

Original Research Article

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Comparative Study of Heterosis for Seed Cotton Yield and Other Agro Morphological Traits in Conventional, GMS and CMS 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. In all the three methods (conventional, GMS and CMS-R), significant standard heterosis and high *per se* performance with regard to seed cotton yield and its components was recorded by viz., G (B) 20 x G.Cot.10, G (B) 20 x DHY-286-1 and LRK-516 x DHY-286-1, 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. However the magnitude of heterosis was comparatively higher in conventional crosses followed by GMS based crosses and CMS-R based crosses.

Keywords

Cotton,
Conventional,
GMS, CMS Seed
cotton yield,
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Standard heterosis

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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 conventional, GMS and CMS based hybrids.

Materials and Methods

The present investigation was conducted with three complete sets of 52 *Gosypium hirsutum* entries comprising of 42 F₁s produced by conventional, GMS and CMS method/system, 7 females and 2 males and 1 check were evaluated 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 F₁s 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, 14 crosses of GMS hybrids, 14 crosses of CMS hybrids making it totally 42 crosses. All the F₁s and selfed seeds of parents were stored properly in thick paper bags for sowing in the next season at three locations.

Results and Discussion

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 4.22 to 4.33 and results obtained are given below:

Days to 50 per cent flowering

In conventional hybrids, standard heterosis ranged from -32.55 to 15.10 per cent. Eight crosses exhibited significant negative heterosis over standard check. Among eight crosses LRK 516 x G.Cot.10, PH 93 x G.Cot.10, G.Cot.100 x G.Cot.10 and LRA 5166 x G.Cot.10 recorded maximum values of standard heterosis.

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.

In CMS based hybrids, standard heterosis ranged from -32.55 to 6.20 per cent, whereas 13 crosses showed significant and negative standard heterosis. The crosses viz., LRK 516 x G.Cot.10, PH 93 x G.Cot.10, G(B) 20 x G.Cot.10 and LRA 5166 x G.Cot.10 exhibited maximum values of standard heterosis.

Plant height (cm)

In hybrids developed by conventional method, the heterosis over standard check ranged from -41.77 to 7.30 per cent. The crosses showing significant and negative standard heterosis were eight. Three crosses viz., LRK 516 x G.Cot.10, LRK 516 x DHY 286-1 and LRA 5166 x G.Cot.10 recorded maximum values of standard heterosis.

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.

In hybrids developed by CMS method, the magnitude of heterosis ranged from -34.54 to 10.48 per cent over standard check. Seven crosses showed significant and negative standard heterosis. The crosses viz., LRK 516 x G.Cot.10, LRK 516 x DHY 286-1 and LH 900 x G.Cot.10 showed maximum values of standard heterosis.

Number of monopodia per plant

In conventional hybrids, the standard heterosis varied from -18.07 to 64.26 per cent and 10 hybrids showed significant and

positive standard heterosis. The crosses viz., G(B) 20 x G.Cot.10, LRK 516 x DHY 286-1, G(B) 20 x DHY 286-1 and G.Cot.100 x DHY-286-1 showed maximum values of standard heterosis.

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 standard heterosis. In CMS based hybrids, the standard heterosis ranged from -29.32 to 44.58 per cent. Eight hybrids showed significant and positive standard heterosis. The crosses viz, G(B) 20 x G.Cot.10, G(B) 20 x DHY 286-1, 76 IH 20 x G.Cot.10, G.Cot.100 x G.Cot.10 and LRK 516 x DHY 286-1 recorded maximum standard heterosis.

Number of sympodia per plant

In conventional hybrids, heterosis over standard check fluctuated between -29.32 and 14.01 per cent and only two crosses viz., G(B) 20 x G.Cot.10 and G.Cot.100 x DHY 286-1 showed significant and positive standard heterosis.

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.

In CMS based crosses, the standard heterosis varied from -27.75 to 12.03 per cent and none of the crosses showed significant superiority over the standard check in desirable direction.

Number of bolls per plant

In hybrids developed by conventional method, the heterosis over standard check ranged from -12.62 to 27.14 per cent. The

crosses showing significant and positive standard heterosis were eight. Among these the crosses viz., LRA 5166 x DHY 286-1, LRA 5166 x G.Cot.10, G(B) 20 x G.Cot.10, PH 93 x G.Cot.10 and 76 IH 20 x DHY 286-1 showed maximum values of standard heterosis.

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.

In crosses developed by CMS system, standard heterosis varied from -21.38 to 15.55 per cent. Three crosses viz., G(B) 20 x G.Cot.10, G.Cot.100 x DHY 286-1 and PH 93 x DHY 286-1 showed significant and positive standard heterosis.

Boll weight (g)

In conventional hybrids, standard heterosis ranged from -5.67 to 24.23 per cent. Twelve crosses exhibited significant and positive heterosis over standard check. The crosses viz., G.Cot.100 x G.Cot.10, G(B) 20 x G.Cot.10, G(B) 20 x DHY 286-1, LRK 516 x G.Cot.10 and LH 900 x DHY 286-1 recorded maximum values of standard heterosis.

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.

In CMS based crosses, heterosis over standard check varied from -7.53 to 29.59 per cent. The crosses which showed significant and positive standard heterosis were nine. The

crosses viz., G.Cot.100 x G.Cot.10, G(B) 20 x DHY 286-1, LRK 516 x DHY 286-1, LH 900 x DHY 286-1 and G(B) 20 x G.Cot.10 registered maximum values of standard heterosis.

Number of seeds per boll

In conventional crosses, heterosis over standard check ranged from -24.56 to 18.77 per cent and six crosses exhibited significant and positive standard heterosis, in which five crosses viz., G.Cot.100 x DHY 286-1, LRK 516 x DHY 286-1, G(B) 20 x DHY 286-1, LH 900 x DHY 286-1, LRA 5166 x DHY 286-1 showed maximum values.

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 standard heterosis.

In CMS based hybrids, the standard heterosis varied from -24.51 to 32.65 per cent. Three crosses viz., G(B) 20 x DHY 286-1, G.Cot.100 x G.Cot.10 and G(B) 20 x G.Cot.10 showed significant and positive standard heterosis.

Seed index (g)

In hybrids developed by conventional method, standard heterosis varied from -11.63 to 26.68 per cent. Five hybrids viz., G.Cot.100 x DHY 286-1, LRK 516 x G.Cot.10, LRK 516 x DHY 286-1, G.Cot.100 x G.Cot.10 and 76 IH 20 x G.Cot.10 showed positive and significant standard heterosis.

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.

In hybrids developed by CMS system, standard heterosis ranged between -13.27 to 28.95 per cent. Seven hybrids showed significant and positive standard heterosis, in which five crosses viz., G.Cot.100 x DHY 286-1, G(B) 20 x DHY 286-1, G(B) 20 x G.Cot.10, G.Cot.100 x G.Cot.10 and LH 900 x DHY 286-1 showed maximum values.

Ginning percentage (%)

In conventional hybrids, heterosis over standard check varied from -6.42 to 29.69 and five hybrids viz., PH 93 x DHY 286-1, PH 93 x G.Cot.10, LRA 5166 x G.Cot.10, G.Cot.100 x DHY 286-1 and 76 IH 20 x G.Cot.10 exhibited significant and positive standard heterosis.

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 standard heterosis.

In CMS based hybrids, heterosis over standard check ranged from -8.40 to 15.79 per cent.

Three hybrids viz., PH 93 x G.Cot.10, PH 93 x DHY 286-1 and LRK 516 x G.Cot.10 exhibited significant and positive heterosis over standard check.

Seed cotton yield per plant (g)

In conventional crosses, standard heterosis ranged from -23.47 to 21.45 per cent. 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 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.

In CMS based crosses, heterosis over standard check ranged from -39.17 to 9.36 per cent. Only one hybrid G(B) 20 x G.Cot.10 exhibited significant and positive standard heterosis.

per cent span length (mm)

In hybrids developed by conventional method, heterosis over standard check ranged from -19.48 to -2.51 per cent. None of the crosses showed positive and significant heterosis over standard check.

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.

In CMS based hybrids, heterosis over standard check varied from -13.44 to -4.69 per cent. None showed positively significant heterosis over standard check.

Fibre strength (g/tex)

In conventional hybrids, standard heterosis ranged from -5.37 to 9.95 per cent., Two hybrids viz., LRK 516 x G.Cot.10 and G.Cot.100 x G.Cot.10 showed significant and positive heterosis over standard check.

Table.1 Estimates of standard heterosis

Method	days to 50 per cent flowering			plant height (cm)			number of monopodia per plant			sympodia per plant		
	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS
Crosses	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
76 IH 20 x G.Cot.10	-11.57**	-16.78**	-19.80**	7.30*	-0.69	10.48**	30.12**	39.36**	41.27**	-29.32**	-11.53	-15.14*
76 IH 20 x DHY 286-1	-1.85	-5.37*	-11.24**	3.99	0.79	4.96	-7.23	22.09**	-16.87*	-12.30*	-0.59	-14.01*
LH 900 x G.Cot.10	-7.22**	-8.39**	-15.27**	-33.17**	-35.66**	-29.87**	-13.25	19.68*	12.45	-24.73**	-16.31	-11.22
LH 900 x DHY 286-1	-2.51	-9.40**	-11.57**	-33.28**	-29.29**	-25.14**	32.96**	-8.03	14.06	-19.82**	-1.08	1.62
PH 93 x G.Cot.10	-20.98**	-23.32**	-29.03**	-2.72	-4.51	-1.17	33.73**	41.77**	23.29**	-9.91	-15.90*	-27.75**
PH 93 x DHY 286-1	-5.71*	-9.40**	-15.44**	-5.97	-3.39	-4.74	-18.07*	1.61	-29.32**	4.32	-30.32**	-4.59
LRA 5166 x G.Cot.10	-16.10**	-20.13**	-23.49**	-34.78**	-36.71**	-21.87**	40.16**	10.84	5.22	5.90	-5.59	-11.22
LRA 5166 x DHY 286-1	-0.67	-7.39**	-8.22**	-28.71**	-29.76**	-10.26*	23.29**	18.88**	40.16**	-16.93**	-9.50	-8.51
LRK 516 x G.Cot.10	-32.55**	-26.31**	-32.55**	-41.77**	-43.57**	-34.54**	9.64	0.00	-14.46**	-19.19	0.90	-6.62
LRK 516 x DHY 286-1	-10.58**	-11.24**	-19.30**	-39.71**	-49.25**	-33.44**	60.64**	42.97**	40.16**	8.11	23.11**	12.03
G(B) 20 x G.Cot.10	-16.95**	-18.96**	-24.33**	0.97	2.82	5.94	64.26**	57.03**	44.58**	14.01*	5.23	-0.90
G(B) 20 x DHY 286-1	0.16	-2.86	-5.37*	-20.76**	-18.8**	-11.05**	44.58**	31.33**	44.58**	7.30	1.40	7.61
G.Cot.100 x G.Cot.10	4.53	0.67	-4.70*	0.00	-1.41	3.26	19.68*	24.10**	40.16**	8.51	2.30	-3.92
G.Cot.100 x DHY 286-1	15.10**	10.57**	6.20**	-10.36**	-7.70*	-0.05	44.58**	2.81	30.12**	13.51*	9.59	-17.12*
S.E. ±	1.64	1.57	1.52	4.18	3.92	4.06	0.21	0.21	0.20	1.29	1.43	1.50

Method	days to 50 per cent flowering			plant height (cm)			number of monopodia per plant			sympodia per plant		
	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Range of heterosis	-32.55to	-26.51to	-32.55to	-41.77to	-49.25to	-34.54to	-18.07to	-8.03to	-29.32to	-29.32to	-30.32to	-27.75to
	15.10	10.57	6.20	7.30	2.8	10.48	64.26	57.03	44.58	14.01	23.11	12.03
No. of significant crosses	8	11	13	8	8	7	10	9	8	2	1	0
Best crosses	9,5,11,7	9,5,11,1	9,5,11,7,	9,10,7	10,9,7	9,10,3	11,10,12	11,10,5,	11,12,1	11,14	10	0
							14	1	13,10			

Table.2 Estimates of standard heterosis

Method	Number of bolls per plant			Boll weight (g)			Number of seeds per boll			Seed index (g)		
	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS
Crosses	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
76 IH 20 x G.Cot.10	2.38	5.81	-19.57**	6.39*	2.37	-2.58	-5.47	-11.04*	-17.87**	14.92*	-5.06	-13.27*
76 IH 20 x DHY 286-1	8.00*	7.52*	5.19	15.98**	16.29**	-2.27	8.86	15.51**	-6.24	3.29	17.19**	3.79
LH 900 x G.Cot.10	2.64	-31.64**	-21.38**	20.00**	18.45**	7.32*	-4.88	-13.61*	-24.51**	-11.63	8.47	-8.09
LH 900 x DHY 286-1	-2.86	0.90	-15.76**	29.28**	28.66**	18.76**	14.52**	5.83	-4.88	11.63	14.66*	12.14*
PH 93 x G.Cot.10	8.83**	1.21	-0.64	9.79**	8.87**	-2.89	-24.56**	-1.54	-21.85**	-9.10	-5.31	0.23
PH 93 x DHY 286-1	6.93*	-0.86	15.29**	-5.67	4.23	-7.53*	-15.42**	-15.83**	-6.06	-4.80	13.40*	-3.67
LRA 5166 x G.Cot.10	14.81**	5.76	-6.88	12.58**	19.69**	11.34**	9.14	-8.50	-12.44*	-2.91	14.54*	12.90*
LRA 5166 x DHY 286-1	27.14**	1.81	5.55	-1.03	6.39*	-0.10	13.61*	-1.45	-10.76	-9.23	-10.11	-0.88
LRK 516 x G.Cot.10	-12.62	-7.62*	-5.98	30.82**	22.78**	6.39*	-4.93	14.93**	-11.71	26.04**	18.58**	5.18
LRK 516 x DHY 286-1	11.05**	6.24	1.17	24.64**	31.75**	21.55**	20.26**	23.43**	5.74	17.07--	23.77**	12.39*
G(B) 20 x G.Cot.10	12.29**	15.67**	19.90**	32.99**	24.95**	13.20**	13.84*	17.91**	11.76*	11.38	15.55*	18.33**
G(B) 20 x DHY 286-1	11.33**	7.83*	-8.36*	30.52**	23.71**	28.04**	18.36**	29.53**	32.65**	11.50	6.95	25.92**
G.Cot.100 x G.Cot.10	4.02	-4.07	-3.33	34.23**	33.30**	29.59**	-2.80	21.57**	16.51**	16.36**	19.09**	16.69**
G.Cot.100 x DHY 286-1	1.05	8.05*	15.55**	16.91**	5.46	13.51**	18.77**	1.90	10.67	26.68**	21.49**	28.92**
S.E. ±	1.61	1.44	1.53	0.10	0.10	0.10	1.20	1.22	1.32	0.49	0.50	0.47

Method	Number of bolls per plant			Boll weight (g)			Number of seeds per boll			Seed index (g)		
	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Range of heterosis	-12.62to	-31.64to	-21.38to	-5.67to	2.37to	-7.53to	-24.56to	-15.83to	-24.51to	-11.63to	-10.11to	-13.27to
	27.14	15.67	15.55	34.23	33.30	29.59	18.77	29.53	32.65	26.68	23.77	28.95
No. of significant crosses	8	4	3	12	11	9	6	6	3	5	9	7
Best crosses	8,7,11,5,	11,12,14	11,14,6	13,11,12	13,10,12	13,12,10	14,10,12	12,10,13	12,13,11	14,9,10,	8,14,13,	14,12,11
	2	2		9,4	11,4	4,11	4,8	11,2		13,1	7,2	13,4

Table.3 Estimates of standard heterosis

Method	Ginning percentage (%)			Seed cotton yield per plant (g)			2.5 per cent span length (mm)			Fibre strength (g/tex)		
	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS
Crosses	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
76 IH 20 x G.Cot.10	7.42*	12.55**	-2.34	-14.89**	-19.95**	-39.17**	-12.57**	-15.48**	-9.91**	-0.51	-3.36	3.29
76 IH 20 x DHY 286-1	4.39	4.65	-2.69	-11.17**	-3.60	-23.92**	-13.87**	-12.26**	-13.12**	-1.41	2.24	-5.95
LH 900 x G.Cot.10	1.88	-4.44	-7.30	-13.05**	-36.83**	-38.11**	-14.37**	-15.87**	-6.83*	-1.30	-4.74	8.36*
LH 900 x DHY 286-1	1.33	4.27	-3.51	1.64	-5.78*	-24.31**	-19.48**	-6.58*	-5.37	1.02	1.23	8.36*
PH 93 x G.Cot.10	21.15**	20.74**	15.79**	-15.42**	-20.94**	-29.28**	-15.44**	-12.84**	-21.23**	0.76	-7.27	-11.44**
PH 93 x DHY 286-1	29.69**	14.21**	14.39**	-23.47**	-21.34**	-16.15**	-12.16**	-16.69**	-12.51**	5.37	-4.21	5.14
LRA 5166 x G.Cot.10	14.07**	7.31*	0.31	5.67	-4.33	-17.11**	-7.16*	-13.27**	-8.94**	0.02	4.24	-1.88
LRA 5166 x DHY 286-1	-1.38	1.94	3.78	-5.11	-19.32**	-18.97**	-10.44**	-14.41**	-13.44	5.56	-6.64	7.73*
LRK 516 x G.Cot.10	-0.51	-0.04	9.26**	-10.32**	-11.29**	-25.27**	-5.91*	-10.48**	-8.87**	9.95**	2.66	-7.53
LRK 516 x DHY 286-1	5.50	-2.22	3.49	6.75*	10.42**	4.51	-16.55**	-14.69**	-13.34**	-1.36	6.51	2.45
G(B) 20 x G.Cot.10	1.56	7.92*	-8.40**	21.45**	15.95**	9.36**	-13.98**	-12.76**	-7.94**	4.72	0.81	3.08
G(B) 20 x DHY 286-1	-4.64	-2.05	2.70	17.37**	4.19	1.41	-18.27**	-12.59**	-7.30**	0.70	2.76	-1.99
G.Cot.100 x G.Cot.10	-6.42	-0.16	-3.33	-3.67	-4.81	9.06**	-2.56	-16.05**	-4.69	7.62*	2.76	2.82
G.Cot.100 x DHY 286-1	9.23**	12.70**	4.07	-8.77	-15.45**	-2.17	-4.16	-17.23**	-9.44**	-0.19	-2.20	2.29
S.E. \pm	1.13	1.10	1.02	4.04	3.79	3.72	0.82	0.74	0.77	0.67	0.98	0.73

Method	Ginning percentage (%)			Seed cotton yield per plant (g)			2.5 per cent span length (mm)			Fibre strength (g/tex)		
	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS	CON	GMS	CMS
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Range of heterosis	-6.42to	-4.44to	-8.40to	-23.47to	-36.83to	-39.17to	-19.48to	-17.23to	-13.44to	-5.37to	-7.27to	-11.44to
	29.69	20.74	15.79	21.45	15.95	9.36	-2.51	-6.58	-4.69	9.95	6.51	8.36
No. of significant crosses	5	6	3	3	2	1	0	0	0	2	0	3
Best crosses	5,6,7,14,	5,6,14,1,	5,6,9	11,12,10	11,10	11	0	0	0	9,13	0	3,4,8
	1	11										

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

In CMS based hybrids, the standard heterosis varied from -11.44 to 8.36 per cent. Three hybrids viz., LH 900 x G.Cot.10, LH 900 x DHY 286-1 and LRA 5166 x DHY 286-1 exhibited significant and positive standard heterosis.

The heterotic response of an F_1 is indicative of genetic diversity among the parents involved (Moll *et al.*, 1962). In the present investigation, in conventional crosses, standard heterosis ranged from -23.47 to 21.45 per cent and three hybrids showed significant and positive standard heterosis, in which the cross G(B) 20 x G.Cot.10 showed maximum value of standard heterosis. Several workers, Joshi *et al.*, (1960) and Pavasia *et al.*, (1999).

In GMS based hybrids, 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), Bhale and Bhat (1990), Rajput *et al.*, (1997), Chauhan *et al.*, (1999), Kajjidoni *et al.*, (1999), Patel *et al.*, (2000), Tuteja *et al.*, (2000) and Tuteja and Singh (2001).

In CMS based crosses heterosis over standard check ranged from -39.17 to 9.36 per cent, where the hybrid G(B) 20 x G.Cot.10 exhibited significant and positive standard heterosis (9.36 per cent). Heterosis for seed cotton yield in CMS based hybrids was also reported by Shroff *et al.*, (1983, 1985), Silva

et al., (1985), Sheetz (1985), Bhale and Bhatt (1990), Anonymous (1993a, b, c), Raveendran *et al.*, (1992), Gunaseelan *et al.*, (1996), Khadi *et al.*, (1998), Cook and Namken (1994), Punitha and Raveendran (1999).

In all the three methods 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. 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. However the magnitude of heterosis was comparatively higher in conventional crosses followed by GMS based crosses and CMS-R based crosses. The standard heterosis ranged from -23.47 to 21.45 per cent in conventional system, -36.83 to 15.95 per cent in GMS system and -39.17 to 9.36 per cent CMS-R system (Table 1, 2 and 3). Similar results have been reported by Kajjidoni *et al.*, (1999), Bhale and Bhat (1990), Srinivasan and Gururajan (1983), Tuteja *et al.*, (2000), Tuteja and Singh (2001).

The low performance of GMS and CMS based hybrids as compared to conventional hybrids might be due to the following reasons:

The genetic background, local adaptability and diversify of parents appeared to be responsible for superiority of GMS hybrids over CMS hybrids. The presence of strong sterile cytoplasm may also be a probable reason for the poor performance of CMS hybrids (Bhale and Bhat, 1990).

Interaction between the cytoplasm and the nuclei not only causes the abortion of the

PMC but also influences the fertility of the embryo sac. In male sterile lines the volume of the ovule is smaller and ratio of abnormal embryo sacs to aborted seeds will be higher (Wang *et al.*, 1997).

Postmeiotic obstruction in pollen development in GMS and premeiotic abnormalities in CGMS caused sterility in cotton. The sterile plants consists of reduced ovary size, staminal column, style and anther filament length and anther number (Khadi *et al.*, 1998).

CMS cytoplasm, interaction between cytoplasm and nuclear genes, detrimental effects of CMS cytoplasm on yield and yield components may cause for poor yield of CMS based hybrids. This detrimental effect also affects the combining ability. The detrimental effect may be closely related to an increased number of immature seeds per boll, which might be caused by partial female sterility associated with CMS cytoplasm (Zhu *et al.*, 1998).

The abortion of auxocyte cells in CMS anthers took place during the development of sporogenous cells and microspore mother cells (MMCs). Abortion might be due to abnormal chromosome behaviour, formation of multi-micro nuclei per cell, high frequency of nucleolus penetration through the nuclear envelope and cell wall, high vacuolization of cytoplasm and coalescence of MMCs. Compared with the tapetal cells of fertile anthers, those sterile anthers will be significantly smaller and more vacuolated. It is suggested that the abnormal tapetum development is associated with the aborting of MMCs. (Li Yue You *et al.*, 2002).

Prospects for successful production of pure and low cost first generation hybrid seed using GMS and CMS system appears to be bright in near future. These systems not only

circumvent emasculation, but may even set aside the necessity of hand pollination by developing effective cross pollination system, possibly developing insect pollinators or atleast by some mechanical device.

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