TCH 1716, GMS Gregg x CCH 15-1 and G(T)-84 x CPD 1501] to 26.19 per cent (GMS Gregg x Suraj). Out of 24 crosses, three crosses showed significant and negative standard heterosis *viz.*, GMS Gregg x TCH 1716 (-2.38 %), GMS Gregg x CCH 15-1 (-2.38 %) and G(T)-84 x CPD 1501 (-2.38 %). Chinchane *et al*. (2018) [4], Lingaraja *et al*. (2017) [10], Sharma *et al*. (2016) [14], Tuteja *et al*. (2014) [17] and Geddam *et al*. (2013) [7] reported similar result for fiber fineness.

The estimates of heterobeltiosis for fiber strength was varied from -12.66 [G(T)-84x TCH 1824] to 10.44 per cent (GMS Gregg x RAH 1069). Out of 24 crosses, only five crosses showed the significant and positive heterobeltiotic effect *viz.*, GMS Gregg x RAH 1069 (10.44 %) which was followed by G(T)-84 x CPD 1501 (5.10 %), S-D-2 x Suraj (3.05 %), G(T)-84 x Suraj (3.05 %) and G(T)-84 x CCH 15-1 (2.04 %). The standard heterosis varied from -10.93 per cent [S-D-2 x RAH 1069 and G(T)-84 x TCH 1716] to 8.61 per cent (GMS Gregg x RAH 1069). Out of 24 crosses, only three crosses showed significant and positive standard heterosis *i.e.* GMS Gregg x RAH 1069 (8.61 %), G(T)-84 x CPD 1501 (2.32 %) and GMS Gregg x TCH 1824 (1.66 %). Heterosis for this character was reported by workers like Chinchane *et al*. (2018) [4], Monicashree *et al*. (2017) [11], Lingaraja *et al*. (2017) [10], Sharma *et al*. (2016) [14], Srinivas and Bhadru (2015) [15], Tuteja and Agrawal (2014) [17], Geddam *et al*. (2013) [7], Tuteja *et al*. (2011a) [18], Jyotiba *et al*. (2010) [8].

On the basis of this study it is concluded that the crosses having highly significant standard heterosis can be exploited for heterosis and heterosis breeding would be rewarding with further testing of these crosses for at least three to four seasons at multilocations.

Table 1: Analysis of variance (Mean sum of squares) for seed cotton yield and fibre quality characters of cotton (*G. hirsutum* L.)

Sources	D.F	SCYP	GO	SL	FF	FS
Replication	2	234.92	8.45	137.80**	83.31**	91.20**
Genotypes	34	161.19*	9.56**	5.64**	0.05**	6.52**
Error	68	87.23	2.80	1.00	0.25	0.35

*, ** significant at 5% and 1% levels, respectively, SCYP = Seed cotton yield per plant, GO = Ginning outturn, SL = 2.5 per cent Span length, FF = Fibre fineness and FS = Fibre Strength

Table 2: Magnitude of heterosis over better parent (BP) and over standard check (SC) for seed cotton yield per plant in cotton (*G. hirsutum* L.)

S. No.	Crosses	Seed cotton yield per plant (g)	
		BP	SC
1.	GMS Gregg x BGDS 1033	11.39	7.05
2.	GMS Gregg x CPD 1501	1.74	8.72
3.	GMS Gregg x TCH 1716	8.20	15.03**
4.	GMS Gregg x TCH 1824	10.92	5.57
5.	GMS Gregg x CCH 15-1	15.38*	5.75
6.	GMS Gregg x Suraj	10.17	8.53
7.	GMS Gregg x RAH 1069	6.42	7.61
8.	GMS Gregg x TCH 321	17.41**	12.62*
9.	S-D-2 x BGDS 1033	15.83*	11.32
10.	S-D-2 x CPD 1501	-0.35	6.49
11.	S-D-2 x TCH 1716	10.65	17.63**
12.	S-D-2 x TCH 1824	8.77	3.53
13.	S-D-2 x CCH 15-1	24.74**	12.24*
14.	S-D-2 x Suraj	9.60	7.98
15.	S-D-2 x RAH 1069	8.26	9.46
16.	S-D-2 x TCH 321	17.02**	12.24*
17.	G(T)-84 x BGDS 1033	14.09*	9.65
18.	G(T)-84 x CPD 1501	1.04	7.98
19.	G(T)-84 x TCH 1716	8.73	15.58*
20.	G(T)-84 x TCH 1824	11.5	6.12
21.	G(T)-84 x CCH 15-1	21.72**	5.01
22.	G(T)-84 x Suraj	9.60	7.98
23.	G(T)-84 x RAH 1069	6.42	7.61
24.	G(T)-84 x TCH 321	17.79**	12.99*
	S.E (d) ±	8.58	8.58
	CD @ 5%	12.19	12.19
	CD @ 1%	16.69	16.69

*, ** significant at 5% and 1% levels, respectively, BP = Better parent and SC = Standard check

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Table 2: Magnitude of heterosis over better parent (BP) and over standard check (SC) for ginning outturn and 2.5 per cent span length in cotton (*G. hirsutum* L.)

S. No.	Crosses	Ginning outturn (%)		2.5 per cent Span length (mm)	
		BP	SC	BP	SC
1.	GMS Gregg x BGDS 1033	-1.11	1.96	4.14**	-4.68**
2.	GMS Gregg x CPD 1501	-10.12**	-6.19**	0.37	-9.36**
3.	GMS Gregg x TCH 1716	-3.45*	-13.18 **	-0.21	4.35**
4.	GMS Gregg x TCH 1824	-9.94**	-8.73**	-3.25**	-10.37**
5.	GMS Gregg x CCH 15-1	-3.27*	1.62	4.27**	-2.01*
6.	GMS Gregg x Suraj	-10.40**	-1.47	-0.35	-4.01**
7.	GMS Gregg x RAH 1069	5.66**	-2.82*	-4.67**	-4.35**
8.	GMS Gregg x TCH 321	1.59	1.70	-1.48*	-11.04**
9.	S-D-2 x BGDS 1033	2.15	5.32**	3.56**	-2.68**
10.	S-D-2 x CPD 1501	-5.15**	-1.00	1.42	-4.68**
11.	S-D-2 x TCH 1716	-7.83**	-6.39**	-6.29**	-2.01*
12.	S-D-2 x TCH 1824	-10.01**	-8.60**	0.71	-5.35**
13.	S-D-2 x CCH 15-1	-2.84*	2.07	2.85**	-3.34**
14.	S-D-2 x Suraj	-9.34**	-0.30	1.39	-2.34**
15.	S-D-2 x RAH 1069	-7.00**	-5.55**	-2.00*	-1.67*
16.	S-D-2 x TCH 321	1.53	3.11*	2.85**	-3.34**
17.	G(T)-84 x BGDS 1033	-1.87	1.17	-3.9**	-12.04**
18.	G(T)-84 x CPD 1501	-2.74	1.52	0.00	-10.03**
19.	G(T)-84 x TCH 1716	2.22	-0.81	-7.89**	-3.68**
20.	G(T)-84 x TCH 1824	-9.77**	-8.56**	4.33**	-3.34**
21.	G(T)-84 x CCH 15-1	-6.64	-1.93	0.71	-5.35**
22.	G(T)-84 x Suraj	-9.74**	-0.74	0.35	-3.34**
23.	G(T)-84 x RAH 1069	1.76	-1.26	-7.00**	-6.69*
24.	G(T)-84 x TCH 321	-0.69	-0.59	-0.37	-10.37**
	S.E (d) ±	1.36	1.36	0.81	0.81
	CD @ 5%	2.75	2.75	1.64	1.64
	CD @1%	3.67	3.67	2.19	2.19

*, ** significant at 5% and 1% levels, respectively, BP = Better parent and SC = Standard check

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Table 2: Magnitude of heterosis over better parent (BP) and over standard check (SC) for fibre fineness and fibre strength in cotton (*G. hirsutum* L.)

S. No.	Crosses	Fibre fineness (mv)		Fibre strength (g/tex)	
		BP	SC	BP	SC
1.	GMS Gregg x BGDS 1033	-2.13**	9.52**	-1.62**	0.33
2.	GMS Gregg x CPD 1501	4.00**	23.81**	-5.05**	-6.62**
3.	GMS Gregg x TCH 1716	13.89**	-2.38**	-5.05**	-6.62**
4.	GMS Gregg x TCH 1824	4.35**	14.29**	-2.85**	1.66**
5.	GMS Gregg x CCH 15-1	-18.00**	-2.38**	0.67	-0.99*
6.	GMS Gregg x Suraj	8.16**	26.19**	0.34	-1.32**
7.	GMS Gregg x RAH 1069	0.00	9.52**	10.44**	8.61**
8.	GMS Gregg x TCH 321	2.00**	21.43**	-6.29**	-7.84**
9.	S-D-2 x BGDS 1033	-8.51**	2.38**	-4.87**	-2.98**
10.	S-D-2 x CPD 1501	-2.04**	14.29**	-6.16**	-9.27**
11.	S-D-2 x TCH 1716	25.00**	7.14**	-5.14**	-8.28**
12.	S-D-2 x TCH 1824	4.35**	14.29**	-11.08**	-6.95**
13.	S-D-2 x CCH 15-1	4.08**	21.43**	-4.45**	-7.62**
14.	S-D-2 x Suraj	2.04**	19.05**	3.05**	0.66
15.	S-D-2 x RAH 1069	-4.35**	4.76**	-8.50**	-10.93 **
16.	S-D-2 x TCH 321	-2.04**	14.29**	0.34	-2.98
17.	G(T)-84 x BGDS 1033	-2.22**	4.76**	-12.01**	-10.26 **
18.	G(T)-84 x CPD 1501	-8.89**	-2.38**	5.10**	2.32**
19.	G(T)-84 x TCH 1716	30.56**	11.9**	-8.50**	-10.93**
20.	G(T)-84 x TCH 1824	-2.22**	4.76**	-12.66**	-8.61**
21.	G(T)-84 x CCH 15-1	0.00	7.14**	2.04**	-0.66
22.	G(T)-84 x Suraj	-2.22**	4.76**	3.05**	0.66
23.	G(T)-84 x RAH 1069	13.33**	21.43**	-1.02*	-3.64**
24.	G(T)-84 x TCH 321	6.67**	14.29**	-2.72**	-5.30**
	S.E (d) ±	0.41	0.41	0.48	0.48
	CD @ 5%	0.83	0.83	0.98	0.98
	CD @ 1%	1.10	1.10	1.31	1.31

*, ** significant at 5% and 1% levels, respectively, BP = Better parent and SC = Standard check

Table 3: Best heterotic crosses and their performance for seed cotton yield per plant in cotton (*G. hirsutum* L.)

Best Crosses (P1 x P2)	Mean yield / Plant (g)	Standard heterosis (%)	Better parent heterosis (%)
S-D-2 x TCH 1716	105.67	17.63**	10.65
G(T)-84 x TCH 1716	103.83	15.58*	8.73
GMS Gregg x TCH 1716	103.33	15.03*	8.20
G(T)-84 x TCH 321	101.50	12.99*	17.79**
GMS Gregg x TCH 321	101.17	12.62*	17.41**
S-D-2 x TCH 321	100.83	12.24*	17.02**
S-D-2 x CCH 15-1	100.83	12.24*	24.74**

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

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