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Heterosis studies for seed cotton yield and other traits in upland cotton (*Gossypium hirsutum* L.)

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Abstract
The present study analysed 40 *Gossypium hirsutum* hybrids, developed on five female parents (testers) using eight male parents (lines), in line x tester analysis along with one standard check (HHH 223) to estimate economic heterosis with the objective of exploring their commercial utilization. The experimental material was grown at CCS Haryana Agricultural University, Cotton Research Station Sirsa, during Kharif 2015-16 in a randomized block design with three replications. Observations were recorded for nine characters viz., plant height, number of monopods, number of sympods, number of bolls, boll weight, ginning out turn, seed index, lint index and seed cotton yield per plant. The economic heterosis was calculated over standard check HHH 223. Maximum heterosis showing cross combinations for seed cotton yield, boll number, boll weight, plant height, number of monopods, number of sympods, ginning out turn, seed index and lint index were H1236 x LH 1960 (69.09%), H1300 x P 729-37 (69.05%), H1300 x LH 1960 (15.82%), H1098i x RST 9 (9.63%), H1300 x Mahalaxmi (65.15%), H1098i x RST 9 (60.40%), H1300 x LH 1960 (18.91%), H1300 x LH 1960 (18.91%) and H1300 x RST 9 (22.59 %) respectively.Where ever cross combinations involving either H1098i or H1117 as female parent recorded significant positive heterosis for most of the yield contributing characters. Thus the female parents H1098i and H1117 can be used within breeding programmes aimed for heterosis breeding after proper evaluation within multi-location trials.

Keywords: *Gossypium*, heterosis, seed cotton yield.

Introduction
Cotton (*Gossypium hirstum* L.) is the king of fibre and an important cash crop of India which exercise profound influence on economics and social affairs. Although cotton in India is grown chiefly for its fiber but it also gained additional economic importance as a major contributor of edible oil, proteins and other byproducts. Cotton is the most important raw material for Indian textile industry, which makes up 70 per cent of its raw material needs. It is one of the largest contributing sectors of India's export.The world-wide trade of textiles and clothing has boosted the GDP of India to a great extent. The textile industry is claimed to be biggest revenue earner in India in term of foreign exchange and also biggest employer in the country, providing employment to over 119 million people either directly or indirectly.

There are four cultivated species of cotton viz. *Gossypium arboreum*, *Gossypium herbaceum*, *Gossypium hirsutum* and *Gossypium barbadense*. Among which *Gossypium hirsutum* is the predominant species which alone contributes about 90% to the global production. India is the only country in the world where all the four cultivated species are grown on commercial scale.

Cotton is one of the few crops which are accessible to the development of genotypes as varieties and at the same time amenable for commercial exploitation of heterosis. Heterosis is the phenomenon in which the F_1 of two genetically dissimilar parents show increased vigour for various characters over the mid parent (relative heterosis) or better parent (heterobeltiosis) or the standard check (standard heterosis). The objective of any plant breeding programme is to evolve varieties with traits of interest coupled with high yield. The yield plateau in cotton productivity can be broken by identifying suitable high yielding hybrids exhibiting high economic heterosis. To develop potential hybrids in cotton, it is necessary to exploit economic heterosis by means of genetic divergence and good combing ability of parents, which can lead to higher production and productivity. In the present study, line × tester analysis has been used to exploit the best heterotic crosses for seed cotton yield and other traits among forty upland cotton hybrids developed by crossing five female parents (testers) with eight male parents (lines) in a line × tester mating design.

Material and Methods
Forty specific crosses were undertaken during *kharif* 2015-2016 by using 13 parents of

G. hirsutum viz., GN 67-1, HS-2, LH 1960, P 729-37, RS 875, MAHALAXMI, RST-9, PIL-18, H1300, H1098i, H1117, H1226 and H1236 with diverse origin. These hybrids along with one standard check HHH 223 were grown in randomized block design with 3 replications at CCS HAU Cotton Research Station Sirsa. Observations were recorded on five randomly selected plants for plant height (cm), number of monopods per plant, number of sympods per plant, number of bolls per plant, boll weight (g), seed cotton yield per plant (g), ginning out turn (%), seed index (g) and lint index (g). The useful heterosis (heterosis over best check) was estimated as per standard method.

Results and Discussion

The phenomenon of heterosis has proved to be the most important genetic tool in boosting the yield of self as well as cross pollinated crops and is considered as the most important breakthrough in the field of crop improvement. Heterosis may be positive or negative, depending on the magnitude of the hybrid mean value. The primary objective of heterosis breeding is to achieve a quantum jump in yield of crop plants.

The data collected from the experimental material was subjected to analysis of variance and results obtained had been presented in Table 1.

Table 1: Analysis of variance for different characters under study in upland cotton

Source of variation	D.F	Plant height (cm)	Number of monopods per plant	Number of sympods per plant	Number of bolls per plant	Boll weight (g)	Seed Cotton Yield per plant (g)	Ginning out turn (%)	Seed index (g)	Lint index (g)
Replication	2	75.68	0.18	1.68	19.43	0.04	34.98	0.60	0.23	0.07
Treatment	40	170.61**	2.30**	10.20**	287.56**	0.11**	1611.35**	5.49**	1.15**	0.38**
Error	80	51.24	0.19	1.93	19.04	0.03	106.04	1.26	0.28	0.12

*Significant at P=0.05, **Significant at P=0.01.

The perusal of data in table revealed that the mean sum of squares due to genotypes was highly significant among the entries for all the traits. This indicated that the material selected for the present investigation was quite appropriate for further genetical analysis as considerable amount of variability existed in the experimental material under study.

Mean performance, range, and heterosis over best check HHH 223 for all the studied nine characters is presented in Table 2. Perusal of data in table revealed that high heterosis was observed for almost all the traits.

Table 2: Mean performance, range and extent of heterosis for different characters in upland cotton

Hybrids	Plant height (cm)	Number of monopods per plant	Number of sympods per plant	Number of bolls per plant	Boll weight (g)	Seed cotton yield per plant	Ginning out turn (%)	Seed index (g)	Lint index (g)
H1098i x GN 67-1	2.01	1.95	37.62**	5.73	11.71**	26.61**	-0.80	1.66	0.51
H1098i x HS-2	-2.21	-50.16**	26.73*	2.29	4.43	24.43*	0.80	7.87	9.64
H1098i x LH 1960	-8.23*	25.73*	11.88	7.74	5.70	55.85**	-3.74	0.61	-4.82
H1098i x P 729-37	-3.41	-6.51	17.82	14.61	10.13*	66.06**	-6.15*	1.82	-7.87
H1098i x RS 875	-10.37**	-19.54	47.52**	66.48**	9.18*	62.73**	-6.95**	13.31*	1.27
H1098i x Mahalaxmi	-2.47	-4.56	27.72*	54.44**	4.43	63.99**	-5.08*	7.26	-1.02
H1098i x RST 9	9.63*	-45.60**	60.40**	21.49*	4.75	50.69**	-8.82**	11.20	-3.30
H1098i x PIL-18	2.74	-11.07	41.58**	29.23**	0.00	45.18**	-2.94	13.77*	8.38
H1236 x LH 1960	3.01	23.78*	35.64**	62.18**	4.43	69.04**	0.53	-23.30**	-22.34**
H1236 x P 729-37	3.68	41.04**	25.74*	30.95**	-6.65	40.60**	0.27	-9.23	-8.88
H1236 x RS 875	8.90*	-2.28	28.71*	9.46	-5.06	26.72**	-1.34	-4.84	-6.85
H1236 x Mahalaxmi	-2.61	49.84**	-12.87	40.69**	-6.01	36.58**	5.61*	-14.52*	-6.35
H1117 x GN 67-1	8.23*	41.04**	17.82	25.21*	10.76*	28.67**	-0.53	16.49*	15.99*
H1117 x LH 1960	-3.01	26.06*	21.78	51.58**	4.11	65.02**	1.87	0.00	3.05
H1117 x P 729-37	7.83*	23.78*	-3.96	28.65**	-0.95	41.63**	6.15**	-12.56	-3.05
H1117 x RS 875	8.49*	4.23	13.86	-3.72	0.95	32.57**	2.41	-3.33	1.02
H1117 x Mahalaxmi	3.01	54.07**	2.97	45.27**	-2.53	28.33**	2.94	-14.67*	-10.66
H1117 x RST 9	5.62	-4.56	16.83	22.06*	13.61**	34.98**	8.82**	-0.61	14.47*
H1226 x GN 67-1	3.34	36.81**	5.94	31.52**	-2.53	33.14**	2.94	-2.72	2.54
H1226 x LH 1960	1.27	45.60**	-11.88	59.89**	-0.32	58.60**	-0.27	10.89	11.17
H1226 x P 729-37	-3.01	28.01*	6.93	0.86	-3.16	25.92**	-1.34	4.84	2.79
H1226 x RS 875	-3.41	36.81**	19.80	63.32**	1.90	68.00**	-0.27	-1.97	-2.03
H1226 x RST 9	1.34	-19.54	23.76*	25.21*	-2.85	31.88**	-1.07	10.89	9.14
H1300 x LH 1960	-2.07	36.81**	-1.98	-0.86	15.82**	36.12**	-2.41	18.91**	14.97*
H1300 x P 729-37	9.63*	56.35**	5.94	69.05**	3.48	66.06**	-1.07	9.98	8.63
H1300 x PIL-18	-2.27	14.98	-0.99	18.34	2.85	26.26**	5.35*	11.80	21.57**
Mean	151.7	3.41	11.5	40.9	3.20	111.0	37.5	6.82	4.09
Range	134.0-163.9	1.53-5.07	7.4-16.2	23.0-59.0	2.82-3.66	69.9-147.4	34.1-40.7	5.07-7.86	3.06-4.83
C.D. at 5%	11.65	0.70	2.26	7.10	0.26	16.76	1.83	0.86	0.57
S.E. (d)	5.84	0.35	1.13	3.56	0.13	8.41	0.92	0.43	0.29
C.V. (%)	4.70	12.68	12.05	10.94	4.99	9.28	2.99	7.77	8.53

*Significant at P=0.05, **Significant at P=0.01.

Range of mean values among the cross combination for seed cotton yield varied from 69.9 g (H1300 x RS 875) to 147.4 g (H1236 x LH 1960). For average bolls/plant, the range of mean values among the hybrids was observed lowest in H1236 x GN 67-1 (23.0 bolls/plant) and highest of 59.0 bolls/plant in cross, H1300 x P 729-37. The cross H1300 x HS-2 exhibited lowest average boll weight of 2.82 g while the cross, H1117 x RST 9 recorded highest average boll weight in tune of 3.66 g. For plant height, crosses H1300 × P 729-37 and H1098i x RST 9 showed highest plant height of 163.9 while cross H1098i x RS 875 revealed the lowest plant height of 134.0 cm. As far as number of monpods is concerned, range of mean values among hybrids varied from, lowest in H1098i x HS-2 (1.53) to highest in H1300 x Mahalaxmi (5.07). For number of sympods, cross H1300 x Mahalaxmi showed the lowest sympods/plant (7.4) and cross H1098i x RST 9 (16.2) showed the highest sympods/plant. For seed index lowest value was observed for cross combination H1236 x LH 1960 (5.07g) and highest value was observed for cross combination H1300 x LH 1960 (7.86g). Mean value of lint index varied from 3.06g (H1236 x LH 1960) to 4.83g (H1300 x RST 9).

For seed cotton yield, important aspect of cotton breeding, twenty five hybrids exhibited highly significant heterotic values. Ten most promising hybrids for seed cotton yield have been listed in Table 3. Among which seven hybrids H1236 x LH 1960 (69.04%), H1226 x RS 875 (68.00%), H1300 x P 729-37 (66.06%), H1098i x P 729-37 (66.06%), H1117 x LH 1960 (65.02%), H1098i x Mahalaxmi (63.99%) and H1098i x RS 875 (62.73%) exhibited heterosis of more than 60 percent. Most of these high heterotic cross combinations involve either H1098i or H1117 as female parent. Thus these seven high heterotic hybrids along with the female parents H1098i and H1117 can be used to exploit high heterotic values for seed cotton yield. Solanki *et al.* (2014) [20], Patel *et al.* (2015) [15], Pushpam *et al.* (2015) [17], Sharma *et al.* (2016) [19] and Gohil *et al.* (2017) [7] also reported significant positive heterosis was observed for seed cotton yield.

Table 3. Best crosses on the basis of heterosis for seed cotton yield and related characters

Sr. No.	Hybrids	Plant height (cm)	Number of monopods per plant	Number of sympods per plant	Number of bolls per plant	Boll weigh t (g)	Seed cotton yield per plant	Ginning out turn (%)	Seed index (g)	Lint index (g)
1	H 1236 x LH 1960	3.01	23.78**	35.64**	62.18**	4.43	69.04**	0.53	-23.30**	-22.34**
2	H 1226 x RS 875	-3.41	36.81**	19.80	63.32**	1.90	68.00**	-0.27	-1.97	-2.03
3	H 1300 x P 729-37	9.63*	56.35**	5.94	69.05**	3.48	66.06**	-1.07	9.98	8.63
4	H 1098i x P 729-37	-3.41	-6.51	17.82	14.61	10.13*	66.06**	-6.15*	1.82	-7.87
5	H 1117 x LH 1960	-3.01	26.06**	21.78	51.58**	4.11	65.02**	1.87	0.00	3.05
6	H 1098i x Mahalaxmi	-2.47	-4.56	27.72*	54.44**	4.43	63.99**	-5.08**	7.26	-1.02
7	H 1098i x RS 875	-10.37**	-19.54	47.52**	66.48**	9.18*	62.73**	-6.95**	13.31**	1.27
8	H 1226 x LH 1960	1.27	45.60**	-11.88	59.89**	-0.32	58.60**	-0.27	10.89	11.17
9	H 1098i x LH 1960	-8.23*	25.73*	11.88	7.74	5.70	55.85**	-3.74	0.61	-4.82
10	H 1098i x RST 9	9.63**	-45.60**	60.40*	21.49*	4.75	50.69**	-8.82**	11.20	-3.30

*Significant at P=0.05, **Significant at P=0.01.

Maximum heterosis (over sixty per cent) for boll number was shown by crosses H1300 × P 729-37 (69.05%), H1098i × RS 875 (66.48%), H1226 x RS 875 (63.32%) and H1236 × LH 1960 (62.18%). Heterosis for this trait was also reported by earlier workers Tuteja *et al.* (2014) [21], Sawarkar *et al.* (2015) [18], Ghevariya *et al.* (2016) [6], and Lingaraja *et al.* (2017) [9].

For boll weight hybrids H1300 × LH 1960 (15.82%), H1117 × RST 9 (13.61%), H1098i × GN 67-1 (11.71%), H1117 × GN 67-1 (10.76%), H1098i × P 729-37 (10.13%), H1098i × RS 875 (9.18%) and H1300 × RST 9 (8.86%) showed high heterosis. Similar finding was reported by Tuteja *et al.* (2014) [21], Pushpam *et al.* (2015) [17], and Monicashree *et al.* (2017) [11].

As far as plant height is concerned high heterosis were shown by H1300 × P 729-37 (9.63%) and H1098i × RST 9 (9.63%) followed by H1300 x HS-2 (9.10%), H1236 × RS 875 (8.90%). Whereas maximum heterosis in negative direction was shown by the cross H1098i × RS 875 (-10.37%) followed by H1226 × Mahalaxmi (-8.96%) and H1098i × LH 1960 (-8.23%). These finding was in accordance with the results obtained by Baloch *et al.* (2014) [4], Sharma *et al.* (2016) [19], Gohil *et al.* (2017) [7] and Devidas *et al.* (2017).

The crosses showing high heterosis for number of monopods were H1300 x Mahalaxmi (65.16), H1300 x P 729-37 (56.35%), H1117 x Mahalaxmi (54.07%) and H1236 x Mahalaxmi (49.84%). Heterosis for this trait was predicted by the earlier workers Ahuja *et al.* (2009) [2], Jaiwar *et al.* (2012) [8], Dave *et al.* (2014) [5], Sawarkar *et al.* (2015) [18] and Munir *et al.* (2016) [12].

For number of sympods, hybrids viz., H1098i × RST 9 (60.40%), H1098i × RS 875 (47.52%), H1098i × PIL-18 (41.58%), H1236 × HS-2 (39.60%), H1098i × GN 67-1 (37.62%), H1236 × LH 1960 (35.64%) and H1236 × RS 875 (28.71%) showed high heterosis. Similar finding was reported by Nakum *et al.* (2014) [13], Patel *et al.* (2015) [15], Sharma *et al.* (2016) [19] and Devidas *et al.* (2017).

Among all the characters studied, the lowest heterotic values were found for ginning out turn. The crosses viz., H1117 x RST 9 (8.82%), H1117 x P 729-37 (6.15%), H1117 x HS-2 (5.88%), H1236 x HS-2 (5.61%), H1236 × Mahalaxmi (5.61%) and H1300 x PIL-18 (5.35%) were showed positively significant heterosis. Heterosis for this trait was also revealed

by the earlier workers Lodam *et al.* (2014) [10], Sawarkar *et al.* (2015) [18], Ghevariya *et al.* (2016) [6] and Lingaraja *et al.* (2017) [9].

For seed index hybrid H1300 × LH 1960 (18.91%) showed the maximum heterotic effect followed by H1236 × RST 9 (16.94%), H1300 x RST 9 (16.94%) and H1117 × GN 67-1 (16.49%). Heterosis for this trait was also reported by the earlier workers Nakum *et al.* (2014) [13], Sawarkar *et al.* (2015) [18], Munir *et al.* (2016) [12] and pundir *et al.* (2017) [16].

The cross with maximum heterotic effect for lint index was H1300 × RST 9 (22.59%) followed by H1300 × PIL-18 (21.57%) and H1117 × GN 67-1 (15.99%). Similar result was reported by Patel *et al.* (2014) [5-14], Pushpam *et al.* (2015) [17] and Balakrishna *et al.* (2017) [3].

Conclusion

In the light of current investigation it is clear that, a substantial degree of heterosis over standard checks HHH 223 was for almost all the traits. However maximum extent of heterosis is recorded for traits like seed cotton yield H1236 x LH 1960 (69.09%), boll number H1300 x P 729-37 (69.05%), number of monopods H1300 x Mahalaxmi (65.15%) and number of sympods, H1098i x RST 9 (60.40%). Cross combinations which involve either H1098i or H1117 as female parent recorded significant positive heterosis for most of the yield contributing characters. Thus the female parents H1098i & H1117 along with the above seven highly heterotic seven hybrids (listed in table 3.) exhibiting heterosis of more than 60 per cent for seed cotton yield and significant heterosis for other attributing traits, can be used within breeding programmes aimed for heterosis breeding after proper evaluation within multi-location trials.

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