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Heterosis for seed cotton yield and other agro morphological traits in GMS based hybrids of upland cotton (*Gossypium hirsutum* L.)

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Abstract
A study was made in upland cotton to assess the extent of heterosis over standard check for seed cotton yield and its related attributes traits at three locations *viz*., Surat, Bharuch and Hansot. The standard heterosis varied from -36.83 to 15.95 per cent. The three hybrids viz., G (B) 20 x G.Cot.10, G (B) 20 x DHY-286-1 and LRK-516 x DHY-286-1 showed significant and positive standard heterosis, in which the cross G(B) 20 x G.Cot.10 showed maximum value of standard heterosis for seed cotton yield per plant and manifested heterotic effects for its contributing characters like number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight, and number of seeds per boll and seed index.

Keywords: Cotton, GMS, seed cotton yield, standard check, standard heterosis

Introduction
Cotton, the king of the fibre, is also called white gold. The increased productivity can be achieved by developing superior varieties/hybrids through genetic improvement and by proper management practices. Thus, the situation offers immense scope for geneticists in general and cotton breeders in particular both at national and state level. To meet the challenges of increasing productivity, *Gossypium hirsutum* L. offers better scope for genetic improvement among the four-cultivated species of cotton. Majority of cotton produced by *G. hirsutum* species is medium and long staple. This species has very high adaptability with rich diversity for yield and yield related characters. However, at present the hybrid cotton seed is being produced by cumbersome and laborious process of hand emasculation and pollination. Probably this single largest factor has affected its further expansion and its production is not within the means of average farmer. To overcome the high cost of hybrid cotton seed, use of male sterility (as in sorghum, pearl millet etc.) Could be the only answer in eliminating labour intensive manual emasculation. Use of male sterile lines appears to be advantageous since the maintenance of male sterile population for seed production is easier and more over sterility source under reference is stable. Cytoplasmic nuclear interaction affects the petal size and anther number which can be used as markers in identifying the parental lines and for ascertaining genetic purity.
At present the only stable and dependable CGMS source under various environment is of *G. harknessii* which in interaction with genome of *G hirsutum* produces male sterility. A single dominant gene 'Rf' from *G. harknessii* is essential for fertility restoration and fertility enhancement factor from *barbadense*. Information on the presence of commercially exploitable heterosis within the available conventional, GMS and CGMS lines, their general combining ability and stability of resultant cross combinations is highly useful in evolving early maturing and high yielding stable hybrids. Accordingly, the present study was planned and executed with producing GMS based hybrids.

Materials and methods
The present investigation was conducted with three complete sets of 24 *Gosypium hirsutum* entries comprising of 14 F_1s produced by GMS method, 7 females and 2 males and 1 check were evaluated during kharif 2002 at three locations *viz*., Surat, Bharuch and Hansot. The experiment was laid out in a *Randomized Complete Block design* (RBD) with three replications. The parents and F_1s with standard checks were represented by a single row plot of 14 plants, placed at 120 cm x 45 cm. All the agronomical practices and plant protection measures were followed as and when required to raise a good crop of cotton. The seeds of these parents were obtained from Main Cotton Research Station, Surat. For obtaining the cross

seeds, parents were grown at Main Cotton Research Station, Surat. The 7 females and 2 males were crossed in L x T mating design to obtain 14 crosses of conventional hybrids making it totally 14 crosses.All the F_1s and selfed seeds of parents were stored properly in thick paper bags for sowing in the next season at three locations.

Results

The estimates of heterosis measured as per cent increase or decrease over standard check (standard heterosis) in individual environment and on pooled basis are presented in Table 1a to 1d and results obtained are given below:

Table 1a: Estimates of standard heterosis for different agro morphological characters in cotton

	Days to 50 per cent flowering				Plant height (cm)				Monopodia per plant			
Crosses	**Loc-I**	**Loc-II**	**Loc-III**	**Pooled**	**Loc-I**	**Loc-II**	**Loc-III**	**Pooled**	**Loc-I**	**Loc-II**	**Loc-III**	**Pooled**
76 IH 20 x G.Cot.10	-18.72**	-12.63**	-19.25**	-16.78**	4.01	-4.77	-1.20	-0.69	64.23**	53.85**	-2.92	39.36**
76 IH 20 x DHY 286-1	-8.38	-3.89	-3.74	-5.37*	-1.14	7.87	-4.86	0.79	2.69	64.78**	0.00	22.09**
LH 900 x G.Cot.10	-3.46	-15.06**	-6.42	-8.39**	-32.91**	-32.74**	-41.72**	-35.66**	58.85**	21.46	-25.00	19.68*
LH 900 x DHY 286-1	-9.86*	-14.08**	-3.74	-9.40**	-22.96**	-29.37**	-34.85**	-29.29**	-46.15**	56.68**	-33.33*	-8.03
PH 93 x G.Cot.10	-26.11**	-21.36**	-22.46**	-23.32**	-3.85	-7.74	-1.69	-4.51	53.85**	42.91**	27.92	41.77**
PH 93 x DHY 286-1	-8.38	-9.23*	-10.69**	-9.40**	-2.19	4.18	-12.86*	-3.39	10.38	-21.96*	25.00	1.61
LRA 5166 x G.Cot.10	-19.71**	-18.45**	-22.46**	-20.13**	-34.33**	-40.58**	-35.03**	-36.71**	43.46**	34.82*	-50.00**	10.84
LRA 5166 x DHY 286-1	-9.86	-11.65**	0.00	-7.39**	-32.83**	-29.17**	-27.16**	-29.76**	48.85**	-43.32*	50.00**	18.88**
LRK 516 x G.Cot.10	-33.01**	-26.21**	-19.78**	-26.31**	-43.36**	-36.66**	-51.31**	-43.57**	-51.15**	10.53	44.58**	0.00
LRK 516 x DHY 286-1	-14.29**	-12.15**	-6.95*	-11.24**	-46.20**	-46.30**	-55.66**	-49.25**	35.77*	16.19	77.92**	42.97**
G(B) 20 x G.Cot.10	-23.16**	-15.54**	-18.18**	-18.96**	-0.03	4.98	3.49	2.82	58.85**	56.68**	55.42**	57.03**
G(B) 20 x DHY 286-1	-5.91	0.96	-3.24	-2.86	-26.74**	-25.53**	-3.16	-18.8**	30.77*	13.36	50.00**	31.33**
G.Cot.100 x G.Cot.10	-7.39	0.00	10.17**	0.67	4.16	-10.92*	3.08	-1.41	20.38	21.46	30.42*	24.10**
G.Cot.100 x DHY 286-1	11.32*	5.33	15.51**	10.57**	-4.53	1.48	-21.01**	-7.70*	7.69	-16.19	16.67	2.81
S.E. ±	2.96	3.06	2.05	1.57	6.53	7.15	6.69	3.92	0.39	0.36	0.35	0.21

Table 1b: Estimates of standard heterosis for different agro morphological characters in cotton

	Sympodia per plant				Number of bolls per plant				Boll weight (g)			
Crosses	**Loc-I**	**Loc-II**	**Loc-III**	**Pooled**	**Loc-I**	**Loc-II**	**Loc-III**	**Pooled**	**Loc-I**	**Loc-II**	**Loc-III**	**Pooled**
76 IH 20 x G.Cot.10	-34.18**	0.29	1.05	-11.53	-11.22	8.21	23.12**	5.81	15.50**	10.71	-20.98**	2.37
76 IH 20 x DHY 286-1	-29.01**	24.41*	2.10	-0.59	-15.83**	26.06**	11.75	7.52*	39.51**	22.92**	-15.74*	16.29**
LH 900 x G.Cot.10	-21.55*	-36.70**	16.05	-16.31	-29.95**	-30.13**	-35.59**	-31.64**	15.81**	11.90*	28.52**	18.45**
LH 900 x DHY 286-1	2.28	19.73	-31.83**	-1.08	-2.30	2.44	2.75	0.90	37.39**	32.14**	15.41*	28.66**
PH 93 x G.Cot.10	-32.46**	-25.48*	16.41	-15.90*	8.00	-12.84*	11.01	1.21	8.81	10.71	7.21	8.87**
PH 93 x DHY 286-1	-18.66	-46.57**	-23.81*	-30.32**	-11.68	-26.80	45.14**	-0.86	25.23**	10.12	-24.92**	4.23
LRA 5166 x G.Cot.10	-20.69	19.48	-19.24	-5.59	6.15	10.65	-0.91	5.76	23.10**	30.36**	4.26	19.69**
LRA 5166 x DHY 286-1	-12.07	-3.00	-14.68	-9.50	-9.38	-2.03	20.01**	1.81	34.65**	-1.19	-16.07**	6.39*
LRK 516 x G.Cot.10	14.96	-5.18	-7.71	0.90	-19.98**	0.28	-2.92	-7.62*	6.38	23.51**	39.67**	22.78**
LRK 516 x DHY 286-1	22.97*	15.37	-33.19**	23.11**	4.91	-8.08	26.07**	6.24	48.33**	26.19**	20.33**	31.75**
G(B) 20 x G.Cot.10	15.22	-9.29	11.54	5.23	27.65**	-3.18	25.32**	15.67**	18.54**	30.36**	25.90**	24.95**
G(B) 20 x DHY 286-1	11.21	9.33	6.61	1.40	-7.37	-13.12*	52.68**	7.83*	42.86**	44.35**	-19.67**	23.71**
G.Cot.100 x G.Cot.10	14.96	-5.18	3.51	2.30	1.08	-5.92	-7.87	-4.07	37.39**	22.32**	41.31**	33.30**
G.Cot.100 x DHY 286-1	9.78	-4.93	27.95*	9.59	9.06	-12.41	32.87**	8.05*	4.26	30.36**	-21.31**	5.46
S.E. ±	2.43	2.79	2.15	1.43	2.46	2.71	2.32	1.44	0.17	0.19	0.18	0.10

Table 1c: Estimates of standard heterosis for different agro morphological characters in cotton

	Number of seeds per boll				Seed index (g)				Ginning percentage (%)			
Crosses	Loc-I	Loc-II	Loc-III	Pooled	Loc-I	Loc-II	Loc-III	Pooled	Loc-I	Loc-II	Loc-III	Pooled
76 IH 20 x G.Cot.10	-11.36	-13.96	-7.56	-11.04*	2.13	-1.92	-16.22	-5.06	10.70	14.77*	12.26**	12.55**
76 IH 20 x DHY 286-1	-29.12**	42.86**	33.82**	15.51**	26.25*	0.48	26.08*	17.19**	-4.85	3.62	15.42**	4.65
LH 900 x G.Cot.10	10.65	-36.50**	-14.97	-13.61*	15.88	11.64	-3.11	8.47	-10.95	10.97	-12.73	-4.44
LH 900 x DHY 286-1	2.40	-3.54	19.51	5.83	10.00	23.29*	9.96	14.66*	3.69	2.33	6.74	4.27
PH 93 x G.Cot.10	-17.75	-23.55**	39.21**	-1.54	-0.8	-12.36	-2.30	-5.31	20.51**	32.60**	9.37*	20.74**
PH 93 x DHY 286-1	8.74	-23.86**	-33.40**	-15.83**	-5.58	33.25**	11.76	13.40*	14.89*	24.67**	3.36	14.21**
LRA 5166 x G.Cot.10	2.40	-10.43	-17.95	-8.50	10.88	-3.60	38.78**	14.54*	9.11	15.58*	-2.57	7.31*
LRA 5166 x DHY 286-1	22.64*	-9.72	-18.42	-1.45	10.38	-14.41	-27.43*	-10.11	8.37	-8.79	5.84	1.94
LRK 516 x G.Cot.10	24.59*	-4.68	25.65*	14.93**	19.63	-1.20	39.59**	18.58**	-2.18	4.67	-2.48	-0.04
LRK 516 x DHY 286-1	12.43	24.30**	34.15**	23.43**	33.75**	12.85	25.27*	23.77**	-4.57	-8.31	6.13	-2.22
G(B) 20 x G.Cot.10	21.17*	7.51	25.51*	17.91**	12.88	22.45*	10.81	15.55*	12.34*	-2.57	13.58**	7.92*
G(B) 20 x DHY 286-1	33.02**	35.09**	19.98	29.53**	-10.88	21.61*	9.46	6.95	-4.60	-8.61	6.98	-2.05
G.Cot.100 x G.Cot.10	8.88	17.10*	39.82**	21.57**	10.88	9.60	38.78**	19.09**	6.16	-11.30	4.23	-0.16
G.Cot.100 x DHY 286-1	10.96	7.95	-14.17	1.90	12.50	46.82**	2.70	21.49**	4.91	18.84**	14.74**	12.70**
S.E. ±	2.34	1.69	2.28	1.22	0.78	0.87	0.93	0.50	2.04	2.11	1.50	1.10

Table 1d: Estimates of standard heterosis for different agro morphological characters in cotton

	Seed cotton yield per plant (g)				2.5 per cent span length (mm)				Fibre strength (g/tex)			
Crosses	Loc-I	Loc-II	Loc-III	Pooled	Loc-I	Loc-II	Loc-III	Pooled	Loc-I	Loc-II	Loc-III	Pooled
76 IH 20 x G.Cot.10	-37.48**	-2.37	-22.79**	-19.95**	-19.52**	-9.24	-17.29**	-15.48**	-2.41	6.57	-13.84	-3.36
76 IH 20 x DHY 286-1	-30.68**	26.73**	-12.85*	-3.60	-13.02**	-11.00*	-12.76*	-12.26**	-1.39	14.94	-6.29	2.24
LH 900 x G.Cot.10	-39.04**	-37.08**	-33.41**	-36.83**	-16.40**	-17.78**	-13.31*	-15.87**	0.67	-4.67	-10.17	-4.74
LH 900 x DHY 286-1	-9.85*	1.66	-11.60*	-5.78*	-5.72	-2.60	-11.57*	-6.58*	3.39	4.38	-4.04	1.23
PH 93 x G.Cot.10	-28.49**	-22.08**	-8.72	-20.94**	-14.19**	-7.40	-16.88**	-12.84**	-7.04	-8.21	-6.66	-7.27
PH 93 x DHY 286-1	-15.75**	-35.01**	-7.97	-21.34**	-18.99**	-9.02	-21.94**	-16.69**	-3.08	-1.64	-7.71	-4.21
LRA 5166 x G.Cot.10	-2.65	5.66	-22.09**	-4.33	-13.89**	-13.71*	-12.12*	-13.27**	3.08	6.35	3.46	4.24
LRA 5166 x DHY 286-1	-12.96**	-26.30**	-17.36**	-19.32**	-12.88**	-11.25*	-19.26**	-14.41**	-8.06	2.19	-13.63	-6.64
LRK 516 x G.Cot.10	-24.94**	-5.02	-2.03	-11.29**	-11.51**	-6.23	-13.69**	-10.48**	-5.50	16.20	-1.94	2.66
LRK 516 x DHY 286-1	16.08**	-6.41	28.53**	10.42**	-18.08**	-11.47	-14.24**	-14.69**	3.39	11.66	4.72	6.51
G(B) 20 x G.Cot.10	3.46	22.45**	23.24**	15.95**	-15.46**	-17.67**	-4.83	-12.76**	-3.08	1.64	3.99	0.81
G(B) 20 x DHY 286-1	-0.02	1.75	18.80*	4.19	-10.67**	-16.97**	-10.26*	-12.59**	-2.77	7.12	4.20	2.76
G.Cot.100 x G.Cot.10	-3.66	-14.80**	8.99	-4.81	-17.04**	-21.55**	-9.41	-16.05**	-2.93	13.68	-1.94	2.76
G.Cot.100 x DHY 286-1	-14.90	-17.47**	-13.09	-15.45**	-21.00**	-11.33*	-19.04**	-17.23**	-1.95	3.45	-7.87	-2.20
S.E. $\pm$	6.51	7.60	5.40	3.79	1.13	1.40	1.33	0.74	1.46	2.18	1.34	0.98

Days to 50 per cent flowering

In GMS based hybrids, the heterosis over standard check ranged from -26.51 to 15.10 per cent. Number of crosses which showed significant negative standard heterosis were eleven. The crosses viz, LRK 516 x G. Cot.10, PH 93 x G. Cot.10, G(B) 20 x G. Cot.10 and 76 IH 20 x G. Cot.10 recorded maximum values of standard heterosis.

Plant height (cm)

In GMS based hybrids, standard heterosis ranged from -49.25 to 2.82 per cent. Eight hybrids exhibited significant and negative heterosis over standard check. Three crosses viz., LRK 516 x DHY 286-1, LRK 516 x G.Cot.10 and LRA 5166 x G.Cot.10 recorded maximum values of standard heterosis in desired direction.

Number of monopodia per plant

In GMS based hybrids, the heterosis over standard check ranged from -8.03 to 57.03 per cent. Nine crosses recorded significant and positive heterosis over standard check. The best cross combinations G(B) 20 x G. Cot.10, LRK 516 x DHY 286-1, PH 93 x G. Cot.10 and 76 IH 20 x G. Cot.10 registered maximum values of standardheterosis.

Number of sympodia per plant

In GMS based hybrids, the standard heterosis ranged from -30.32 to 23.11 per cent. In standard heterosis, only one hybrid LRK 516 x DHY 286-1 showed significant and positive heterosis.

Number of bolls per plant

In hybrids developed by GMS method, the standard heterosis ranged between -31.64 and 15.67 per cent. Four crosses viz., G(B) 20 x G. Cot.10, G(B) 20 x DHY 286-1, G. Cot.100 x DHY 286-1 and 76 IH 20 x DHY 286-1 reported significant and positive standard heterosis.

Boll weight (g)

In GMS based hybrids, the standard heterosis fluctuated between 2.37 to 33.30 per cent and 11 hybrids reported significant and positive standard heterosis, in which crosses viz., G.Cot.100 x G.Cot.10, LRK 516 x DHY 286-1, G(B) 20 x DHY 286-1, G(B) 20 x G.Cot.10 and LH 900 x DHY 286-1 showed maximum values of standard heterosis.

Number of seeds per boll

In GMS based crosses, standard heterosis ranged from -15.83 to 29.53 per cent. Six hybrids showed positive and significant standard heterosis. The crosses viz., G (B) 20 x DHY 286-1, LRK 516 x DHY 286-1, G. Cot.100 x G. Cot.10, G (B) 20 x G. Cot.10 and 76 IH 20 x DHY 286-1 exhibited maximum values of standardheterosis.

Seed index (g)

In crosses developed by GMS method, heterosis over standard check varied from -10.11 to 23.77 per cent. Nine crosses exhibited significant and positive heterosis over standard check. Five crosses viz., LRA 5166 x DHY 286-1, G.Cot.100 x DHY 286-1, G.Cot.100 x G.Cot.10, LRA 5166 x G.Cot.10 and 76 IH 20 x DHY 286-1 recorded maximum values of heterosis over standard check.

Ginning percentage (%)

In GMS based crosses, standard heterosis ranged from -4.44 to 20.74 per cent. Six hybrids viz., PH 93 x G. Cot.10, PH 93 x DHY 286-1, G. Cot.100 x DHY 286-1, 76 IH 20 x G. Cot.10 and G (B) 20 x G. Cot.10 exhibited significant and positive standardheterosis.

Seed cotton yield per plant (g)

In GMS based hybrids, standard heterosis varied from -36.83 to 15.95 per cent. Two hybrids showed significant and positive standard heterosis. Two crosses viz., G(B) 20 x G.Cot.10 and LRK 516 x DHY 286-1 showed maximum values of standard heterosis.

2.5 per cent span length (mm)

In crosses developed by GMS method, standard heterosis ranged from -17.23 to -6.58 per cent. None of the hybrids recorded significant and positive standard heterosis.

Fibre strength (g/tex)

In GMS based hybrids, heterosis over standard check varied from -7.27 to 6.51 per cent. None exhibited positive and significant standard heterosis.

Discussion

The heterotic response of an F_1 is indicative of genetic diversity among the parents involved (Moll *et al*., 1962). In the present investigation, the standard heterosis varied from -36.83 to 15.95 per cent, where two hybrids showed significant and positive standard heterosis, whereas the cross G(B) 20 x

G. Cot.10 recorded maximum values of standard heterosis (15.95 per cent). Heterosis for seed cotton yield in GMS based hybrids was also reported by Santhanam *et al*. (1972), Srinivasan and Gururajan (1973, 1975, 1978, 1983) [34], Bhale and Bhat (1990) [4], Rajput *et al*.(1997), Chauhan *et al*. (1999), Kajjidoni *et al*. (1999) [13], Patel *et al*.(2000), Tuteja *et al*. (2000) [38] and Tuteja and Singh (2001) [37].

The three crosses viz., G (B) 20 x G.Cot.10, G (B) 20 x DHY-286-1 and LRK-516 x DHY-286-1 performed better for standard heterosis, where their SCA effects were also significantly higher. It was observed that hybrids showing high heterosis for seed cotton yield per plant in general, also manifested heterotic effects for its contributing characters like number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight, number of seeds per boll and seed index. The standard heterosis ranged from -36.83 to 15.95 per cent. Similar results have been reported by Kajjidoni *et al*. (1999) [13], Bhaleand Bhat (1990) [4], Srinivasan and Gururajan (1983) [35], Tuteja *et al*. (2000) [38], Tuteja and Singh (2001) [37].

Singh and Murty (1971) [32] reported heterosis to the extent of -76.2 to 137.2 per cent and -87.4 to 68.2 per cent over mid parent and better parent respectively in intra specific crosses of *G.hirsutum*L. The maximum heterosis for yield in intra specific crosses was observed by Patel (1974). He reported 148 to 184 per cent heterobeltiosis for seed cotton yield in Hybrid-4. Vadodaria and Patel (1995) [39] reported high heterosis to the extent of -8.30 to 15.93 per cent and -23.94 to 112.09 per cent over better parent and standard check respectively in intraspecific crosses of *G. hirsutum* L.

The moderate to high heterosis observed in present study has also been reported by several workers for number of bolls per plant (Desai *et al*., 1982 [8]; Duhoon *et al*., 1983 [10]; Tiwari *et al*., 1987 [36]; Kalsy and Garg 1989 [14]; Duhoon 1990 [9]; Patil *et al*., 1991 [21]; Phundan Singhs and Narayanan 1992; Siddique 1993 [30] and Bhatade and Rajewar 1994) [5]; boll weight (Desai *et al*., 1982 [8]; Patil and Chopde 1985 [23]; Duhoon 1990 [9]; Patil *et al*., 1991 [21]; Pundan Singh and Narayanan 1992 and Bhatade *et al.* 1994) [6]; number of monopodia per plant (Khan and Ali 1980 [16]; Duhoon *et al*., 1983) [10]; number of sympodia per plant (Singh and Singh 1981 [33]; Duhoon *et al*., 1983) [10]; seed index (Singh and Singh 1981 [33], Phundan Singh 1982; Nadarajan and SreeRangasamy 1990 [19]; Siddiqui 1993 [30]; Bhatade *et al.* 1994) [5]; ginning percentage (Singh and Singh 1981 [33]; Phundan Singh 1982; Duhoon *et al*., 1983 [10]; Tiwari *et al*., 1987 [36]; Duhoon 1990 [9], Gururajan and Basu 1992 [12]; Phundan Singh and Narayanan 1992; Siddiqui 1993 [30] and Bhatade and Rajewar 1994) [6]; early maturity (Patil and Sheriff 1980 [22], Singh and Singh 1981 [33], Patil and Chopde 1985 [23], Siddiqui 1993 [30], Vadodaria and Patel 1995) [39]; plant height (Singh and Singh 1981 [33], Patil and Chopde 1985 [23], Bhatade and Rajewar 1994) [6]; fibre length (Prakash 1982 [24], Gururajan and Basu 1992 [12], Duhoon *et al*., 1983 [10], Duhoon 1990 [9], Sidiqui 1993 [30], Bhatade *et al.* 1994) [5] and fibre strength (Prakash 1982 [24]; Singh and Narayanan 1992) [26].

Prospects for successful production of pure and low cost first generation hybrid seed using GMS system appears to be bright in near future. This system not only circumuent emasculation but may even set aside the necessity of hand pollination by developing effective cross pollination system, possibly developing insect pollinators or at least by some mechanical device.

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