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Research Note

Estimation of heterosis for seed cotton yield and biochemical parameters in genetic male sterile based hybrids of *Gossypium arboreum* L.

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Abstract
The present investigation was undertaken to study heterosis and explore its commercial utilization in *desi* cotton (*G. arboreum* L.) by using Line x Tester design with four genetic male sterile females and fifteen male parents. Out of sixty hybrids studied, a total thirty three hybrids showed positive heterobeltiosis and seventeen hybrids showed positive economic heterosis over standard check, AAH 1 and thirty nine crosses showed positive mid parent heterosis for seed cotton yield. The F_1 hybrids DGMS 34 x HD 517 (53.19 %), DGMS 34 x HD 523 (40.00 %), DGMS 2 x HD 528 (39.96 %) and DGMS 1 x HD 432 (39.97 %) recorded positive standard heterosis for number of bolls, seed cotton yield and low gossypol content, while the maximum heterobeltiosis for seed cotton yield per plant was exhibited by the hybrid DGMS 2 x HD 528 (121.82 %) followed by DGMS 1 x HD 432 (114.48 %) and DGMS 1 x CNA 398 (84.62 %). Hybrid DGMS 34 x HD 517 had reduced level of gossypol and DGMS 1 x LD 1026 had high level of protein while DGMS 9 x CNA 398 had high level of oil content over standard check AAH 1.

Key words
Gossypium arboreum L., Heterosis, Line x Tester analysis, Genetic Male Sterility

Gossypium arboreum, (diploid cotton) is very well adapted to the fluctuating environmental conditions and is still under cultivation because of its inherent ability to resist major pests and diseases. As the world's foremost natural fibre crop, cotton supports a multibillion dollar production and processing industry. Cotton is widely cultivated worldwide for its natural fiber, but the byproduct of cotton processing industry is also important. Like cotton seed is an important source of vegetable oil and high protein meal. Cotton seed contains 18-20% seed oil which is edible after removal of gossypol by hydrogenation (Narayanan *et al.*, 1975) and 17- 23 per cent seed protein meal.

The cost of hybrid seed production at a commercial scale is cheaper in cotton due to naked floral biology, more number of seeds per cross, higher rate of seed setting and higher percentage of successful crosses. Genetic male sterility adds to the advantages. These important characteristics offer opportunity to crop improvement and development of new crop variety through hybridization. The extent of heterosis acts as a basic tool for the choice of desirable parents for developing superior F_1 hybrids to exploit hybrid vigour and for building new gene pools to be employed in further breeding programmes. Exploitation of heterosis on commercial scale and systematic varietal improvement through hybridization are the main tools to increase cotton production. For the success of cotton breeding programme, there is a basic need in selecting proper parents for hybridization. Keeping in view the above points, the present investigation was carried out with the objectives to know the extent the heterosis for seed cotton yield and biochemical parameters in *G. arboreum* L.
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The material for the present investigation comprised of 80 *G. arboreum* L. cotton genotypes *viz.*, 60 hybrids developed on 4 Genetic Male Sterile (GMS) female parents (lines) and 15 male parents (testers) in Line x Tester mating design along with their parents and one standard check (AAH 1). Table 1 explains male and female parent characteristics used in the experiment. The crosses were made during *kharif* 2014 in Line x Tester mating design at the Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar and the experimental material was grown during *kharif* 2015 in a randomized block design with three replications. They were sown in two rows of 6.0 m length with spacing of 67.5 cm between rows and 60 cm between the plants. Economic heterosis was calculated as per method suggested by Turner (1953) for seed cotton and other traits as the deviation of F_1 values over the check variety (AAH 1) for each trait and expressed in percentage. The per cent increase or decrease of F_1 over the mid parent is referred as average heterosis, while heterobeltiosis denotes the per cent increase or decrease of F_1 over the better parent and is estimated as per method given by Fonseca and Peterson (1968). All the recommended cultural package of practices and need based plant protection measures were followed from sowing till harvesting the crop. Thirteen characters including seed cotton yield and its related traits and biochemical parameters were studied. Five plants randomly selected were tagged and labeled for recording the observations on days to first flower, number of monopods per plant, number of bolls per plant, boll weight, plant height, seed cotton yield per plant, ginning out turn, seed index, lint index, number of seeds per boll, oil content, protein content and gossypol content were recorded on the randomly selected plants.

The heterotic response of F_1 is indicative of genetic diversity among the parents involved (Moll *et al.*, 1962). Table 2 have been described top five hybrids based on mean yield, among this top five hybrids DGMS 34 x HD 517 exhibited highest mean performance (125.68) and same hybrids gave better performance for economic heterosis and mid parent heterosis for seed cotton yield and number of bolls. DGMS 2 x HD 528 (144.83) recorded as best hybrid and exhibited good heterotic performance all three type of heterosis for boll weight. The extent of economic heterosis, average heterosis and heterobeltiosis were studied for yield and its attributing characters and biochemical characters of crosses have been presented in the table 3. The brief description of heterotic response is given here under.

Heterosis for seed cotton yield and its attributes: Increase in seed cotton yield is one of the major objectives in cotton breeding programmes. Heterosis for seed cotton yield per plant over standard check, better parent and mid parent ranged from -51.25% (DGMS 2 x HD 527) to 53.19% (DGMS 34 x HD 517), -63.02 (DGMS 2 x HD 527) to 121.82 (DGMS 2 x HD 528) and -49.96 (DGMS 2 x NDLA 3020) to 164.74 (DGMS 2 x CNA 398), respectively. Seventeen crosses were found to have positive heterotic effect over standard check AAH 1, thirty three crosses over better parent, and thirty nine crosses over mid parent exhibited positive heterosis. The crosses DGMS 1 x HD 432, DGMS 2 x HD 528 and DGMS 34 x HD 517 recorded overall better performance for all three types of heterosis *viz.*, mid parent, better parent and economic heterosis. These results are in line with the findings of Punitha *et al.* (2012) and Patil *et al.* (2012) over both mid and better parents while Tuteja *et al.* (2013) over standard check. For number of bolls per plant, a total of ten crosses exhibited positive heterosis over standard check AAH 1. Range of economic heterosis against the check was -46.60% to 41.05%. The maximum heterosis was shown by DGMS 34 x HD 517 (41.05%) followed by DGMS 1 x HD 432 (27.16%) and DGMS 2 x HD 528 (24.85%). Maximum heterosis over better parent and mid parent was exhibited by crosses DGMS1 x HD 432 (132.77%) and DGMS 1 x CNA 398 (169.65%), respectively. Economic heterosis for boll weight varied from -9.21% to 17.21%. Forty five crosses were found to have positive heterotic effect over standard check AAH 1, thirty crosses over better parent and thirty nine crosses over mid parent exhibited positive heterosis for boll weight. Out of total sixty crosses, DGMS 2 x HD 432 reported highest heterosis value for economic heterosis (17.21%), mid parent heterosis (20.75) and better parent heterosis (19.19P). Followed by DGMS 2 x LD 1026, DGMS 2 x HD 528, DGMS 34 x HD 523 and DGMS 9 x LD 1026 for economic heterosis, DGMS 2 x HD 528 for mid parent and better parent heterosis. The crosses showing high heterosis for number of monopods was DGMS 1 x HD 432 (9.92%). Hybrids DGMS 1 x HD 533 and DGMS 9 x HD 533 also showed better performance of heterotic effect in positive direction for all three types of heterosis. Thus, number of monopods also seems to play role in increased seed cotton yield per plant. These findings are in confirmation to the findings of Giri *et al.* (2006) and Kumari *et al.* (2009).

For seed index, the higher economic heterosis was observed in DGMS 34 x HD 532 (23.55%). Out of sixty crosses, thirty crosses over standard check, thirty three crosses over better parent and forty six crosses over mid parent exhibited positive heterotic effects for seed index. Cross DGMS 1 x HD 503 (1.20%) showed maximum heterotic effects over better parent and cross DGMS 1 x CNA398 (1.44%) showed maximum heterotic effects over mid parent. While for lint index, range of heterosis was from -18.85% (DGMS 1 x HD 523) to 44.45% (DGMS 9 x LD 1019) over commercial check, -1.18% (DGMS 1 x HD 523) to 1.07% (DGMS 9 x LD 1019) over better parent and -0.90% (DGMS 1 x HD 523) to 1.15% (DGMS 9 x LD 1019) over mid parent. Maximum heterotic value over standard check was recorded in cross DGMS 9 x LD 1019 (44.45%). The cross DGMS 9 x LD 1019 exhibited highest positive heterotic effects of all three types of heterosis for lint index. Similar results were reported by Saini *et al.* (2005) and Giri *et al.* (2006).

The cross DGMS 1 x LD 1026 (-3.46%) over standard check, DGMS 2 x HD 532 (-10.73%) over better parent and DGMS 2 x HD 532 (-6.77%) over mid parent indicated earliness. Range of economic heterosis for plant height varied from -4.88% (DGMS 2 x HD 534) to 25.81% (DGMS 9 x LD 1026), -41.00% (DGMS 34 x HD 528) to 26.00% (DGMS 9 x HD 503) over better parent and -38.67(DGMS 34 x LD 1019) to 29.67% (DGMS 9 x HD 503) over mid parent. Only three crosses over commercial check, fifty two crosses over better parent and forty nine over mid parent exhibited negative heterotic response for plant height. For ginning out turn the highest heterotic value was recorded for the cross DGMS 9 x HD 534 (18.71%). The maximum better parent heterosis was exhibited by the cross DGMS 9 x HD 522 (7.81%) and the maximum mid parent heterosis was exhibited by the cross DGMS 9 x HD 527 (7.87%).

Heterosis for biochemical parameters: For biochemical parameters, the cross DGMS 9 x CNA 398 (21.03%) showed higher heterosis over standard check for oil content. Maximum better parent and mid parent heterosis for oil content was shown by cross DGMS 2 x HD 527 *i.e.* 3.60% and 3.84% respectively. For protein content, hybrids DGMS 1 x HD 514 and DGMS 1 x HD 503 (27.16%) showed maximum heterosis over standard check AAH 1. The cross DGMS 1 x HD 514 exhibited highest heterotic effects of all three types of heterosis. Fifty four crosses over commercial check, fifty one over better parent and forty crosses over mid parent revealed negative heterotic effects for gossypol content. Heterotic effects for reduced amount of gossypol content were showed by the hybrids DGMS 34 x HD 523 (-61.98%), DGMS 34 x HD 534 (-56.75), DGMS 34 x HD 503 (-55.96%), DGMS 34 x HD 533 (-55.94%) and DGMS 34 x HD 517 (-51.08%). Maximum desirable better parent heterosis was observed in cross DGMS 34 x HD 523 (-0.42%). Varying magnitude of heterosis has been reported in *G. hirsutum* and *G. arboreum* species by Solanke *et al.* (2015).

The present study revealed that a number of crosses produced high heterosis for seed cotton yield per plant. The good hybrids for mid parent, better parent and economic heterosis were DGMS 34 x HD 517, DGMS 2 x HD 528 and DGMS 1 x HD 432 which also had high *per se* performance. Crosses DGMS 1 x CNA 398 and DGMS 2 x CNA 398 showed better performance for average heterosis and heterobeltiosis for number of bolls and seed cotton yield and cross DGMS 2 x HD 527, for oil content. the cross DGMS 1 x HD 514 was found to be the best among all the crosses in respect of all three types of heterosis for protein content and cross DGMS 34 x HD 523 reported highest better parent and economic heterosis for gossypol content. Performances of these hybrids warrant them for further testing.

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Table 1. Characteristics of female & male parents and standard check used in the present study

Female Parents		**Characteristics**			**Characteristics**
1.	DGMS 1	Green plant, broad leaves & cream petal (GBC)	3.	DGMS 9	Red plant, narrow leaves & yellow petal (RNY)
2.	DGMS2	Red plant, narrow leaves & cream petal (RNC)	4.	DGMS 34	Green plant, narrow leaves & cream petal (GNC)
Male Parents					
1.	HD 432	GNW	9.	HD 523	GNY
2.	HD 503	GNW	10.	CNA 398	GNW
3.	HD 514	GNW	11.	HD 528	GNY
4.	HD 517	GNW	12.	HD 527	GNY
5.	HD 533	GNY	13.	LD 1026	White petal
6.	HD 522	GNC	14.	LD 1019	Yellow petal
7.	HD 534	GNY	15.	NDLA 3020	White petal
8.	HD 532	GNY			
	Standard Check	AAH 1			Genetic Male Sterility based world's first *G. arboreum* hybrid

GNW = Green plant, narrow leaves & white petal**; GNY =** Green plant, narrow leaves & yellow petal

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Table 2. Top five hybrids based on mean of yield traits and their heterosis values

S. no.	Top five hybrids Based on mean of yield	Heterosis value								
		Seed cotton yield/plant			No. of boll			Boll weight/boll		
		C.C.	M.P.	B.P.	C.C.	M.P.	B.P.	C.C.	M.P.	B.P.
1	DGMS 34 x HD 517 (125.68)	**53.19**	**158.35**	82.52	**41.05**	**144.71**	73.11	11.17	6.79	3.09
2	DGMS 34 x HD 523 (114.86)	40.00	84.85	66.80	20.83	65.54	48.30	13.00	14.29	12.66
3	DGMS 2 x HD 528 (114.83)	39.96	128.68	121.82	24.85	114.31	111.23	**13.65**	**19.63**	**18.54**
4	DGMS 1 x HD 432 (114.34)	39.37	124.75	114.98	27.16	136.10	**132.77**	10.00	17.59	16.45
5	DGMS 1 x LD 1026 (103.03)	25.58	82.92	60.76	15.92	78.85	51.44	12.25	13.67	14.96

Table 3. Top five hybrids and their Heterosis value for yield and its component traits

Traits	Heterosis		
	Commercial Check	Mid Parent	Better parent
Seed cotton yield/plant	DGMS 34 x HD 517 **(53.19)**	DGMS 1 x CNA 398 **(164.74)**	DGMS 2 x HD 528 **(121.82)**
	DGMS 34 x HD 523 **(40.00)**	DGMS 2 x CNA 398 **(164.46)**	DGMS 1 x HD 432 **(114.98)**
	DGMS 2 x HD 528 **(39.96)**	DGMS 34 x HD 517 **(158.35)**	DGMS 1 x CNA 398 **(84.62)**
	DGMS 1 x HD 432 **(39.37)**	DGMS 2 x HD 528 **(128.68)**	DGMS 34 x HD 517 **(82.52)**
	DGMS 1 x LD 1026 **(25.58)**	DGMS 1 x HD 43 **(124.75)**	DGMS 2 x CNA 398 **(81.19)**
Boll weight/boll	DGMS 2 x HD 432 **(17.21)**	DGMS 2 x HD 432 **(20.75)**	DGMS 2 x HD 432 **(19.19)**
	DGMS 2 x LD 1026 **(14.83)**	DGMS 2 x HD 528 **(19.63)**	DGMS 2 x HD 528 **(18.54)**
	DGMS 2 x HD 528 **(13.65)**	DGMS 2 x LD 1026 **(18.11)**	DGMS 1 x HD 432 **(16.45)**
	DGMS 34 x HD 523 **(13.00)**	DGMS 1 x HD 432 **(17.59)**	DGMS 2 x LD 102 **(16.40)**
	DGMS 9 x LD 1026 **(12.32)**	DGMS 1 x LD 1026 **(14.96)**	DGMS 1 x LD 102 **(13.67)**
No. of boll	DGMS 34 x HD 517 **(41.05)**	DGMS 1 x CNA 398 **(169.65)**	DGMS 1 x HD 432 **(132.77)**
	DGMS 1 x HD 432 **(27.16)**	DGMS 2 x CNA 398 **(154.34)**	DGMS 2 x HD 528 **(111.23)**
	DGMS 2 x HD 528 **(24.85)**	DGMS 34 x HD 517 **(144.71)**	DGMS 1 x CNA 39 **(92.44)**
	DGMS 9 x LD 1026 **(22.07)**	DGMS 1 x HD 432 **(136.10)**	DGMS 2 x CNA 398 **(77.42)**
	DGMS 34 x HD 523 **(20.83)**	DGMS 34 x CNA 398 **(116.59)**	DGMS 34 x HD 517 **(73.11)**