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Research Article

Heterosis and combining ability in genetic male sterility based diploid cotton hybrids for yield, yield component, fibre quality characters and oil content

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Abstract
Sixteen genetic male sterility based diploid cotton hybrids along with parents and check were evaluated during Kharif 2012 at Cotton Research Station, Dr.PDKV, Akola to estimate the level of heterosis and combining ability. Among the lines GAK-8615 exhibited significant gca effect for more number of characters *viz.,* days to 50% flowering, number sympodia per plant, number boll per plant and seed cotton yield per plant. Among the testers, AKA-7 exhibited significant gca effects for seed cotton yield per plant and 2.5% span length. The genetic male sterility based hybrids GAK-8615 x AKA-7 and GAK-8615 x AKA-0209 were found to be highly heterotic for seed cotton yield, number of bolls per plant and oil content. For fibre quality traits, hybrids *(viz.,)*GAK-423 x AKA-0209, GAK-423 x AKA-7, GAK-8615 x AKA-9703, GAK-423 x AKA-9009-1, GAK-423 x AKA-5 were found to be promising.

Key words
Genetic male sterility, line x tester analysis, heterosis, combining ability, diploid cotton.

Introduction

Cotton *(Gossypium sp.)* is a major crop of global importance and has high commercial value. It is a fibre crop an important source of edible oil throughout the world. Heterosis in cotton is important in improving yield and fibre quality. Cotton being an often cross pollinated crop, is amenable for heterosis breeding. Male sterility is an effective means of producing hybrid cotton since it does not need labour intensive hand emasculation.In cotton, mainly two types of male sterility systems *viz*., Cytoplasmic Genetic Male Sterility (CGMS) and Genetic Male Sterility (GMS) systems could be used for hybrid seed production. GMS is preferred than CGMS as it overcomes the drawbacks of cytoplasmic effect and problem of fertility restoration.

Diploid hybrids are high yielding with short to medium fibre (22.0 to 25.0 mm) and GOT around 35-39%. In spite of these qualities, diploid hybrids cover an insignificant area due to non availability of a suitable cost effective system for large scale production of quality F_1 seed. Hybrid seed production based on GMS system is cheaper as compared to conventional method as it can reduce the cost of hybrid seed production at least by 40 to 50 per cent (Bhatt, 1995). The genetic male sterility system (GMS) in diploid cotton developed by Singh and Kumar (1993) and Meshram *et al.* (1994).

Desi cotton varieties are still preferred in the low rainfall areas because of their resistance to diseases and pests, drought tolerance and suitability under low rainfall conditions, which aroused the interest for developing superior hybrids in Asiatic cotton. Information about combining ability and the extent of heterosis is most useful for breeding programme. Hence, the present study was undertaken to identify better parents on the basis of their gca effect, cross combination on the basis of their sca effect and to estimate the extent of heterosis for various yield and yield contributing traits.

Material and method

The experimental material for the present study comprised of 16 cotton genotypes: 2 genotypes (GAK-423 and GAK-8615) were used as lines and remaining 8 genotypes (AKA-9703, AKA-0110, AKA-9620, AKA-9009-1, AKA-0209, AKA-5,AKA-7, HD-162) were ued as a testers. These genotypes were crossed in a line x tester design. The resulting 16 hybrids along with 10 parents and one check (PKV Suvarna) were grown in trhe randomised block design with three replications during kharif 2012-13 at Cotton Research Station, Dr. PDKV, Akola. The experiment was conducted in randomized block design, replicated thrice with a spacing 60 cm between rows and 45 cm between plants. Package of practices recommended for diploid cotton were followed. Data was recorded on five randomly selected plants in each replication for yield and yield attributing traits *viz*., days to 50% flowering, plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight, ginning percentage, seed index, 2.5% span length, fiber strength, fiber fineness, per cent oil content and seed cotton yield per plant. The data were analyzed for combining ability as per the procedure given by Kempthorne (1957) and heterosis was calculated in percentage.

Result and discussion

The analysis of variance (ANOVA) for various characters are presented in Table 1. The analysis of variance for parent revealed significant difference among the parents for all the characters except for numbers of monopodia per plant, ginning percentage and oil content. This indicated presence of considerable genetic variability between the genotypes. Further partitioning of genotypic variance into components *viz.*, parents, crosses and parents vs. crosses revealed that the parents differed significantly among themselves for plant height, number of monopodia per plant, number of bolls per plant, and 2.5% span length. The mean square due to crosses also showed highly significant differences for days to 50% flowering, plant height, number of sympodia per plant, number of bolls per plant, seed cotton yield per plant, seed index and 2.5% span length.

The estimates of general combining ability effects are presented in Table 2. None of the line and tester parents exhibited significant gca effects for all characters under study. The line GAK-8615 exhibited significant gca effect for more number of characters *viz.*, days to 50% flowering, number sympodia per plant, number boll per plant, seed cotton yield per plant.Among the male parent AKA-9703 was the best general combiner, with high gca effects for plant height, number of bolls per plant and 2.5% span length. The tester AKA-5 exhibited significant gca effects for seed cotton yield per plant. The tester AKA-7 exhibited significant gca effects for seed cotton yield per plant and 2.5% span length.

The estimates of specific combining ability effects of the crosses are presented in Table 3 which revealed that, hybrids, GAK-423 x AKA-9703 for number sympodia per plant, GAK-423 x AKA-9620 and GAK-8615 x HD-162 for seed index, GAK-423 x AKA-7 and GAK-8615 x AKA-9703 for 2.5% span length, GAK-423 x AKA-5 for fibre fineness exhibited significant positive sca effects indicating predominant role of non-additive gene action. These crosses can be exploited for further evaluation on large-scale basis to confirm their superiority.

The percentage of heterosis over better parent and standard check for seed cotton yield and its component traits is presented in Table 4 which revealed that for character days to 50% flowering per cent heterosis ranged from -6.80 to 3.85 per cent over better parent and 0.52 to 13.09 per cent over the check PKV Suvarna. However, number of sympodia per plant recorded -16.5 to 26.15 per cent and - 0.73 to 19.27 per cent heterosis over better parent and check PKV Suvarna, receptively. Out of 16 crosses, eight crosses over better parent and four crosses over standard check recorded significant positive heterosis for number of boll per plant. The cross GAK-8615 x AKA-7 exhibited maximum heterosis over better parent (63.39%) and check (43.75) for this trait. In case of boll weight, the cross GAK-8615 x AKA-9703 showed maximum positive heterosis over better parent (723%) and check (14.1%). Similar results have been noticed by Khadi *et al.* (1992), Rajput *et al.* (1997).

The seed cotton yield exhibited appreciable amount of heterosis which ranged from -5.47 to 51.28 per cent over the better parent and -5.07 to 28.26 per cent over the check. Out of the 16 crosses, four crosses showed significant positive heterosis over the better parent while only one cross over the check. The cross GAK-8615 x AKA-7 exhibited maximum heterosis over better parent (51.28%) and check (28.26%). The high heterosis for seed cotton yield was also reported by Khadi *et al.* (1992), Rajput *et al.* (1997), Kajjidoni *et al.* (1999), Tuteja *et al.* (2000).

Cotton is mainly grown for fibre, hence, lint yield is the most important economic trait. It is majorly correlated with the ginning out turn. Hence, apart from high seed cotton yield, high ginning out turn is also a desirable character. With respect to ginning percentage, the cross GAK-8615 x AKA-9703 exhibited higher magnitude of heterosis over better parent (8.93%) and check (10.91%). However, cross GAK-423 x AKA-9620 recorded significant positive estimates of heterosis over better parent (14%) and over check (7.55%). These findings are in conformity with the reports of Tuteja *et al.* (2000) and Karande *et al.* (2004).

With respect to 2.5% span length, only one cross showed significant positive heterosis over the better parent while 10 crosses over check. The crosses GAK-423 x AKA-7 (16.87%), GAK-8615 x AKA-9703 (13.47%), GAK-423 x AKA-0209 (10.20%) and GAK-8615 x HD-162 (7.76%) recorded significant positive heterosis over check. The results of heterosis are in conformity with the reports of Reddy (2001) and Tuteja *et al.* (2001). For fibre strength, two crosses GAK-423 x AKA-9009-1(14.31%) and GAK- 423 x AKA-5 (9.88%) over better parent and the crosses GAK-423 x AKA-9009-1 (12.58%), GAK-423 x AKA-5 (8.22%) and GAK-8615 x AKA-9703 (7.89%) over check exhibited significant heterosis in desirable direction. The results of heterosis are in conformity with the reports of Reddy (2001) and Tuteja *et al.* (2001)

Micronaire requires negative heterosis. The cross GAK-8615 x AKA-0110 showed highest negative heterosis over better parent (-5.67%) and over check (-8.3%). Similar results have been noticed by Tuteja *et al.* (2000).

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Table 1. ANOVA for various characters

		Mean sum of squares												
Source of variation	d. f.	Days to 50% flowering	Height (cm)	No. of monopodia / plant	No. of sympodia /plant	No. of bolls/ plant	Boll weight (g)	GP	Seed Index (g)	2.5 % Span length (mm)	Fibre strength (g/tex)	Fibre fineness (µg/ inch)	Oil conte nt (%)	SCY/ Plant (g)
Replications	2	0.474	55.16	0.096	5.96	24.64	0.055	1.192	0.199	1.069	0.265	0.585	2.42	95.23
Genotypes	25	21.70**	484.8**	1.77	9.31**	97.91**	0.146**	13.98	0.62**	3.031**	2.036**	0.320*	1.40	160.8**
Parents	9	5.792	832.0**	4.311**	5.93	51.32**	0.071	16.08	0.444	1.579*	1.515	0.284	1.61	36.96
Crosses	15	19.46**	252.53*	0.296	10.9**	57.84**	0.194*	13.02	0.765**	3.54**	1.148	0.36	1.36	211.1**
Parents Vs Crosses	1	198.51**	845.3**	1.03	15.88*	1118.4**	0.107	9.59	0.799*	8.443**	20.05**	0.064*	0.107	521.0**
Error	50	5.074	112.40	1.74	3.17	14.69	0.084	8.018	0.281	0.625	0.93	0.166	2.139	42.56

Table 2. Estimation of general combining ability effects in desi cotton

Sr. No.	Parents	Days to 50% flowering	Height (cm)	No. of sympodia / Plant	No. of bolls / plant	Boll weight (g)	Seed Index (g)	2.5 % Span length (mm)	Fibre strength (g/tex)	Fibre Fineness (µg/ inch)	SCY/ plant (g)
	Lines										
1	GAK-423	1.813**	-2.25	-0.771*	-2.942**	-0.09	0.1	0.135	0.223	0.085	-3.563*
2	GAK-8615	-1.813**	2.25	0.771*	2.942**	0.09	-0.1	-0.135	-0.223	-0.085	3.563*
	SE (gj) ±	0.368	2.092	0.354	0.87	0.066	0.084	0.15	0.188	0.07	1.33
	CD at 5%	0.752	4.272	0.724	1.77	0.135	0.171	0.31	0.384	0.15	2.72
	CD at 1%	1.013	5.753	0.975	2.38	0.182	0.230	0.41	0.516	0.20	3.67
	Testers										
1	AKA-9703	0.979	13.167**	0.046	3.47	0.14	0.129	0.66*	0.28	0.252	-8.646**
2	AKA-0110	-0.021	-7.167	-1.054	2.40	-0.394	-0.121	0.13	-0.42	-0.265	-8.813**
3	AKA-9620	-1.354	1.667	-0.921	-3.30	0.023	0.713**	-0.81	-0.09	-0.148	-0.313
4	AKA-9009-1	0.813	10.333*	1.446	-0.37	-0.094	-0.038	-0.22	0.72	-0.181	-0.479
5	AKA-0209	0.479	0.667	0.379	1.10	0.006	0.129	-0.19	-0.40	-0.115	4.021
6	AKA-5	0.646	-9.5*	0.713	1.20	0.173	-0.371*	-0.12	0.18	0.135	8.688**
7	AKA-7	0.313	-6.16	0.179	0.17	0.123	-0.454*	1.094*	-0.39	0.419*	7.188*
8	HD-162	-1.854	-3.0	-0.788	-4.67	0.023	0.013	-0.54	0.12	-0.098	-1.646
	SE (gj) ±	0.737	4.184	0.709	1.73	0.132	0.167	0.30	0.38	0.15	2.67
	CD at 5%	1.505	8.545	1.449	3.54	0.271	0.341	0.61	0.77	0.30	5.45
	CD at 1%	2.027	11.506	1.951	4.77	0.365	0.460	0.82	1.03	0.40	7.33

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Tabl 3. Estimation of specific combining ability effects of crosses in desi cotton

Sr. No.	Crosses	Days to 50% flowering	Height (cm)	No. of sympodia / Plant	No. of bolls / plant	Boll weight (g)	Seed Index (g)	2.5 % Span length (mm)	Fibre strength (g/tex)	Fibre Fineness (µg/ inch)	SCY/ plant (g)
1	GAK-423 x AKA-9703	-0.979	-5.25	2.738*	-1.392	-0.227	-0.1	-1.269**	-0.54	-0.05	5.229
2	GAK-423 x AKA-0110	-2.313*	-6.917	0.904	-0.992	0.14	0.15	-0.102	0.53	0.07	6.396
3	GAK-423 x AKA-9620	-0.313	1.583	-1.296	-0.225	0.056	0.483*	-0.269	-0.41	0.15	-3.771
4	GAK-423 x AKA-9009-1	2.188*	2.917	-2.596 *	-2.158	-0.094	-0.267	-0.085	0.59	-0.15	-0.938
5	GAK-423 x AKA-0209	-0.146	3.917	0.404	2.108	0.106	0.233	1.048*	-0.12	0.08	-2.104
6	GAK-423 x AKA-5	1.021	-0.583	0.337	-1.325	0.173	0.067	0.348	0.26	-0.502*	2.896
7	GAK-423 x AKA-7	1.354	4.083	-0.396	1.575	0.09	0.15	1.398**	0.09	0.35	-2.938
8	GAK-423 x HD-162	-0.813	0.25	-0.096	2.408	-0.244	-0.717**	-1.069*	-0.41	0.07	-4.771
9	GAK-8615 x AKA-9703	0.979	5.25	-2.738*	1.392	0.227	0.1	1.269**	0.54	0.05	-5.229
10	GAK-8615 x AKA-0110	2.313*	6.917	-0.904	0.992	-0.14	-0.15	0.102	-0.53	-0.07	-6.396
11	GAK-8615 x AKA-9620	0.313	-1.583	1.296	0.225	-0.056	-0.483*	0.269	0.41	-0.15	3.771
12	GAK-8615 x AKA-9009-1	2.188*	-2.917	2.596*	2.158	0.094	0.267	0.085	-0.59	0.15	0.938
13	GAK-8615 x AKA-0209	0.146	-3.917	-0.404	-2.108	-0.106	-0.233	-1.048*	0.12	-0.08	2.104
14	GAK-8615 x AKA-5	-1.021	0.583	-0.337	1.325	-0.173	-0.067	-0.348	-0.26	0.502 *	-2.896
15	GAK-8615 x AKA-7	-1.354	-4.083	0.396	-1.575	-0.09	-0.15	-1.398**	-0.09	-0.35	2.938
16	GAK-8615 x HD-162	0.813	-0.25	0.096	-2.408	0.244	0.717**	1.069*	0.41	-0.07	4.771
	SE (Sij) ±	1.042	5.9174	1.003	2.45	0.187	0.236	0.42	0.53	0.21	3.772
	CD at 5%	2.129	12.084	2.049	5.01	0.383	0.483	0.86	1.08	0.43	7.703
	CD at 1%	2.867	16.272	2.759	6.75	0.516	0.650	1.16	1.46	0.57	10.372

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Table 4: Percentage of heterosis over better parent and standard check for various traits

Sr. No.	Hybrids	Days to 50% flowering		Plant Height (cm)		No. of sympodia/ Plant		No. of bolls/ plant		Boll weight (g)	
		H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
1	GAK-423 x AKA-9703	-0.48	8.38 **	13.55	0	0	4	39.29 *	12.5	-9.09	-10.26
2	GAK-423 x AKA-0110	-3.85	4.71	-15.63 *	-18.75 *	-15.38 *	-12	15.08	10.1	-22.62 *	-16.67
3	GAK-423 x AKA-9620	-2.88	5.76 *	13.8	-3.98	-26.22 **	-23.27 **	14.29	-7.69	-3.85	-3.85
4	GAK-423 x AKA-9009-1	3.85	13.09 **	13.93	4.55	-20.63 **	-17.45 *	-10.34	-4.09	-12.99	-14.1
5	GAK-423 x AKA-0209	0	8.90 **	11.4	-2.84	-10.49	-6.91	-0.1	16.59	-3.8	-2.56
6	GAK-423 x AKA-5	1.92	10.99 **	0.34	-15.34*	-9.09	-5.45	29.46	4.57	7.79	6.41
7	GAK-423 x AKA-7	1.92	10.99 **	8.42	-8.52	-15.73 *	-12.36	37.80 *	11.3	2.6	1.28
8	GAK-423 x HD-162	-4.33	4.19	-26.4**	-9.09	-19.23 *	-16.0*	10.71	-3.12	-18.52	-15.38
9	GAK-8615 x AKA-9703	-1.94	5.76 *	22.91**	12.78	-6.2	-17.45 *	63.39**	43.75**	7.23	14.1
10	GAK-8615 x AKA-0110	-1.46	6.28 *	0.59	-3.13	-1.65	-13.45	44.72**	38.46**	-26.19 **	-20.51
11	GAK-8615 x AKA-9620	-6.31**	1.05	5.88	-2.84	6.64	-0.73	30.87 *	15.14	-7.23	-1.28
12	GAK-8615 x AKA-9009-1	-6.80**	0.52	12.69	3.41	26.15 **	19.27 *	24.04 *	32.69 *	-6.02	0
13	GAK-8615 x AKA-0209	-3.88	3.66	2.79	-5.68	10.33	-2.91	5.05	22.6	-9.64	-3.85
14	GAK-8615 x AKA-5	-5.34 *	2.09	-2.48	-10.51	12.81	-0.73	53.83**	35.34**	-6.02	0
15	GAK-8615 x AKA-7	-6.31**	1.05	-3.72	-11.65	14.05	0.36	37.70 *	21.15	-4.82	1.28
16	GAK-8615 x HD-162	-6.31**	1.05	-23.68 **	-5.68	6.2	-6.55	14.48	0.72	3.61	10.26
	SE(d)	1.47	1.47	8.37	8.37	1.42	1.42	3.47	3.47	0.27	0.27
	C.D. at 5%	3.01	3.01	17.09	17.09	2.90	2.90	7.08	7.08	0.54	0.54
	C.D. at 1%	4.05	4.05	23.01	23.0	3.90	3.90	9.54	9.54	0.73	0.73

Table 4: Contd..

Sr. No.	Hybrids	Seed Index (g)		2.5% Span Length (mm)		Fibre strength (g/tex)		Fibre Fineness (µg/ inch)		SCY/plant (g)	
		H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
1	GAK-423 x AKA-9703	0	-5.66	-1.29	4.22	1.13	4.7	15.79*	6.21	-16.06	-16.67
2	GAK-423 x AKA-0110	0	-5.66	1.16	6.80 **	2.75	6.54	6.77	-2.07	-7.81	-14.49
3	GAK-423 x AKA-9620	14.00 **	7.55	-3.09	2.31	5.11	3.52	11.28	2.07	-14.39	-18.12
4	GAK-423 x AKA-9009-1	-5.88	-9.43 *	-0.13	5.44 *	14.31 **	12.58 **	3.76	-4.83	-5.47	-12.32
5	GAK-423 x AKA-0209	1.96	-1.89	4.38	10.20 **	4.94	3.36	10.53	1.38	2.34	-5.07
6	GAK-423 x AKA-5	-4	-9.43 *	1.93	7.62 **	9.88 *	8.22 *	3.01	-5.52	25	15.94
7	GAK-423 x AKA-7	-4	-9.43 *	10.70 **	16.87 **	1.3	4.53	28.57**	17.93 **	7.81	0
8	GAK-423 x HD-162	-12.31 **	-13.96 **	-5.15 *	0.14	3.32	4.53	10.53	1.38	-17.19	-23.19
9	GAK-8615 x AKA-9703	-1.96	-5.66	2.96	13.47 **	4.21	7.89 *	7.8	4.83	-23.36	-23.91 *
10	GAK-8615 x AKA-0110	-7.84	-11.32 **	-3.33	6.53 *	-4.53	-1.01	-5.67	-8.28	-15.13	-26.81 *
11	GAK-8615 x AKA-9620	-1.96	-5.66	-6.17 **	3.4	4.15	5.37	-4.96	-7.59	18.94	13.77
12	GAK-8615 x AKA-9009-1	-1.96	-5.66	-4.69 *	5.03 *	3.15	4.36	0.71	-2.07	17.46	7.25
13	GAK-8615 x AKA-0209	-5.88	-9.43 *	-8.77 **	0.54	1.16	2.35	-2.84	-5.52	44.74 **	19.57
14	GAK-8615 x AKA-5	-9.80 *	-13.21 **	-5.93 *	3.67	2.16	3.36	19.12**	11.72	45.13 **	18.84
15	GAK-8615 x AKA-7	-11.76 **	-15.09 **	-5.31 *	4.35	-1.79	1.34	2.84	0	51.28 **	28.26 *
16	GAK-8615 x HD-162	1.92	0	-2.22	7.76 **	5.14	6.38	-2.13	-4.83	38.05 *	13.04
	SE(d)	0.33	0.33	0.60	0.60	0.75	0.75	0.29	0.29	5.33	5.33
	C.D.at 5%	0.68	0.68	1.22	1.22	1.53	1.53	.0.60	0.60	10.89	10.89
	C.D.at 1%	0.92	0.92	1.65	1.65	2.07	2.07	0.81	0.81	14.67	14.67

* - Significant at 5 % level of significance
** - Significant at 1 % level of significance