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Studies on economic heterosis for yield and fibre quality traits in American cotton (*Gossypium hirsutum* L.)

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ABSTRACT : The objective of this study was to determine economic heterosis of hybrids, with respect to seed cotton yield and fiber quality. Twelve cotton lines, 4 testers and 48 F_1 hybrids (generated by crossing 12 lines with 4 testers in line x tester design in the year 2017) along with check hybrid HHH 223 were grown in randomized complete block design with 3 replications in *kharif* 2018. Eleven crosses recorded a magnitude of heterosis for seed cotton yield/plant of above 40 per cent. The highest economic heterosis for seed cotton yield was observed by the cross H 1489 x C 210 (64.02%), which also exhibited highest *per se* performance for important characters; bolls/plant and boll weight. It was followed by H 1472 × C 211 (63.74%), H 1522 × C 211 (57.62%), H 1488 × C 211 (52.60%) and H 1522 × C 201(47.87%). The cross H 1472 × C 211 (63.74%), H 1489 × C 210 (9.30%) and H 1098i × C 201 (19.72%) registered the highest significant heterosis for boll weight, bolls/plant and ginning out turn respectively. Significant economic heterosis in desirable direction was recorded in fiber strength, upper half mean length, uniformity index and micronaire value. The cross H 1472 x C 201 observed best hybrid for fibre quality traits,

Key words: American cotton, economic heterosis, line x tester, seed cotton yield

Cotton is the "King of Fibers" and plays a major role on economics and social affairs of the world. It is a commercial crop grown in about 111 countries of the world. It is also known as "White Gold" because it is a leading natural fiber, which provides income to millions of cotton farmers and textile industries workers and contributes significantly in export earnings of many countries. Oil is extracted from the seeds after ginning and is refined for consumption. The lint is used in textile industries for production of cloth fabrics.

India is the leading country in terms of area under cotton cultivation and raw cotton production in the world. Per hectare productivity in India still much lower compared to many leading cotton growing countries. Development of new variety with high yield and fibre quality is the primary objective of all cotton breeders. Heterosis breeding is an important genetic tool to facilitate yield enhancement and help to enrich many other desirable quantitative and qualitative traits in crops. Economic heterosis or hybrid vigour is the increment in performance of a hybrid in relation to standard check and can assume positive or negative values. Cotton is an often cross pollinated crop and amenable for both heterosis breeding as well as hybridization followed by selection in subsequent generations. The phenomenon of heterosis has proven 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. The exploitation of hybrid vigour in cotton on commercial scale has become feasible and economical due to easy hand emasculation and pollination. Line × Tester analysis provides a systematic approach for the detection of appropriate parents and crosses in terms of investigated traits.

Heterosis breeding is useful to identify the cross combinations which are promising in conventional breeding programme. India is pioneer in commercialization of heterosis in cotton and noticeable heterosis reported in cotton by many workers (Dave, (2014), Tuteja, (2014), Lingaraja *et al.*, (2017b), Vekariya *et al.*, (2017). There is a need of developing superior and high yielding hybrids in cotton due to increasing demand of natural fiber products with superior quality parameters like fiber length, strength, elongation, micronnaire and uniformity ratio which determines the spinability in the modern mills.

MATERIALS AND METHODS

The present investigation was undertaken to study economic heterosis for yield and fibre quality traits in American cotton (*Gossypium hirsutum* L.). Forty eight F_1 hybrids were derived by crossing twelve lines with four testers in line x tester mating design in the year 2017. The experimental materials consisted of 48 F_1 hybrids, 16 parents and one check hybrid HHH 223. The experiment was conducted at Cotton Research Area, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during *kharif* 2018. Each entry was sown in two rows of 3.0 meter length adopting a spacing of 67.5 cm between rows and 60cm between the plants in randomized block design with three replications. All the recommended packages of practices were followed from sowing to harvesting. Observations were recorded on randomly selected five competitive plants from each entry *i.e.*, parents, hybrids and check for days 1^{st} flowering, plant height (cm), monopods/plant, sympods/plant, bolls/plant, boll weight (g), seed index (g), seed cotton yield/plant (g), ginning outturn and lint index (g). Analysis for fibre quality trait *viz.*, uniformity index, fiber strength (g/tex), Upper half mean length (mm) and micronaire (µg/inch) was done at ICAR CIRCOT Lab Sirsa.

The analysis of variance was performed to test the significance of the differences among parents and F_1 hybrids/crosses for all characters. The analysis of variance was carried out as per the standard statistical method. The estimates of economic heterosis of F_1 hybrids over commercial check HHH 223 were calculated as given below:

Per cent heterosis in F_1 over commercial

$$\text{check (CC)} = \frac{\overline{F_1} - \overline{CC}}{\overline{CC}} \times 100$$

Where,

CC = performance of commercial check

F_1 = Performance of across

RESULTS AND DISCUSSION

In most crops, high mean values for characters are desirable and cotton is not exceptional. However lower mean values for days to first flower, number of monopods per plant and micronaire value are desirable in cotton.

The analysis of variance (Table 1) indicated significant variation among the genotypes for all the characters except for sympods/plant indicating sufficient amount of wide genetic variability in the material as indicated by the significance of the mean squares.

The magnitudes of economic heterosis over check hybrid HHH 223 for different characters have been tabulated in Table 2. In cotton, positive heterosis is desirable for all traits except days to flowering, monopods/plant and fibre fineness (micronaire value) where negative

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

Source of variation	Df	Days to first flower	Plant height (cm)	Monopods/ plant	Sympods/ plant	Bolls/ plant	Boll weight(g)	Seed index (g)
Replication	2	5.818	389.266	2.974	715.661	65.349	0.377	0.046
Treatment	64	18.062**	274.598**	0.378**	12.692	39.768**	0.506**	1.096**
Error	128	3.606	130.541	0.355	9.386	6.614	0.175	0.070

Table 1. (cont.) Analysis of variance for different characters under study in upland cotton

Source of variation	Df	Seed cotton yield(g)	Ginning Outturn (%)	Lint index	Uniformity index	Fibre strength (g/tex)	Micronaire (µg/inch)	UHML (mm)
Replication	2	208.00	26.254	0.478	0.0008	0.002	0.0225	0.0338
Treatment	63	1455.87**	17.699**	1.144**	0.7034**	3.846**	0.2361**	1.9647*
Error	126	141.14	3.073	0.152	0.4005	1.652	0.1018	1.556

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

heterosis is desirable. All the 14 tested characters exhibited significant heterosis in desirable direction over check hybrid HHH 223.

Heterosis for yield and its attributing traits:

The ultimate aim of cotton breeder is to develop new varieties/hybrids with high seed cotton yield with good fibre quality. Heterosis breeding is an important genetic tool to facilitate yield enhancement and help to enrich many other desirable quantitative and qualitative traits in crops. Seed cotton yield is one of the most important economic characters and is the final product of the multiplicative interaction of contributing traits.

Earliness in flowering is desirable in cotton and hence the cross combinations having negative heterosis for days to first flower was desirable. No hybrid was reported the desirable (negative) significant heterosis for days to first flower over check in the present study. The maximum economic heterosis for tallness over standard check hybrid HHH 223 was observed in the cross H 1519 × C 210 (16.57%) followed by the crosses H 1480 x C 201 (16.01%), H 1480 x C 210 (16.01%) and H 1480 x C 211 (16.01%).The economic heterosis for number of monopods per plant was desired in negative direction the cross H 1471 × C 202 (-45.0%) showed highest negative economic heterosis followed by H 1520 × C 201 (-43.33%) and H 1508 × C 201 (-40.00%). Sympodial branches in cotton are desirable as they bear the bolls. Three crosses, H 1489 × C 210, H 1518 x C 201 and H 1518 x C 211 recorded significant positive heterosis (28.33 %) for sympods/plant followed by the crosses H 1472 x C 202 (26.67%) and H 1520 x C 202 (26.67%). Similar results were reported by Bankar *et al.*, (2018) for plant height, monopods and sympods/plant.

In cotton, bolls/plant and boll weight are two important yield attributing components which are mostly positively associated with seed cotton yield. For bolls/plant, highest heterotic effect was recorded in H1489 x C 210 (9.30%) followed by H1480 x C 210 (8.53%), H 1472 x C 202 (6.20%) and H 1522 x C 211 (6.20%). These hybrids also showing high heterosis for seed cotton yield, pin pointing that increased bolls were mainly responsible for increase in seed cotton yield. The highest significant economic heterosis for boll weight was recorded by the cross H 1472 × C 201 (54.02%), followed by H 1472 × C 211 (49.43%), H 1489 × C 210 (47.13%), H 1518 × C 201 (47.13%), H 1518 × C 202 (47.13%) and H 1522 x C 201 (47.13%). Both bolls/plant and boll weight directly affect the seed cotton yield. Similar results were reported by Sawarkar *et al.*, (2015), Sivia *et al.*, (2017) and Lingaraja *et al.*, (2017a). Hence these crosses need special attention for their further testing over locations for commercial utilization.

For seed cotton yield/plant the economic heterosis ranged from 1.36 to 64.02 per cent. The eleven crosses showed heterosis more than 40% for seed cotton yield/plant. The crosses with high heterosis for seed cotton yield were H1489 × C 210 (64.02%), H 1472 × C 211 (63.74%), H 1522 × C 211 (57.62%), H 1488 × C 211 (52.60%) and H 1522 × C 201 (47.87%). Whereas the hybrid H 1471 x C 202 (1.36%) was recorded lowest economic heterosis for seed cotton/per plant.

Heterosis for seed cotton yield in American cotton has also been reported earlier by Nirania *et al.*, (2013), Patil *et al.*, (2011), Jaiwar *et al.*, (2012), Sawarkar *et al.*, (2015), Lingaraja *et al.*, (2017a) and Bankar *et al.*, (2018). From the above results it is clear that, the magnitude of heterosis over standard check varied for cross to cross for various traits studied. Seed index, ginning outturn and lint index exhibited the highest significant positive heterosis in the crosses H 1519 × C 210 (25.87%), H 1098i × C 201 (19.72%) and H 1472 × C 201 (60.1%), respectively.

Economic heterosis for fibre quality traits:

Estimation of heterotic effects is necessary to identify the new cross combinations that are suitable for direct exploitation. Fibre fineness, uniformity index, length and strength affect spinning efficiency. For the fibre uniformity, positive heterosis is desirable. Out of forty eight crosses, eighteen crosses showed desirable positive heterosis for fibre uniformity index. Maximum heterosis for this character was recorded by the hybrid H 1523 x C 202 (2.68%) followed by H 1480 x C 201 (2.58%) and H 1472 x C 201 (2.53%)

Fibre length is critical for textile processing and varies greatly for different cotton species due to genetic differences. The fibres of long staple lengths produce smoother and stronger fabrics as cotton fibres of long staple lengths are finer, stronger and also more flexible than fibres of short staple length. Out of 48 hybrids evaluated, 46 hybrids manifested positive and significant heterosis over standard check HHH 223 and two hybrids observed significant negative heterosis for UHML. The maximum economic heterosis was observed for the cross H 1523 x C 202 (18.51 %) followed by H 1472 × C 201 (17.52%) and H 1480 x C 201 (14.79%). The results of heterosis are in conformity with the reports of Shinde *et al.*, (2012) and Lingaraja *et al.*, (2017b).

Fibre strength (g/tex) is one of the most important fibre properties and it is quantitatively inherited. Stronger, longer, finer and more uniform cotton fibres are desired for modern textile industries. For fibre strength the economic heterosis ranged from -3.46 to 20.18 per cent. The top five crosses with high heterosis for fibre strength were H 1480 × C 201 (20.18%), H 1480 × C 210 (18.46%), H 1472 × C 201 (16.45%), H 1523 × C 202 (15.84%) and H 1523 × C 201 (13.44%). The similar results were observed by Lingaraja *et al.*, (2017b).

Fibre fineness or micronaire is very important characteristic of the fibre quality of cotton and are extremely useful for textile industry. Negative heterosis is desirable for this trait as more micronaire value indicates the roughness of the fibre. Lower the micronaire value, the finer would be the fibre. In the present study, out of 48 hybrids studied the fifteen hybrids observed significant and negative heterosis over standard check, which indicated that the greater the micronaire value, the lower the fineness. The crosses H 1472 x C 201 (-0.14%) and H 1520 × C201 (-0.14%) showed maximum significant and negative economic heterosis followed by H 1520 × C 202 (-0.12%) and H 1508 × C 202 (-0.11%). This is in agreement with what was reported by Karademir *et al.*, (2009), Sawarkar *et al.*, (2015) and Monicashree *et al.*, (2017) for micronaire value.

CONCLUSION

All the tested characters depicted significant economic heterosis in desirable direction over check hybrid HHH 223. Out of forty eight crosses tested the eleven crosses showed heterosis more than 40 per cent for seed cotton yield/plant over check hybrid HHH 223. The crosses H1489 × C 210 (64.02%), H 1472 × C 211 (63.74%), H 1522 × C 211 (57.62%), H 1488 × C 211 (52.60%) and H 1522 × C 201 (47.87%) were found to be best on the basis of their high magnitude of heterosis for seed cotton

Table : 2 Extent of heterosis for the crosses in different characters in upland cotton

S. No.	Hybrids	Days to first flower	Plant height (cm)	Monopods /plant	Sympods /plant	Bolls /plant	Boll weight (g)	Seed cotton yield/ plant (g)	Seed index (g)	GOT (%)	Lint index	Uniformity value	UHML (mm)	Fibre strength (g/tex)	Micronaire (µg/inch)
1	H1471×C201	2.34	8.47*	-30.00**	0.00	-9.30*	31.03**	27.26**	12.94**	16.48**	44.5**	-0.03	5.27**	8.74**	0.01
2	H1471×C202	15.79**	-0.94	-45.00**	6.67	-13.18**	14.94*	1.36	1.49	12.87**	19.1	0.10	2.28**	0.13	-0.08**
3	H1471xC210	18.13**	9.23*	-6.67	0.00	-6.98	33.33**	26.15**	5.47**	10.65*	23.3	0.01	5.59**	9.39**	0.05**
4	H1471×C211	17.54**	14.12**	3.33	23.33*	-2.33	33.33**	33.67**	2.49	4.17	8.9	0.08	6.13**	12.25**	0.00
5	H1472×C201	18.71**	6.40	-30.00**	5.00	-14.73**	54.02**	31.72**	24.38**	16.85**	60.1**	2.53**	17.52**	16.45**	-0.14**
6	H1472×C202	7.02*	9.79**	-6.67	26.67**	6.20	35.63**	47.59**	11.44**	2.96	16.1	1.38	10.05**	13.18**	-0.03*
7	H1472×C210	19.30**	9.23*	-1.67	20.00*	3.10	-1.15	4.71	11.44**	14.35*	37.6**	0.05	5.38**	11.61**	-0.06**
8	H1472x C211	12.28**	12.05**	0.00	20.00*	6.20	49.43**	63.74**	-4.98*	5.83	8.7	1.16**	10.39**	9.33**	-0.02
9	H1480×C201	13.45**	16.01**	-13.33	15.00	4.65	31.03**	42.02**	13.93**	12.04*	36.1**	2.58**	14.79**	20.18**	0.03*
10	H1480×C202	18.13**	10.73**	-6.67	18.33*	5.43	35.63**	43.14**	14.93**	8.06	29.3**	0.07	0.60**	4.44**	0.06**
11	H1480×C210	19.88**	16.01**	0.00	20.00*	8.53*	28.74**	41.74**	15.92**	-4.07	8.4	1.37**	12.66**	18.46**	-0.07**
12	H1480×C211	21.64**	16.01**	0.00	21.67*	6.98	31.03**	43.41**	10.95**	2.59	14.6	1.28**	10.35**	11.30**	0.10**
13	H1488×C201	19.88**	13.56**	-33.33**	13.33	-6.98	37.93**	35.34**	3.48	-3.06	-1.0	0.15	4.38**	2.78**	0.17**
14	H1488×C202	14.62**	6.21	-36.67**	15.00	-3.88	12.64*	11.39	5.97**	9.81*	22.0*	0.03	5.26**	3.36**	-0.01
15	H1488×C210	22.81**	13.56**	6.67	15.00	-0.78	21.84**	22.53**	14.93**	10.19*	33.5**	-0.06	4.74**	11.16**	0.01
16	H1488×C211	21.05**	15.82**	-30.00**	23.33*	7.75	37.93**	52.60**	8.46**	11.57*	28.6**	-0.01	1.67**	8.06**	0.07**
17	H1489×C201	15.20**	8.85*	-10.00	15.00	-8.53*	42.53**	36.73**	1.00	7.41	12.6	0.07	3.22**	-2.02**	0.13**
18	H1489×C202	18.71**	11.49**	-15.00*	18.33*	-3.88	14.94*	12.23	-6.47**	4.81	0.2	0.04	3.47**	5.47**	-0.02
19	H1489×C210	16.96**	15.63**	-11.67	28.33**	9.30*	47.13**	64.02**	-0.50	4.17	6.1	-0.01	1.24**	3.17**	0.07**
20	H1489×C211	22.22**	9.98**	-5.00	13.33	-2.33	26.44**	26.98**	-5.97*	10.74*	10.3	0.03	4.64**	3.41**	0.03*
21	H1508×C201	21.05**	2.82	-40.00**	8.33	-17.83**	33.33**	11.39	4.48*	14.26**	28.8**	1.38**	9.97**	10.34**	0.06**
22	H1508×C202	20.47**	-6.03	-28.33**	-5.00	-27.91**	8.05	-23.42**	5.47*	10.74*	23.5**	1.24**	12.05**	13.07**	-0.11**
23	H1508×C210	20.47**	3.20	-6.67	20.00*	-6.20	10.34	5.26	12.44**	11.30*	32.8**	1.29**	7.38**	9.28**	-0.01
24	H1508×C211	22.22**	3.58	-36.67**	15.00	-10.85**	17.24*	7.21	-0.50	11.94*	18.7*	1.30**	6.95**	8.81**	-0.03*
25	H1518×C201	16.37**	12.81**	-33.33**	28.33**	-2.33	47.13**	46.20**	8.96**	18.89**	44.2**	1.19**	11.06**	11.50**	-0.05**
26	H1518×C202	17.54**	8.66*	-30.00**	20.00*	-10.08**	47.13**	33.11**	0.50	11.67*	19.7*	-0.03	2.55**	7.29**	0.03*
27	H1518×C210	22.22**	13.37**	20.00**	25.00**	-0.78	17.24*	20.30**	-2.49	16.11**	24.4**	1.39**	6.86**	6.75**	0.04**
28	H1518×C211	20.47**	10.55**	-6.67	28.33**	-10.85**	42.53**	30.88**	0.00	12.22*	19.6*	0.02	2.90**	7.28**	-0.08**
29	H1519×C201	15.20**	8.47*	-23.33**	20.00*	-6.98	31.03**	13.90*	5.97*	15.46**	33.3**	0.06	3.51**	3.81**	0.12**
30	H1519×C202	13.45**	9.23*	-33.33**	16.67	-3.10	33.33**	36.45**	17.41**	12.78**	41.9**	1.32**	8.00**	9.91**	-0.03*
31	H1519×C210	22.81**	16.57**	6.67	16.67	-10.08**	37.93**	25.59**	25.87**	3.33	31.8**	1.44**	9.75**	10.40**	-0.06**
32	H1519×C211	21.64**	9.79**	-10.00	15.00	-6.20	21.84**	17.52**	11.44**	9.81*	28.7**	0.00	5.82**	9.95**	0.07**
33	H1520×C201	9.94**	9.23*	-43.33**	11.67	-14.73**	44.83**	27.54**	13.43**	15.00**	42.0**	1.32**	10.46**	3.29**	-0.14**
34	H1520×C202	19.30**	10.36**	-13.33	26.67**	-7.75	26.44**	20.02**	9.95**	2.41	14.0	1.36**	14.13**	5.61**	-0.12**
35	H1520× C210	21.05**	8.66*	-6.67	5.00	-16.28**	33.33**	13.06*	2.49	16.48**	31.7**	0.11	6.23**	5.56**	-0.02**

to be continued...

S. No.	Hybrids	Days to first flower	Plant height (cm)	Monopods /plant	Sympods /plant	Bolls /plant	Boll weight (g)	Seed cotton yield/ plant (g)	Seed index (g)	GOT (%)	Lint index	Uniformity value	UHML (mm)	Fibre strength (g/tex)	Micronaire (µg/inch)
36	H1520×C211	22.22**	9.98**	-33.33**	11.67	-3.88	12.64*	18.07**	2.99	13.15**	25.7**	0.13	3.41**	-3.46**	0.14**
37	H1522×C201	18.71**	8.10*	-10.00	5.00	-1.55	47.13**	47.87**	8.46**	16.85**	39.4**	0.07	5.86**	1.45**	0.11**
38	H1522×C202	20.47**	0.75	18.33**	8.33	-6.98	31.03**	24.20**	-9.45**	12.78**	10.1	-0.04	6.58**	6.53**	0.11**
39	H1522×C210	22.81**	7.53*	20.00**	15.00	-8.53*	40.23**	28.65**	11.94**	12.31**	35.6**	0.02	2.07**	-0.76**	0.12**
40	H1522×C211	16.37**	10.92**	-18.33**	16.67	6.20	44.83**	57.62**	4.98*	12.31**	26.3**	0.18	4.08**	11.61**	-0.10**
41	H1523×C201	17.54**	2.45	-30.00**	-8.33	-9.30*	24.14**	15.57*	1.99	8.89	16.2	1.21**	7.67**	13.44**	0.03*
42	H1523×C202	21.64**	7.91*	-3.33	11.67	1.55	5.75	16.96**	-3.48	3.80	1.7	2.68**	18.51**	15.84**	-0.01
43	H1523×C210	18.71**	8.66*	13.33	15.00	-4.65	21.84**	19.47**	-8.46**	2.04	-6.3	1.39**	8.37**	13.57**	0.03*
44	H1523×C211	21.64**	6.78	-20.00**	-8.33	-24.81**	33.33**	4.43	0.00	14.91**	24.5**	0.09	-0.73**	5.35**	0.09**
45	H1098i×C201	18.71**	9.60*	-16.67*	5.00	-6.98	17.24*	11.39	-8.96**	19.72**	21.5**	-0.07	3.45**	4.25**	0.02
46	H1098i×C202	19.88**	3.77	13.33	10.00	-4.65	26.44**	25.59**	11.94**	1.39	13.8	0.07	1.56**	4.70**	0.04**
47	H1098i×C210	20.47**	10.73**	18.33**	10.00	-20.16**	24.14**	1.92	1.99	0.00	1.7	0.06	2.62**	-3.02**	0.00
48	H1098i×C211	19.30**	9.60*	0.00	5.00	-8.53*	17.24*	18.07**	-2.49	13.98**	20.1*	-1.22**	-0.78**	2.77**	0.059
Range		2.34 to 22.81	-6.03 to 16.57	-45.0 to 20.00	-8.33 to 28.33	-27.91 to 9.30	-1.15 to 54.02	1.36 to 64.02	-9.45 to 25.87	-4.07 to 19.72	-6.3 to 60.1	-1.22 to 2.68	-0.78 to 18.51	-3.46 to 20.18	-0.14 to 0.17
SEd	1.095	6.64	0.135	1.81	1.79	0.18	7.31	0.14	1.64	0.32	0.08	0.06	0.06	0.07	
CD (p = 0.05)		3.49	15.60	0.325	4.24	4.19	0.35	14.33	0.28	3.21	0.64	0.20	0.12	0.14	0.14
CD (p = 0.05)		4.90	21.89	0.385	5.96	5.88	0.45	18.83	0.37	4.22	0.85	0.26	0.16	0.18	0.18

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

yield/plant and other yield related characters. Hence, the mentioned crosses should be considered for use in commercial exploitation of heterosis. Fibre quality parameters of cotton such as fibre length and fineness have a vital influence on the yarn industries. The increasing fibre length results in improved yarn strength because a long fibre generates a greater frictional resistance to an external force. The cross H 1472 x C 201 was found to be promising for uniformity index, upper half mean length, fibre strength and micronaire value, whereas the crosses H 1480 x C 201 and H 1523 x C 202 were found to be promising for uniformity index, upper half mean length and fibre strength.

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