RESEARCH ARTICLE

Heterosis for Seed Cotton Yield and other Traits in GMS based Hybrids of American Cotton (*Gossypium hirsutum*)

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Abstract

A line x tester analysis was undertaken to estimate the magnitude of heterosis in *Gossypium hirsutum* for yield, its component traits and fibre quality parameters in 52 GMS based cross combinations. These hybrids along with 17 parents and check hybrid CSHH 198 were raised during 2012-13 at the Central Institute for Cotton Research, Regional Station, Sirsa. The analysis of variance indicated that the mean squares of genotypes were significant for seed cotton yield, number of bolls plant^{-1}, boll weight, ginning outturn, 2.5% span length, bundle strength (g/tex) except micronaire value indicating the presence of variability among hybrids and their parents. Among 52 GMS based cross combination GMS 20 X MC 88 recorded the highest seed cotton yield of 1944 kg ha^{-1} and had significant positive heterotic values over the check hybrid CSHH 198 (14.5%). The results indicated that other 4 GMS based cross combinations (GMS 17 X MC 127, GMS 20 X SA 1652, GMS 26 X MC 88 and GMS 26 X CSH 3129) had relatively better performance over the check hybrid CSHH 198 so these hybrids could be used for hybrid seed production, however, none of the cross combinations exhibited significant economic heterosis over the check hybrid CSHH 198 for micronaire value, but significant economic heterosis was found for number of bolls plant^{-1}, boll weight, ginning percentage, 2.5% span length and fibre strength.

Keywords: Cotton, Heterosis, GMS

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Introduction

Cotton is an important commercial crop in India which provides raw material to the textile industry playing a key role in national economy. India became the pioneer country for the cultivation of hybrids on commercial scale. However, it has not been utilized widely in cotton even noticeable heterosis has been reported by Khadi et al. (1995), Khosla *et al.* (2007) and Tuteja *et al.* (2011a, b) after due to difficulties in producing cheap hybrid seed through hand emasculation and pollination. Thus the hybrid seed in cotton can be effectively and economically produced using either genetic male sterility or cytoplasmic male sterility approach. The use of GMS approach may prove to be the better method in cotton due to various detrimental effects on seed cotton yield as reported by many workers (Dutt *et al.* 2004, Tuteja *et al.* 2004, 2007). Therefore the present study was undertaken to find out the suitable GMS based hybrid combination with heterosis for seed cotton yield and other traits.

Materials and Methods

The experimental material consisted of seventeen parents of cotton *viz.* four genetic male sterile lines GMS-26, GMS-20, GMS-27 and GMS-17 used as females and thirteen testers SA 1017, SA 1422, SA 1652, MC 88, MC 127, SV 413, EC 358371, EC 128334, EC 138572, EC 141679 _EC 359051, ND 163 and CSH 3129 used as males were crossed at the Central Institute for Cotton Research, Regional Station, Sirsa in line x tester crossing programme during 2011-12 to generate a total of 52 hybrids. These fifty two hybrids along with seventeen parents and one check hybrid CSHH 198 were grown in a Randomized Block Design (RBD) with three replications and with a spacing of 100 x 60 cm between row to row and plant to plant respectively. Data were recorded on five competitive plants for number of bolls plant^{-1}, boll weight (g), ginning outturn (%), 2.5% span length (mm), micronaire value (µg inch^{-1}), fibre strength (g/tex). The data on seed cotton yield was recorded on per plot basis and converted to kg/ha^{-1} basis. The data were used for statistical analysis using the method developed by Kempthorne (1957) and economic heterosis was estimated as suggested by Rai (1978).

Results and Discussion

The analysis of variance indicated that the mean squares of genotypes for the characters under present study were significantly different, indicating the presence of variability among hybrids and their parents. The range of mean values for seed cotton yield varied from 123 kg ha^{-1} (EC 128334)) to 1528 kg ha^{-1} (CSH 3129)) in parents and it ranged from 278 kg ha^{-1} (GMS 17 X CSH 3129) to 1944 kg/ha (GMS 20 X MC 88) for cross combinations. For number of bolls $plant^{-1}$, lowest mean values of the parents were observed in EC 128334 (23.3 bolls $plant^{-1}$) and highest in EC 141679 (45.3 bolls $plant^{-1}$). Among hybrids it was found to be lowest in GMS 17 X CSH 3129 (26.7 bolls $plant^{-1}$) and highest in GMS 20 X CSH 3129 (57.0 bolls $plant^{-1}$). The mean values for boll weight ranged from 2.5g (EC 128334) to 3.9 g (MC 127) in parents and 2.2g (GMS 17 X CSH 3129) to 4.2 g (GMS 27 X EC 359051) in hybrids. For ginning percentage, the range of mean values among the parents was lowest in MC 88 (31.1 %) and highest in GMS-17(35.9 %), however, in hybrids it varied from 30.9 per cent in GMS 17 X CSH 3129 to 36.6 per cent in GMS 17 X SA 1652. The mean value for 2.5 % span length ranged from 24.5 mm (SA 1422) to 28.1mm (GMS 17) and 23.3 (GMS 17 x CSH 3129) to 29.3 mm (GMS 26 x SA 1652 and GMS 26 x ND 163) in parents and hybrids (Table 1), respectively. The mean values among the parents varied from 4.1 (CSH 3129) to 5.4 (SA 1422) and for cross combination, it was 4.1 (GMS 26 x SA 1017) to 5.4 (GMS 17 x SA 1422) for fibre fineness. In parents, the lowest mean for bundle strength was observed in MC 88 (18.4g/tex) and highest in CSH 3129 (22.1g/tex). Among cross combinations, it was lowest in cross GMS 17 x CSH 3129 (18.1 g/tex) and highest in GMS 27 x EC 138572 (23.5 g/tex).

Table 1 *Per se* performance of parents and hybrids for seed cotton yield and its component traits in cotton

Parents/crosses	Seed cotton yield (kg/ha^{-1})	No of bolls $plant^{-1}$	Boll weight (g)	Ginning out turn (%)	2.5% span length (mm)	Micronaire value (µg $inch^{-1}$)	Bundle strength (g/tex)
GMS 17	1235	42.3	3.7	35.9	28.1	5.0	20.8
GMS 20	772	45.0	3.5	33.0	27.6	4.4	21.9
GMS 26	849	42.0	3.8	31.8	27.8	5.0	20.1
GMS 27	648	35.3	3.0	35.7	26.5	4.8	20.5
SA 1017	756	25.0	3.3	35.5	26.3	4.8	19.7
SA 1422	1250	37.3	3.0	31.8	24.5	5.4	18.6
SA 1652	633	32.3	3.5	33.4	26.2	5.0	18.8
EC 128334	123	23.3	2.5	32.5	27.5	5.0	20.8
EC 138572	664	33.0	2.8	35.4	25.9	4.7	19.8
EC 141679	1512	45.3	3.4	34.3	24.7	5.0	19.2
MC 88	1080	32.7	3.7	31.1	25.3	5.1	18.4
MC 127	772	34.3	3.9	35.0	25.9	4.9	18.7
358371	123	35.0	3.3	31.1	25.7	4.8	19.7
359051	648	27.7	3.4	35.5	24.8	4.4	18.9
SV 413	1080	41.0	3.3	34.4	26.1	4.6	20
ND 163	833	37.3	3.9	33.7	27.0	4.2	21.7
CSH 3129	1528	42.0	3.3	31.3	27.9	4.1	22.1
Range	123-1528	23.3-45.3	2.5-3.9	31.1-35.9	24.5-28.1	4.1-5.4	18.4-22.1
GMS 17 X SA 1017	1065	43.7	3.3	34.3	26.9	4.2	19.8
GMS 17 X SA 1422	1543	45.7	3.5	34.8	25.7	5.4	19.3
GMS 17 X SA 1652	710	39.0	3.0	36.6	23.5	5.1	18.7
GMS 17 X EC 128334	1049	37.3	3.7	34.2	27.0	5.1	20.5
GMS 17 X EC 138572	525	28.0	3.4	31.3	25.4	4.7	20.5
GMS 17 X EC 141679	698	38.3	3.1	35.0	25.3	4.8	20.1
GMS 17 X MC 88	1358	47.0	3.1	36.5	25.4	4.7	19.2
GMS 17 X MC 127	1770	47.7	3.3	35.0	25.8	4.9	19.2
GMS 17 X 358371	1173	43.7	3.2	35.5	26.6	4.9	19.8
GMS 17 X 359051	1219	41.3	3.5	34.6	25.4	5.1	19.1
GMS 17 X SV 413	1096	49.0	3.5	34.8	26.1	5.2	19.4
GMS 17 X ND 163	448	38.7	3.7	35.3	28.7	4.2	22.6
GMS 17 X CSH 3129	278	26.7	2.2	30.9	23.3	4.9	18.1
GMS 20 X SA 1017	1327	38.0	3.4	34.9	25.2	5.0	20.3
GMS 20 X SA 1422	1451	38.7	3.7	35.6	25.8	4.8	19.6
GMS 20 X SA 1652	1763	41.3	3.6	35.4	26.6	5.0	20.9
GMS 20 X EC 128334	880	36.0	3.5	35.6	25.3	4.0	20
GMS 20 X EC 138572	1049	51.0	3.8	35.4	26.5	4.0	21
GMS 20 X EC 141679	1019	53.3	4.0	34.8	26.9	4.4	21.2
GMS 20 X MC 88	1944	43.7	3.6	35.0	25.7	5.0	19.8
GMS 20 X MC 127	941	43.0	2.8	36.2	27.4	5.0	20.1
GMS 20 X 358371	1003	44.7	3.5	34.7	26.5	4.5	20.2
GMS 20 X 359051	1157	42.0	3.7	34.3	27.7	4.3	21.3
GMS 20 X SV 413	1451	39.7	4.1	34.9	26.2	4.9	19.6
GMS 20 X ND 163	1188	39.0	3.5	33.8	27.9	4.7	21.6
GMS 20 X CSH 3129	802	57.0	3.4	34.6	27.0	4.6	22.1
GMS 26 X SA 1017	1543	44.7	3.6	34.9	26.5	4.1	19.9
GMS 26 X SA 1422	1296	39.0	3.2	34.5	27.0	5.0	20.3
GMS 26 X SA 1652	1034	37.0	3.4	34.3	29.3	5.0	21.1
GMS 26 X EC 128334	1343	44.3	3.5	33.3	26.6	4.7	19.8
GMS 26 X EC 138572	1281	41.3	4.1	34.1	27.3	4.6	21.7
GMS 26 X EC 141679	1111	45.3	3.6	35.7	25.2	4.3	19.7

GMS 26 X MC 88	1773	47.0	3.1	32.5	27.7	4.4	21.4
GMS 26 X MC 127	1204	40.0	3.6	34.7	27.8	4.7	20.5
GMS 26 X 358371	525	39.7	3.9	33.3	27.6	4.6	21
GMS 26 X 359051	849	42.0	3.6	35.7	25.7	4.6	19.8
GMS 26 X SV 413	1065	46.7	4.0	34.2	25.9	4.9	20
GMS 26 X ND 163	1111	38.0	3.7	34.3	29.3	4.7	22.6
GMS 26 X CSH 3129	1730	55.7	3.4	33.8	27.6	5.0	20.5
GMS 27 X SA 1017	1296	48.0	3.9	35.1	25.0	4.9	20.6
GMS 27 X SA 1422	1481	39.3	3.4	33.9	25.3	5.1	19.2
GMS 27 X SA 1652	1142	44.7	3.6	35.1	27.2	5.0	20.5
GMS 27 X EC 128334	602	35.3	3.4	35.6	26.5	4.9	19.5
GMS 27 X EC 138572	1204	43.3	3.6	34.6	28.9	4.6	23.5
GMS 27 X EC 141679	787	39.3	3.2	35.4	25.8	5.0	20.4
GMS 27 X MC 88	710	44.0	3.6	34.2	24.9	5.1	18.7
GMS 27 X MC 127	494	39.7	3.4	32.8	26.4	4.9	19.4
GMS 27 X 358371	1204	40.7	3.5	35.5	26.9	5.0	20.6
GMS 27 X 359051	417	52.3	4.2	34.6	28.8	4.7	22.5
GMS 27 X SV 413	1528	38.3	3.6	35.7	26.0	4.9	20.1
GMS 27 X ND 163	941	40.0	3.6	33.8	25.5	4.8	19.9
GMS 27 X CSH 3129	509	49.0	3.3	34.1	26.7	4.5	19.8
CSHH 198	1698	36.3	3.3	33.1	26.9	5.0	20.7
Range	278-1944	26.7-57.0	2.2-4.2	30.9-36.6	23.3-29.3	4.1-5.4	18.1-23.5
CD (%)	177.23	9.85	.31	1.00	2.31	0.86	2.33
CV (%)	10.16	14.50	5.31	1.75	5.24	10.88	6.92

Heterosis estimates over the conventional check hybrid CSHH 198 for different characters is presented in Table 2. The results indicated that the phenomenon of heterosis was of general occurrence and its magnitude varied with the characters. Among 52 cross combinations, the cross combination GMS 20 X MC 88 recorded the highest seed cotton yield of 1944 kg/ha and also had significant positive heterotic values over the check hybrid CSHH 198 (14.5%). It was also found that other 4 GMS-based cross combinations (GMS 17 X MC 127, GMS 20 X SA 1652, GMS 26 X MC 88 and GMS 26 X CSH 3129) had relatively better performance over the check hybrid CSHH 198 so these hybrids could be used in hybrid seed production. These results are in accordance with the earlier reports (Tuteja et al. 2005; Khosla *et al.* 2007; Tuteja *et al.* 2011,a b). For boll number, 12 crosses exhibited significant positive heterosis and the cross combination (GMS 20 X CSH 3129) showed maximum heterotic effects to the tune of 57.0%. Thirteen crosses exhibited significant positive heterosis, but GMS 27 X EC 359051 showed maximum heterotic value of 25.8% for boll weight. For ginning percentage, 39 cross combinations recorded positive and significant heterosis, GMS 17 X SA 1652 showed maximum heterotic effects (10.6%). For 2.5% span length two combinations showed significant and maximum heterosis (GMS 26 x ND 163, GMS 26 x SA 1652) to the tune of 8.9 and 8.8 per cent respectively. The results are in conformity with Rajamani *et al.* (2009) and Patil *et al.*(2011). For fibre fineness majority of the cross combinations showed negative heterotic effect and decrease in micronaire value are an indication of fibre fineness. Few crosses showed non-significant positive heterotic effect for fibre fineness. The results are in the agreement with the findings of Rajamani *et al.* (2009) but in contradiction of Patil *et al.*(2012). One cross GMS-27 x EC 138572 (13.53%) showed significant and positive heterotic effects for fibre strength and others crosses had negative heterotic effect as the parents involved in the present study did not have variability for this trait.

Table 2 Estimates of economic heterosis of GMS based hybrids for seed cotton yield and other traits in cotton

Crosses	Seed cotton yield (kg/ha^{-1})	Number of bolls plant^{-1}	Boll weight (g)	Ginning out turn (%)	2.5% span length (mm)	Micronaire value (µg inch^{-1})	Bundle Strength (g/tex)
GMS 17 X SA 1017	-37.3	20.3	-1.01	3.5*	0.0	-16.0	-4.4
GMS 17 X SA 1422	-9.1	25.8	6.1	5.0*	-4.5	8.0	-6.8
GMS 17 X SA 1652	-58.2	7.4	-9.1	10.6*	-12.6	2.0	-9.7
GMS 17 X EC 128334	-38.2	2.8	12.3*	3.4*	0.4	2.0	-1.0
GMS 17 X EC 138572	-69.1	-22.9	2.0	-5.5	-5.6	-6.0	-1.0
GMS 17 X EC 141679	-58.9	5.6	-5.1	5.7*	-5.8	-4.0	-2.9
GMS 17 X MC 88	-20.0	29.5*	-7.1	10.4*	-5.6	-6.0	-7.3
GMS 17 X MC 127	4.3	31.3*	0.0	5.6*	-4.1	-2.0	-7.3
GMS 17 X 358371	-30.9	20.3	-2.0	7.4*	-1.1	-2.0	-4.4
GMS 17 X 359051	-28.2	13.9	7.1	4.4*	-5.6	2.0	-7.7
GMS 17 X SV 413	-35.5	35.0*	5.1	5.2*	-3.0	4.0	-6.3
GMS 17 X ND 163	-73.6	6.5	12.1*	6.5*	6.7	-16.0	9.2
GMS 17 X CSH 3129	-83.6	-26.5	-33.3	-6.7	-13.4	-2.0	-12.6
GMS 20 X SA 1017	-21.8	4.7	4.0	5.5*	-6.3	0.0	-1.9
GMS 20 X SA 1422	-14.5	6.5	13.1*	7.7*	-4.0	-4.0	-5.3
GMS 20 X SA 1652	3.9	13.9	9.1	7.0*	-1.1	0.0	1.1
GMS 20 X EC 128334	-48.2	-0.8	5.1	7.7*	-6.0	-20.0	-3.4

GMS 20 X EC 138572	-38.2	40.5*	14.1*	6.9*	-1.5	-20.0	1.5
GMS 20 X EC 141679	-40.0	46.9*	22.2*	5.2*	0.0	-12.0	2.4
GMS 20 X MC 88	14.5*	20.3	8.1	5.6*	-4.5	0.0	-4.4
GMS 20 X MC 127	-44.5	18.5	-16.2	9.4*	1.9	0.0	-2.9
GMS 20 X 358371	-40.9	23.0	6.1	4.9*	-1.5	-10.0	-2.4
GMS 20 X 359051	-31.8	15.7	13.1*	3.6*	3.0	-14.0	2.9
GMS 20 X SV 413	-14.5	9.3	25.3*	5.5*	-2.6	-2.0	-5.3
GMS 20 X ND 163	-30.0	7.4	6.1	2.1	3.7	-6.0	4.4
GMS 20 X CSH 3129	-52.7	57.0*	3.0	4.4*	0.4	-8.0	6.8
GMS 26 X SA 1017	-9.1	23.0	8.1	5.5*	-1.5	-18.0	-3.9
GMS 26 X SA 1422	-23.6	7.4	-2.0	4.1*	0.4	0.0	-1.9
GMS 26 X SA 1652	-39.1	1.9	2.0	3.6*	8.8*	0.0	1.9
GMS 26 X EC 128334	-20.9	22.1	6.1	0.6	-1.1	-6.0	-4.4
GMS 26 X EC 138572	-24.5	13.9	25.3*	3.1	1.5	-8.0	4.8
GMS 26 X EC 141679	-34.5	24.9	10.1	8.0*	-6.3	-14.0	-4.8
GMS 26 X MC 88	4.5	29.5*	-5.1	-1.9	3.0	-12.0	3.4
GMS 26 X MC 127	-29.1	10.2	9.1	4.9*	3.4	-6.0	-1.0
GMS 26 X 358371	-69.1	9.3	19.2*	0.5	2.6	-8.0	1.5
GMS 26 X 359051	-50.0	15.7	9.1	7.8*	-4.5	-8.0	-4.4
GMS 26 X SV 413	-37.3	28.6*	21.2*	3.3*	-3.7	-2.0	-3.4
GMS 26 X ND 163	-34.5	4.7	11.1*	3.5*	8.9*	-6.0	9.2
GMS 26 X CSH 3129	1.9	53.4*	4.0	2.0	2.6	0.0	-1.0
GMS 27 X SA 1017	-23.6	32.2*	18.3*	6.0*	-7.1	-2.0	-0.5
GMS 27 X SA 1422	-12.7	8.4	3.8	2.5	-6.0	2.0	-7.3
GMS 27 X SA 1652	-32.7	23.0	9.8	6.1*	1.1	0.0	-1.0
GMS 27 X EC 128334	-64.5	-2.7	2.0	7.5*	-1.5	-2.0	-5.8
GMS 27 X EC 138572	-29.1	19.4	8.3	4.6*	7.4	-8.0	13.5*
GMS 27 X EC 141679	-53.6	8.4	-2.6	6.9*	-4.1	0.0	-1.5
GMS 27 X MC 88	-58.2	21.2	8.0	3.2	-7.4	2.7	-9.7
GMS 27 X MC 127	-70.9	9.3	3.1	-0.9	-1.9	-2.0	-6.3
GMS 27 X 358371	-29.1	12.0	7.1	7.2*	0.0	0.0	-0.5
GMS 27 X 359051	-75.5	44.2*	25.8*	4.4*	7.1	-6.0	8.7
GMS 27 X SV 413	-10.0	5.6	10.5	7.8*	-3.4	-2.0	-2.9
GMS 27 X ND 163	-44.5	10.2	9.2	2.2	-5.2	-4.0	-3.9
GMS 27 X CSH 3129	-70.0	35.0*	1.4	2.9	-0.7	-10.0	-4.4

* Significant at P= 0.05.

The cross combination involving female parent GMS 20 and male parents CSH 3129, CNH 911 recorded significant positive heterosis for most of the characters. For seed cotton yield, cross combinations namely GMS 17 X MC 127, GMS 20 X SA 1652, GMS 26 X MC 88 and GMS 26 X CSH 3129 showed heterosis in positive direction. Thus, to reduce the cost of hybrid seed production and to overcome the labour problems, these crosses may be used in the development of GMS-based hybrids in cotton and some new parents having good general combining ability may be tested for exploitation of heterosis at commercial level.

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References

Dutt Yagya, Xue De Wang and Nirania, K.S. (2004) – Effect of sterile cytoplasm on lint yield and contributing traits of F1 hybrids in cotton (*Gossypium hirsutum*, L)- In: International Symposium on "*Strategies for sustainable Cotton Production*- A Global Vision" 1. Crop Improvement 23-25th November, 2004, UAS, Dharwad, Karnataka (ed B. M. Khadi, H. M. Vamadevaiah, I. S. Katageri, B. R. Patil, S. S. Patil and S. M. Manjula) : 217-219

Khadi, B.M., Janagoudar, B.S., Katageri I.S. and Eshanna, M.R. (1995) – Some superior upland cotton hybrid combinations for rainfed conditions – *J. Indian Soc. Cotton Improv*., **18:** 47-49.

Khosla, Gaurav, Gill B.S. and Sohu, R.S. (2007) - Heterosis and Combining ability analysis for plant and seed characters in upland cotton (*Gossypium hirsutum* L.) - *J. Cotton Res. Dev.,* **21** : 12-15.

Kempthrone, O. (1957) - An Introducation of Genetic Statistics. John Willey and Sons Inc. New York. Pp545.

Patil, S. A., Naik, M. R., Patil, A. B. and Chaugule, G. R. (2011) - Heterosis for seed cotton yield and its contributing characters in Cotton (*Gossypium hirsutum* L.) - *Plant Archives* **11:** 461-465.

Patil, Sandip A., Naik, M. R., Pathak V.D. and Kumar V. (2012) - Heterosis for yield and fibre properties in upland cotton (*Gossypium hirsutum* L.) - *J. Cotton Res. Dev*., **26 (1):** 26-29.

Rai, B. (1978) - Heterosis Breeding. Agro Biological Publications. New Delhi Rajamani, S., C. M. Rao and Naik, R. K. (2009) - Heterosis for yield and fibre properties in upland cotton (*G. hirsutum* L.) - *J. Cotton Res. Dev*., **23**: 43-45.

Tuteja, O.P., Kumar Sunil and Singh Mahendar (2004) – Identification of new fertility restorers based on cytoplasmic male sterility system in cotton (*Gossypium hirsutum* L)- In**:** International Symposium on "*Strategies for sustainable Cotton Production* - A Global Vision" 1.

Crop Improvement, 23-25th, November 2004, UAS Dharwad, Karnataka (ed B. M. Khadi, H. M. Vamadevaiah, I. S. Katageri, B. R. Patil, S. S. Patil and S. M. Manjula): 107-111.

Tuteja, O. P., Kumar Sunil, Singh, Mahendar and Kumar, Manoj. (2005) **-** Heterosis in Single cross hybrids of *Gossypium hirsutum* L. in cotton - *J. Cotton Res. Dev*. **19:** 165-67.

Tuteja, O. P., Verma, S.K., Singh Mahendar and Khadi, B.M. (2007**) –** Effect of restorer lines on *Gossypium harknessii* based cytoplasmic male sterility on yield and fibre quality traits in cotton – *J. Indian Soc. Cotton Improv*., **32 (1)** : 41-49.

Tuteja, O.P., Verma, S.K. and Banga Manju (2011a). Heterosis for seed cotton yield and other traits in GMS based hybrids of *Gossypium hirsutum* cotton **-** *J. Cotton Res. Dev*. **25**(1): 14-18.

Tuteja, O. P., Banga Manju and Nirania, K.S. (2011b). Heterosis studies on GMS based hybrids in *Gossypium hirsutum* cotton **-** *J. Cotton Res. Dev*., **25**: 162-164.