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Genetic studies for biochemical parameters in GMS based hybrids of diploid cotton (*Gossypium arboreum* L.)

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ABSTRACT : An investigation was taken up to explore the possibility of commercial utilization of hybrid vigour and transferring the genes responsible for seed oil, protein and gossypol content in *desi* cotton through intra *arboreum* crosses. The inheritance of seed oil, seed protein and gossypol content were studied in sixty hybrids involving four adapted GMS based females (lines) and the fifteen *G. arboreum* accessions as males (testers) in line x tester analysis. It was found that all the characters studied *i.e.*, seed oil, seed protein and gossypol content are controlled by predominantly non additive gene action. The best general combiners among the parents were HD 528 for increasing level of protein content, CNA 398, HD 532 and LD 1026 for oil content, HD 523, HD 432, HD 517 and DGMS 34 for reducing level of gossypol content. The best specific combiners in the hybrids were DGMS 1 x LD 1026 and DGMS 2 x HD 527 for seed oil and DGMS 1 x HD 503 and DGMS 1 x HD 514 for seed protein and DGMS 34 x HD 534, DGMS 9 x LD 1026 and DGMS 9 x NDLA 3020 for reducing the gossypol content. The present study indicated the possibility of developing high quality hybrids or lines with high seed oil, protein and reducing gossypol content traits through heterosis breeding and population improvement breeding method.

Key words : GCA, gene action, *Gossypium arboreum,* gossypol, heterosis, oil, protein, SCA

Cotton is widely grown worldwide for its natural fiber. Cotton seed is also a good source of oil and protein. Cotton seed contain 18-20 per cent seed oil which is edible after removal of gossypol by hydrogenation and 17- 23 per cent seed protein by weight. The cotton seed, a by-product, is an important source of edible oil and is the second largest source of vegetable oil in the world. Cotton seed oil is generally considered as healthy vegetable oil. It is cholesterol free and hence termed as "heart oil". After extraction of oil, the cotton seed meal is a protein rich byproduct and assumes great importance in feed and fermentation industries. Therefore, cotton seed has an important contribution in helping to feed the world in the future. The annual world wide cotton seed yield could supply the dietary protein needs of 240 - 350 million people, but presence of gossypol is a major deterrent. Ruminant animals could tolerate the gossypol, but it is toxic to non ruminants, if gossypol content absent, cotton seed oil and cotton seed meal could be made more economically processed for food and feed. Improvement in yield and other quality parameters has been achieved through distant hybridization, particularly through intra specific hybridization. Evaluation of breeding materials for general combining ability and specific combining ability as well as to study the extent of heterosis for yield and other quality parameters are pre requisites for any breeding programme aimed in development of high quality hybrids. The breeding methods to be adopted for improvement of a crop depend on the nature of gene action involved in the potential inheritance of economically important traits. The success of a hybridization program depends upon the selection of parents. For a sound hybridization program parents should be selected not only on the basis of their diversity but also on the basis of *per se* performance, heterosis and their combining ability effects. Consider the above points, the present investigation was carried out with the objectives to know the extent the heterosis, *per se* performance, GCA and SCA effects and gene action for biochemical parameters in *desi* cotton (*Gossypium arboreum* L.)

MATERIALS AND METHODS

A field experiment was conducted to evaluate the genetic potential of genotypes and combining ability in parents and F_1 hybrids for biochemical parameters such as oil, protein and gossypol content in *desi* cotton genotypes (*Gossypium arboreum* L.). The genotypes consisting of four female parent, namely, DGMS 1, DGMS 2, DGMS 9 and DGMS 34 and fifteen male parents, namely, HD 432, HD 503, HD 514, HD 517, HD 522, HD 523, HD 532, H D 533, HD 534, CNA 398, LD 1026, LD 1019 and NDLA 3020 were crossed during *kharif,* 2014 in line x testers mating design. The conventional hand emasculation and pollination were done and crossed bolls were collected separately and ginned to obtain F_1 seeds. The F_1 hybrids along with their parents were grown randomized block design (RBD) with three replications along with the standard check (AAH 1) at Research Area of Cotton Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana (India) during *kharif* 2015 for their evaluation.

In each genotype and their cross combinations, data were recorded for biochemical parameters namely, oil content, protein content and gossypol content. Nitrogen content (%) was estimated by micro-Kjeldahl method (AOAC, 1990) and protein content calculated by multiplying with a factor of 6.25. Oil content (%) was also determined by Soxhelt method and Gossypol content (%) was determined by the method by Bell, 1967. The data for various biochemical parameters were analyzed on the mean basis. The combining ability analysis was performed as modified method of line x testers mating design given by Arunachalam, 1974. Estimation of economic heterosis was performed as per the method suggested by Turner (1953) the deviation of F_1 values over the check variety for each trait and expressed in percentage. Statistical analysis was carried out by using the mean values over sample plants through OP STAT package.

RESULTS AND DISCUSSION

Analysis of variance : Analyses of variance for general and specific combining ability of three characters under study are presented in Table 1. General combining ability variances for male and female parents were significant for all the characters studied at 1 per cent level of significance except oil content of female parents which were significant at 5 per

Table 1. Analysis of variance for combining ability in *Gossypium arboreum* L. for biochemical parameters

Source of variance	D.F	Oil content (%)	Protein content (%)	Gossypol content (%)
Replication	2	0.01	0.11	0.001
Lines	3	1.08*	12.69**	0.24**
Testers	14	3.80**	8.16**	0.04**
Lines x Testers	42	2.14**	7.65**	0.04**
Error	118	0.36	1.39	0.002
ó^{2}(GCA)	-	0.03	0.29	0.008
ó^{2}(SCA)	-	5.34	18.78	0.168
ó^{2}(GCA)/ ó^{2}(SCA)	-	0.006	0.02	0.05

cent level of significance. Mean squares due to line, tester and line x tester were found significant for seed oil, seed protein and gossypol traits studied thereby suggesting differences between parents and crosses and possibility of heterotic effects for some of the characters. These significant mean squares due to lines, testers and line x tester interaction revealed the presence of significant variance among them. Similar results were found by Jaiwar *et al.,* (2013) who also reported the presence of heterosis due to the significant differences in the mean performance of crosses and parents.

Effects of gene action : The variance components and also the ratio between GCA and SCA variances give idea about preponderance of gene action which may be additive or non additive gene action. Additive gene action provides fixable effects *i.e.* heterosis is fixed to one generation to next generation and the non additive gene action provides non-fixable effects *i.e.* heterosis is not fixed to one generation to next generation. If SCA variance is greater than GCA variance for the particular character, it will give idea about the traits which are governed by non-additive gene action. In current study, analysis of combining ability revealed that magnitude of SCA variance was greater than GCA variance for all the characters studied (Table 1). The non-additive gene action of seed oil suggests that seed oil content can be improved through heterosis breeding. Seed protein and gossypol content also predominantly governed by non additive gene action as seen from the proportion of the SCA variance to GCA variance. All the traits which are governed by non additive gene action could be improved by heterosis and population improvement breeding method, similar findings were reported by Kaliyaperumal and Ravikesavan (2011) for protein and oil content, Munawar and Malik (2013) and Abid *et al.,* (2016) for oil and protein content, respectively.

Choice of parents based on GCA effects : The combining ability analysis gives useful information regarding selection of parents based on the performance of their hybrids and further it helps for the exploitation of heterosis. The estimates of general combining ability (GCA) effects of all the parents comprising four female parents and fifteen male parents for all the characters investigated are presented in Table 2. With regarding biochemical parameters among male and female parents only single male

Table 2. Mean performance and GCA of testers and lines for biochemical parameters in *Gossypium arboreum* L.

Male parents (Testers)	Oil content (%)		Protein content (%)		Gossypol content (%)	
	Mean	GCA	Mean	GCA	Mean	GCA
HD 432	17.03	0.41	11.64	-0.85	0.48	-0.06**
HD 503	16.88	0.46	11.14	-0.27	0.51	-0.02
HD 514	17.30	-0.51	12.99	0.33	0.64	-0.05**
HD 517	17.00	-0.40	11.81	1.21	0.27	-0.06**
HD 533	19.43	-0.77*	11.22	-1.31	0.37	-0.05**
HD 522	17.48	0.41	14.25	-1.34	0.41	0.02
HD 534	17.05	-1.12**	10.97	-1.33	0.37	0.04*
HD 532	15.65	0.81**	13.32	0.25	0.58	-0.04*
HD 523	16.85	0.27	14.75	0.35	0.26	-0.08**
CNA 398	16.80	0.98**	16.11	-0.28	0.58	-0.02
HD 528	15.95	0.53	13.07	2.03**	0.49	0.12**
HD 527	14.65	-0.15	12.48	1.21	0.70	0.06*
LD 1026	16.15	0.69*	11.73	0.56	0.54	0.02
LD 1019	18.95	-0.97**	14.16	-0.68	0.66	0.09**
NDLA 3020	15.28	-0.65*	14.25	0.12	0.72	0.02
SE (d)	-	0.30	-	0.59	-	0.02
Female parents (Lines)						
DGMS 1	15.93	-0.26	10.13	0.21	0.70	-0.03**
DGMS 2	15.13	0.18	10.72	0.53	0.62	0.11**
DGMS 9	17.25	-0.01	12.48	-0.95**	0.60	-0.03**
DGMS 34	15.78	0.10	11.89	0.21	0.29	-0.05**
SE(d)	-	0.15	-	0.30	-	0.01

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

parent HD 528 was found best general combiner for increased level of protein content and exhibit above average in *per se* performance. For oil content male parent CNA 398 reported highest general combiner and above average in *per se* performance which are followed by HD 532 and LD 1026 for oil content and poor in *per se* performance. The genotypes HD 523 from male and DGMS 34 from female were best general combiner for reducing gossypol content but poor in *per se* performance followed by HD 432, HD 517, HD 514, HD 533 and HD 532 among male parents and DGMS 1 and DGMS 9 among female parents which were found negatively significant and best general combiner for reducing level of gossypol content. In general, none of the male and female parents was found posses high GCA effects with high *per se* performance and vice-versa for all the characters under study. The respective best combiners for various characters could be used for improvement in those characters. However, considering the economic important of various characters HD 523, CNA 398, HD 532 and HD 528 among the male and DGMS 34 among female were best general combiner for oil, protein and reducing gossypol content in seed, which may be useful in future breeding for improvement of biochemical parameters in *desi* cotton. Similar results were reported by Kaliyaperumal and Ravikesavan

(2011), Jaiwar *et al.,* (2013) for both traits oil and protein content, Munawar and Malik (2013) and Abid *et al.* (2016) for oil and protein content, respectively, while no similar research work has been reported for gossypol content.

Choice of hybrids based on *per se* performance, heterosis and SCA effects : SCA effects alone are not appropriate for choosing parents for hybridization program and exploitation of heterosis because the hybrid with high mean and high heterosis value not always revealed high SCA effect and *vice versa.* Selection of hybrids based on any one of the criteria may not be effective. For exploitation of hybrid vigour *per se* performance, the extent of heterosis and SCA effects of hybrids are important. Hence, the effective cross combinations are to be identified based on all three parameters involved in the crosses for further exploitation. The estimates of specific combining ability (SCA) effects of all sixty GMS based hybrids with *per se* performance and standard heterosis (SH) of all three biochemical parameters in *Gossypium arboreum* L. are presented in Table 3. With regards to biochemical parameters, hybrid DGMS 9 x CNA 398 reported highest value of mean (19.43) and standard heterosis (21.03%) and found significant SCA effects (1.48*) for oil content. Highest specific combiner hybrid for oil content was DGMS 1 x LD 1026 (1.95**) and also reported as second highest in *per se* performance (19.35) and heterotic performance (20.56%) followed by DGMS 2 x HD 527, DGMS 34 x HD 534 exhibited significant SCA effects and above average mean and heterotic performance for oil content. For protein content hybrid DGMS 1 x HD 503 and DGMS 1 x HD 514 were reported best specific combiner hybrid (3.79** and 3.20** respectively) with highest mean (16.94) and heterotic performance (27.16%). The hybrid DGMS 9 x HD 523 found positively significant SCA effects (2.82*) and found above average mean and heterotic performance for protein content. The DGMS 34 x HD 534 cross reported best and highest negatively significant SCA effects (-0.21**) and found to be better in mean and heterotic performance among all sixty hybrids for reducing of gossypol content followed by hybrids DGMS 9 x LD 1019 (-0.19**), DGMS 9 x NDLA 3020 (-0.16**) and DGMS 34 x HD 503 (-0.14**) also reported better and negatively significant for SCA effects. Almost identical results have been reported by Kaliyaperumal and Ravikesavan (2011), Jaiwar *et al.,* (2013) for protein and oil content, Munawar and Malik (2013) and Abid *et al.* (2016) for oil and protein content, respectively, while no work has been reviewed for gossypol content.

The selection of hybrids and exploitation of hybrid vigour *per se* performance, standard heterosis and SCA effects were most important criteria for improvement of hybrids by using further breeding method in cotton (Jaiwar *et al.*, 2013). Three important hybrids DGMS 9 x CNA 398 for oil content, DGMS 1 x HD 503 for protein content and DGMS 34 x HD 534 for reducing gossypol content were reported best hybrids on the basis of *per se* performance, standard heterosis and SCA effects and may used in future breeding program for improvement of protein, oil and gossypol traits in *desi* cotton trough heterosis breeding and population improvement breeding method.

Table 3. Performances of crosses based on mean, standard heterosis (SH) and specific combining ability (SCA) for biochemical parameters in GMS based hybrids of *Gossypium arboreum* L.

Hybirds	Oil content (%)			Protein content (%)			Gossypol content (%)		
	Mean	SH	SCA	Mean	SH	SCA	Mean	SH	SCA
DGMS 1 x HD 432	16.70	4.05	-0.42	14.84	11.38	2.27	0.38	-43.94	-0.05
DGMS 1 x HD 503	17.55	9.35	0.38	**16.94**	**27.16**	**3.79****	0.44	-35.44	-0.03
DGMS 1 x HD 514	17.08	6.39	0.88	**16.94**	**27.16**	**3.20****	0.43	-36.75	-0.01
DGMS 1 x HD 517	16.48	2.65	0.16	**16.60**	**24.63**	1.98	0.54	-20.96	0.10
DGMS 1 x HD 533	14.38	-10.44	-1.57**	9.54	-28.37	-2.56*	0.46	-32.73	0.02
DGMS 1 x HD 522	17.13	6.70	0.00	9.88	-25.85	-2.20	0.54	-20.88	0.03
DGMS 1 x HD 534	14.05	-12.46	-1.54*	11.89	-10.71	-0.19	0.62	-8.17	0.09*
DGMS 1 x HD 532	18.18	13.24	0.65	15.68	17.69	2.02	0.46	-32.17	0.01
DGMS 1 x HD 523	16.38	2.02	-0.61	10.72	-19.54	-3.05*	0.37	-46.02	-0.04
DGMS 1 x CNA 398	17.38	8.26	-0.32	11.31	-15.12	-1.82	0.47	-30.71	0.00
DGMS 1 x HD 528	18.20	13.40	0.96	**16.68**	**25.26**	1.24	0.56	-17.23	-0.05
DGMS 1 x HD 527	16.10	0.31	-0.46	14.08	5.70	-0.54	0.43	-37.35	-0.12**
DGMS 1 x LD 1026	**19.35**	**20.56**	**1.95****	13.74	3.18	-0.23	0.39	-42.77	-0.12**
DGMS 1 x LD 1019	16.13	0.47	0.39	11.47	-13.86	-1.26	0.67	-1.77	0.09*
DGMS 1 x NDLA 3020	15.63	-2.65	-0.44	10.89	-18.26	-2.64*	0.59	-13.02	0.08*
DGMS 2 x HD 432	16.60	3.43	-0.96	12.73	-4.40	-0.15	0.49	-27.69	-0.07
DGMS 2 x HD 503	16.58	3.27	-1.04	12.06	-9.44	-1.40	0.73	6.81	0.13**
DGMS 2 x HD 514	16.43	2.34	-0.21	14.16	6.33	0.10	0.61	-10.48	0.03
DGMS 2 x HD 517	16.53	2.96	-0.23	14.42	8.22	-0.53	0.55	-18.63	-0.01
DGMS 2 x HD 533	16.73	4.21	0.34	12.23	-8.18	-0.19	0.59	-12.60	0.02
DGMS 2 x HD 522	**18.80**	**17.13**	**1.24***	15.00	12.64	**2.61***	0.63	-7.08	-0.01
DGMS 2 x HD 534	16.43	2.34	0.39	12.65	-5.03	0.25	0.64	-5.52	-0.02
DGMS 2 x HD 532	17.70	10.28	-0.26	12.48	-6.29	-1.50	0.71	3.83	0.12**
DGMS 2 x HD 523	17.65	9.97	0.23	12.65	-5.03	-1.43	0.66	-2.63	0.12**
DGMS 2 x CNA 398	17.50	9.03	-0.63	13.15	-1.24	-0.30	0.57	-16.73	-0.04
DGMS 2 x HD 528	15.98	-0.47	-1.70**	14.08	5.70	-1.69	0.68	0.65	-0.06
DGMS 2 x HD 527	**18.73**	**16.67**	**1.73****	16.43	**23.37**	1.49	0.68	0.73	0.00
DGMS 2 x LD 1026	18.43	14.80	0.59	14.25	6.96	-0.04	0.56	-17.06	-0.07
DGMS 2 x LD 1019	16.30	1.56	0.13	14.42	8.22	1.36	0.71	4.56	0.00
DGMS 2 x NDLA 3020	16.88	5.14	0.38	15.26	14.53	1.40	0.50	-26.94	**-0.14****
DGMS 9 x HD 432	**18.70**	**16.51**	**1.33***	11.97	-10.13	0.56	0.50	-25.77	0.08*
DGMS 9 x HD 503	17.15	6.85	-0.28	10.18	-23.59	-1.81	0.51	-25.15	0.05
DGMS 9 x HD 514	16.35	1.87	-0.11	10.04	-24.59	-2.54*	0.44	-34.71	0.01
DGMS 9 x HD 517	16.53	2.96	-0.04	13.91	4.44	0.44	0.41	-39.10	-0.02
DGMS 9 x HD 533	17.68	10.12	**1.48***	12.06	-9.44	1.12	0.51	-25.04	0.08*
DGMS 9 x HD 522	16.08	0.16	-1.31*	11.39	-14.49	0.48	0.52	-23.13	0.02
DGMS 9 x HD 534	15.30	-4.67	-0.55	10.55	-20.80	-0.37	0.67	-1.23	0.14**
DGMS 9 x HD 532	17.53	9.19	-0.26	13.15	-1.24	0.66	0.38	-44.83	-0.07
DGMS 9 x HD 523	17.58	9.50	0.34	15.42	15.80	**2.82***	0.45	-33.65	0.05
DGMS 9 x CNA 398	**19.43**	**21.03**	**1.48***	14.50	8.86	**2.53***	0.48	-29.50	0.01
DGMS 9 x HD 528	17.98	11.99	0.48	14.33	7.59	0.05	0.63	-7.25	0.03
DGMS 9 x HD 527	14.85	-7.48	-1.97**	10.95	-17.79	-2.51*	0.50	-26.31	-0.04

Table 3 contd...

Table 3 contd...

DGMS 9 x LD 1026	16.58	3.27	-1.08	11.89	-10.71	-0.92	0.52	-23.60	0.02
DGMS 9 x LD 1019	15.73	-2.02	-0.27	9.71	-27.11	-1.87	0.38	-43.92	**-0.19****
DGMS 9 x NDLA 3020	17.08	6.39	0.76	13.74	3.18	1.37	0.34	-50.25	**-0.16****
DGMS 34 x HD 432	17.53	9.19	0.05	9.88	-25.85	-2.69*	0.43	-36.35	0.03
DGMS 34 x HD 503	18.48	15.11	0.94	12.57	-5.66	-0.58	**0.30**	**-55.96**	**-0.14****
DGMS 34 x HD 514	16.00	-0.31	-0.56	12.99	-2.50	-0.76	0.39	-43.02	-0.03
DGMS 34 x HD 517	16.78	4.52	0.11	12.73	-4.40	-1.89	**0.33**	**-51.08**	-0.07
DGMS 34 x HD 533	16.05	0.00	-0.25	13.74	3.18	1.64	**0.30**	**-55.94**	-0.11**
DGMS 34 x HD 522	17.55	9.35	0.07	11.18	-16.05	-0.89	0.43	-36.98	-0.05
DGMS 34 x HD 534	17.65	9.97	**1.70****	12.40	-6.92	0.31	**0.29**	**-56.75**	**-0.21****
DGMS 34 x HD 532	17.75	10.59	-0.13	12.48	-6.29	-1.18	0.37	-45.33	-0.06
DGMS 34 x HD 523	17.38	8.26	0.04	15.42	15.80	1.66	**0.26**	**-61.98**	-0.12**
DGMS 34 x CNA 398	17.53	9.19	-0.53	12.73	-4.40	-0.41	0.47	-31.13	0.02
DGMS 34 x HD 528	17.85	11.21	0.26	15.84	18.95	0.40	0.67	-1.88	0.08*
DGMS 34 x HD 527	17.63	9.81	0.71	**16.18**	**21.48**	1.56	0.68	0.02	0.16**
DGMS 34 x LD 1026	16.30	1.56	-1.46*	15.17	13.90	1.19	0.64	-5.29	0.17**
DGMS 34 x LD 1019	15.85	-1.25	-0.25	14.51	8.92	1.77	0.66	-2.40	0.11**
DGMS 34 x NDLA 3020	15.73	-2.02	-0.70	13.41	0.65	-0.13	0.70	2.98	0.22**
SE (d)	-	-	0.60	-	-	1.18	-	-	0.04

"**" Significant at 1% level of significance and "*" Significant at 5% level of significance

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