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ASSESSMENT OF HETEROTIC EFFECTS IN F_1 HYBRIDS OF COTTON (*GOSSYPIUM HIRSUTUM* L.)

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ABSTRACT

The present research was conducted to determine the mean performance of parental lines and heterotic effects in F_1 hybrids of upland cotton. Ten parental genotypes were included in the present study CRIS-134, NIAB-78, AA-802, CIM-496, CRIS-534, BH-160, IR-1524, MG-06, IR-3701 and FH-113. All the ten parents were randomly crossed and ten F_1 hybrids were developed for evaluation. The experiment was laid-out in a randomized complete block design with four replications. The mean squares from analysis of variance revealed that parents and F_1 hybrids differed significantly for their mean performance regarding all the traits studied, except that hybrids were non-significant for staple length. The importance of heterotic effects was evident from the significant mean squares of parents vs. hybrids. *Per se* mean performance revealed that F_1 hybrids performed better over the parents for all the traits due to manifestation heterotic effects. Nonetheless, among the parents, IR-3701 performed better for setting higher number of bolls, producing more seed cotton yield and ginning higher lint%. While among the hybrids, the crosses CIM-534 x AA-802 produced more sympodial branches per plant, formed higher number of bolls per plant and also gave higher seed cotton yield, yet maximum lint% was given by CIM-496 x MG-06 and longer fibre was measured in BH-160 x IR-1524. The parental performance was not reflected in hybrid combinations; therefore potentiality of parents *per se* may not be taken as granted for expecting similar performance in the F_1 hybrids. The heterotic effects of the hybrids revealed that at least three hybrids viz. CIM-534 x AA-802, NIAB-78 x AA-802 and CIM-496 x MG-06 were identified which exhibited relative heterosis above 100% and heterobeltiosis over 80% for bolls per plant and seed cotton yield. The same hybrids also expressed fair amount of heterosis for lint% and seed index. The high heterotic effects for sympodial branches per plant, number of bolls and seed cotton yield absolutely favour the exploitation of heterosis breeding due to the greater number of favourable dominant and over dominant genes involved at many loci.

Keywords: Heterosis, heterobeltiosis, yield and fibre traits, upland cotton.

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INTRODUCTION

The genetic improvement of a new cotton varieties with high seed cotton yield and fibre quality parameters has been the unique target of all cotton breeders. Industrial demand for cotton with superior fiber traits is also a source of guideline to cotton breeders. The success of transgressive segregation depends on the identification of genotypes with the ability to transmit potential genes for higher production to the subsequent filial generations. Heterosis is the performance of F_1 hybrids in relation to mid and better parents. It is useful in determining the most appropriate parents for improving specific traits (Khan *et al*., 2010). The term heterotic pattern refers to a group of related or unrelated genotypes from the same or different populations, which display superior combining ability and heterotic response when crossed with genotypes from other genetically distinct germplasm groups (Melchinger and Gumber, 1998). In recent years, the concept of developing heterotic populations is extended predominantly to often cross-pollinated crops like cotton. Segregating populations based on diverse pairs of genotypes can be the ideal base material required for implementing breeding procedures like reciprocal selection for improving combining ability (Patil and Patil, 2003; Patil *et al.,* 2011). In hybrid research studies, a large number of crosses involving varietal lines are used for assessing heterotic effects. On constantly observing the most potential crosses, attempts are made to infer about the causes of high heterosis. Utilization of heterosis depends on genetic diversity existing between the parents, magnitude of dominance at loci which influence yield and the genetic distance between the chosen parental genotypes. It is possible to maximize heterosis by enhancing genetic distance between two chosen parental populations. Many population improvement schemes are being used in cross-pollinated plants to increase genetic diversity, to create heterotic groups and exploit them for hybrid vigour. In the present scenario, heterotic boxes were developed by involving barbadense and hirsutum crosses and were exploited by creating variability through recombination.

The hybrid vigour with regards to yield is generally defined as an increase in the yield over the mean of the two parents or over the better parent. Useful heterosis is explained as an increase in the yield of F_1 hybrid over the standard commercial check. Heterosis works like a basic tool for the improvement of crops in the form of F_1 hybrids. The feasibility of economic heterosis in inter and intraspecific crosses of *Gossypium* is emphasized where manpower is cheaper (Khan and Khan 1979; Salam, 1991). Altaf *et al*. (1996) and Keerio *et al*. (1996) conducted such studies for monopodial and sympodial branches per plant and reported promising heterosis. Khan *et al*. (2000) suggested that, through heterosis breeding for seed cotton yield along with quality traits can be improved significantly. For achieving a high degree of heterotic response, it is essential to have better knowledge about the performance of desirable parents in terms of hybrid combination; the heterotic studies are helpful in creating such information. Heterosis is the superiority in the performance of F_1/F_2 hybrids for specific traits (Khan *et al*., 2010). Several researchers have observed significant amount of heterosis for various traits, like Ashokkumar and Ravikesavan (2013) recorded positive heterotic effects for fibre elongation; Baloch *et al.* (2014) demonstrated substantial heterobeltiotic effects for bolls plant^{-1}, seed cotton yield plant^{-1} and lint%. Abro *et al.* (2014) noticed considerable heterosis for sympodial branches per plant, bolls per plant and seed cotton yield. Basal *et al*. (2011) suggested that the identification and selection of best new F_1 hybrids should not only be based on GCA and SCA, but it must be coupled with mean performance. The present research therefore was carriedout with the objectives to estimate relative heterotic and heterobeltiotic effects in F_1 hybrids for seed cotton yield and fibre traits in intra-hirsutum crosses.

MATERIALS AND METHODS

The present research was carriedout at experimental field of the Department of Plant Breeding and Genetics, Faculty of Crop Production, Sindh Agriculture University Tandojam during 2013. Ten parents viz. CRIS-134, NIAB-78, AA-802, CIM-496, CIM-534, BH-160, IR-1524, MG-6, IR-3701 and FH-113 were randomly crossed and 10 F_1 hybrids were developed for experimentation. The seed of ten parents and their 10 F_1 hybrids was grown in a randomized complete block design with four replications. The distance between row to row and plant to plant was kept at 75.0 and 30.0 cm respectively. Sowing was done by dibbling method. Three seeds per hill were sown to ensure a uniform plant stand. After 25 days of planting, seedlings were thinned and only one vigorous growing plant was left for reduced plant competition and optimum plant growth and development. Ten plants were tagged at random from central rows of each genotype per replication for recording the observations. The data were recorded for plant height, sympodial branches plant^{-1}, number of bolls plant^{-1}, boll weight (g), seed cotton yield plant^{-1} (g), seed index (100 seeds wt. g), ginning outturn percentage (GOT %) and fibre length (mm). The analysis of variance was carriedout according to Gomez and Gomez (1984) for determining the differences among the parents and the F_1 hybrids, whereas heterosis was calculated with the formulae developed by Fehr (1987).

RESULTS AND DISCUSSION

The analysis of variance revealed that the genotypes (including ten F_1 hybrids and their ten parental lines) and parents vs. hybrids differed significantly for all the characters except staple length (Table 1). Several previous research workers including Basal *et al*. (2011); Khan (2011); Panni *et al*. (2012); Alkuddsi *et al*. (2013); Nassar *et al*. (2013); Abro *et al*. (2014) and Muhammad *et al*. (2014) also observed significant differences among the genotypes and the expression of heterotic effects in F_1 hybrids of upland cotton. The mean performance of parents and their F_1 hybrids for important yield and fibre traits was compared and it was observed that for all the traits, hybrids performed better than the parents (Table 2). On average, F_1 hybrids produced plants measuring 125.14 cm as compared to 99.79 cm of the parents; however parent NIAB-78 and hybrid CIM-496 x AA-802 proved to produce desirably shorter plants. On average, parents formed 22.65 fruiting branches against 26.41 of the hybrids, yet parent MG-06 and the hybrids CIM-534 x AA-802 and NIA-78 x AA-802 recorded maximum sympodial branches. The parents set number of bolls ranging from 33.2 to 58.3, the same range in the hybrids was a much greater that varied from 72.5 to 103.0 bolls per plant. The parent IR-3701 (59.8 bolls) and the cross CIM-534 x AA-802 (103.3 bolls) produced highest number of bolls per plant, hence proved to be the best parents and hybrids, respectively. Very surprisingly, parental performance is not reflected in the hybrids, which suggested that parental performance may not be taken as settled matter for expecting similar performance in hybrid combinations.

The results depicted in the Table 2 revealed that among parents, the bigger bolls were produced by the variety CRIS-134, while among the hybrids, cross FH-113 x AA-802 recorded maximum boll weight. For seed cotton yield, the parents produced seed cotton yield in the range of 105.53 g to 200.28 g, the same range in the hybrids was far greater, yet varied from 249.07 to 356.45 g. The highest seed cotton yield was produced by the parent IR-3701, nevertheless from the hybrids, the cross CIM-534 x AA-802 produced remarkably higher seed cotton yields (356.45 g). These results indicated that both parents and hybrids which set higher number of bolls correspondingly gave maximum seed cotton yield. It is also well established fact that for achieving higher seed cotton yields in cotton, number of boll per plant is the main contributing trait. The parent IR-3701 ginned the highest lint (42.39%) whereas, among hybrids, CIM-496 x MG-06 recorded maximum lint (45.05%). For staple length, the parent AA-802 proved to be the better by measuring longer fibre, whereas cross BH-160 x IR-1524 measured the longest staple length. The parent BH-160 showed the maximum seed index value (5.55 g), while the hybrid IR-3701 x AA-802 recorded highest seed index (6.20 g), yet the hybrid CIM-496 x MG-06 exhibited the lowest seed index value (4.83 g).

Table 1. Mean squares from analysis of variance for seed cotton yield and fiber traits in upland cotton.

Source of variation	D.F.	Mean squares							
		Plant height	Sympodial branches (plant^{-1})	Bolls (plants^{-1})	Boll weight	Seed cotton yield	Staple length	Ginning outturn %	Seed index
Replications	3	17.8	2.9	2.35	0.01	68.31	0.22	0.32	0.06
Genotypes	19	1424.7**	32.6**	2072.6**	0.13**	26399.5**	4.13**	13.06**	1.09**
Parents (P)	9	1075.9**	14.7**	362.8**	0.08**	4641.8**	3.54**	6.65**	0.68**
Hybrids (H)	9	504.0**	22.7**	367.1**	0.16**	6077.1**	0.514n.s	6.81**	0.72**
P vs. H	1	12849.7**	282.7**	32811.1**	0.31**	405120.9**	41.85**	126.90**	8.16**
Error	57	25.48	1.94	5.93	0.014	109.2	0.27	0.42	0.04

*Significant at 1 and 5% probability levels, respectively

The heterotic effects for plant height (Table 3) indicated that all the ten F_1 hybrids expressed positive relative heterosis and heterobeltiosis. The positive relative heterosis however varied from 7.86 to 54.83%, whereas heterobeltiosis ranged between 0.99 to 51.98%. The high heterosis for plant height is not desirable because such heterotic effects could produce taller plants. Some crosses like CIM-496 x MG-06 and MG-06 x FH-113, however are desirable which exhibited minimum heterosis. Our findings are in conformity with those of Khan *et al*. (2009); Rajmani *et al.* (2009); Khan (2011) and Panni *et al*. (2012) who reported positive but moderate mid-parent and better-parent heterosis in various hybrids of cotton. To evolve either medium-tall or short statures varieties, the hybrids which expressed low positive mid-parent or better-parent heterosis are recommended to be used in breeding programmes to develop such varieties. Negative heterosis is mostly desirable to develop varieties with shorter plant heights, yet the hybrids which expressed low positive heterosis are also desirable. Sympodia are the fruiting branches; hence they add value unshakably towards increasing seed cotton yield. Thus plant breeders and researchers support the concept that sympodial branches serve as the best selection criterion to develop high yielding cotton varieties. The heterotic effects for sympodial branches per plant (Table 3) revealed that all the ten hybrids manifested positive relative heterosis ranging from 2.94% to 31.60%. Likewise, all the ten hybrids also manifested positive heterobeltiosis ranging from 0.19 to 24.62%, yet there were five hybrids that manifested positive relative heterosis ranging from 16.72 to 31.60%, whereas the heterobeltiotic range in same hybrids was 8.96 to 24.62%. These hybrids may be preferred for the exploitation of hybrid cotton. The high positive heterosis indicated that such hybrids possess dominant and over dominant favorable genes with increasing effects. Our findings are in conformity with those of Nemati *et al.* (2010) and Abro *et al*. (2014) who reported positive mid-parent and better-parent heterosis for sympodial branches in many hybrids of cotton.

The heterotic effects for bolls per plant were moderate to high (Table 3), where hybrid CRIS-134 x AA-802 demonstrated highest positive relative heterosis and heterobeltiosis of 130.32 and 122.32%, respectively followed by NIAB-78 x AA-802 and CIM-496 x MG-06 with relative heterosis and heterobeltiotic effects of 110.94 and 93.06%, and 111.93 and 83.29%, respectively. Among all the hybrids, there were seven hybrids which manifested relative heterosis above 80% and better parent heterosis over 60%. Present results indicated that hybrids which gave both relative heterosis and heterobeltiosis above 80% are worth for the exploitation of hybrid cotton development so as to increase seed cotton yield via increasing bolls per plant. Present results are in consonance with those of Alkuddsi *et al*. (2013); Tuteja and Agarwal (2013); Abro *et al.* (2014) and Tuteja (2014). Theoretically, cotton breeders believe that bigger bolls produce more seed cotton yield but such assumptions are reversed when varieties with bigger bolls set less number of bolls and produce fewer yields as compared to those varieties/hybrids which form medium sized bolls, yet produce higher numbers and give more seed cotton yield. The results concerning heterosis and heterobeltiosis of ten F_1 hybrids (Table 3) indicated that out of the ten hybrids, eight gave low to moderate positive mid parent heterosis which varied from 2.56% to 15.52%. Similarly, eight out of the ten hybrids manifested positive heterobeltiosis ranging from 1.51% to 7.81%. The highest relative heterosis (15.52%), however was expressed by the cross MG-06 x FH-113 and the same hybrid recorded the next maximum heterobeltiosis (5.50%). Nonetheless hybrid MG-06 x FH-113 manifested maximum relative heterosis and was also ranked first (7.81%) in heterobeltiosis for boll weight. The present findings are in conformity with those already reported by Nemati *et al.* (2010), Kumar *et al.* (2013) and Tuteja and Agrawal (2013) who also noted fair amount of heterosis for boll weight in upland cotton.

Table 2. Mean performance of parents and their F_1 hybrids for various yield and fibre traits in upland cotton.

Parents and Cross combinations	Plant height (cm)	Sympodial branches ($plant^{-1}$)	Bolls ($plant^{-1}$)	Boll weight (g)	Seed cotton yield (g)	Staple length (cm)	G.O.T. %	Seed index (g)
Parents								
AA-802	89.43	23.47	43.30	3.25	140.76	28.14	39.94	5.04
CIM-496	84.66	22.72	33.20	3.17	105.53	25.50	40.82	4.66
CIM-534	92.86	24.42	46.40	3.27	151.85	27.86	38.67	4.69
IR-1524	109.3	22.42	54.80	3.10	169.94	26.91	41.35	4.46
MG-06	126.23	26.2	45.50	3.00	136.40	26.61	39.45	4.26
IR-3701	124.12	22.15	59.80	3.35	200.28	27.56	42.39	4.67
CRIS-134	89.57	19.56	48.30	3.45	166.91	26.76	39.64	4.84
FH-113	111.11	22.82	58.30	3.42	199.71	27.91	41.69	5.01
BH-160	86.80	20.03	34.80	3.15	109.51	25.76	38.74	5.55
NIAB-78	83.87	22.72	36.30	3.32	120.52	27.95	39.30	5.47
Average	99.79	22.65	46.07	3.25	150.14	27.09	40.19	4.86
F_1 hybrids								
CIM-496 x AA-802	105.12	23.77	72.50	3.30	239.40	28.22	41.67	5.27
CRIS-134 x AA-802	111.36	23.81	84.40	3.47	303.74	28.48	41.23	5.45
CIM-534 x AA-802	141.12	29.32	103.30	3.45	356.45	28.22	42.57	5.72
BH-160 x IR-1524	124.68	27.93	77.80	3.20	249.07	29.28	42.93	6.07
NIAB-78 x AA-802	129.31	29.07	83.60	3.37	279.75	28.65	40.50	5.30
CIM-496 x MG-06	127.50	28.55	83.40	3.05	254.66	28.36	45.05	4.83
IR-3701 x AA-802	134.27	27.72	98.00	3.20	313.58	28.12	43.14	6.20
IR-1524 x AA-802	134.25	23.67	84.30	3.37	284.48	28.77	43.10	5.52
FH-113 x AA-802	115.68	24.02	95.40	3.60	343.42	28.88	43.64	5.63
MG-06 x FH-113	128.14	26.25	80.50	3.72	300.09	28.42	43.36	5.04
Average	125.14	26.41	86.32	3.37	292.46	28.54	42.72	5.50
L.S.D. (5%)	7.14	1.96	3.44	0.17	14.76	0.74	0.92	0.30

Positive heterosis however may be exploited to increase seed cotton yield via improving average boll weight. Among the ten F_1 hybrids, all the hybrids showed positive relative heterosis and heterobeltiosis for seed cotton yield (Table 3). Relative heterosis varied from 78.26% to 143.64%, whereas heterobeltiosis ranged from 46.56% to 134.74% yet the top three ranking F_1 hybrids manifested higher relative heterosis and their percentages increases over mid parents were above 110% and heterobeltiosis was over 80%. The high heterotic effects for seed cotton yield absolutely favour the exploitation of heterosis breeding in cotton and the hybrids which possessed huge number of favourable dominant and over dominant genes at many loci are the most dependable breeding material for hybrid cotton development. Our findings are in conformity with those of Soomro *et al.* (2012); Vineela *et al.* (2013); Muhammad *et al*. (2014) and

Siwach *et al.* (2014), who reported positive mid parent and better parent heterosis for seed cotton yield in various hybrids of cotton. One of the most important fiber traits is the staple length. Generally, low heterosis and heterobeltiotic effects were recorded for this trait (Table 3), however, all the ten hybrids exhibited positive mid-parent heterosis while nine hybrids expressed positive heterobeltiosis except one.

The magnitude of positive relative heterosis ranged from 0.78% to 11.20%. While considering the heterobeltiosis, nine hybrids manifested positive but low better parent heterosis, yet the cross BH-160x IR-1524 exhibited highest heterobeltiosis (8.81%) and the next highest heterobeltiotic effects (6.57%) were manifested by CIM-496 x MG-06. Our findings are in accordance with those of Zangi *et al.* (2009); Khan *et al*. (2010); Tuteja and Agrawal (2013) and Siwach *et al*. (2014), who reported positive mid parent and better parent heterosis in various hybrids of cotton for fibre length.

Table 3. Heterosis and heterobeltiotic effects in intra-hirsutum F_1 hybrids for seed cotton yield and fibre traits.

F_1 hybrids	Plant height		Sympodia (plant^{-1})		Bolls plants^{-1}		Boll weight		Seed cotton yield (plant^{-1})		Staple length		G.O.T. %		Seed index	
	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB
CIM-496 x AA-802	20.76	17.53	2.94	1.27	89.54	67.44	2.8	1.5	94.41	70.07	5.22	0.28	3.19	2.08	8.65	4.56
CRIS-134 x AA-802	24.42	24.32	10.69	1.44	84.27	74.74	5.2	3.6	97.45	81.97	3.75	1.21	3.62	3.22	10.32	8.13
CIM-534 x AA-802	54.83	51.98	22.57	20.06	130.32	122.63	5.8	5.5	143.64	134.74	0.78	0.28	8.32	6.58	17.69	13.49
BH-160 x IR-1524	27.17	14.08	31.60	24.62	73.66	41.97	2.5	1.6	78.26	46.56	11.20	8.81	7.21	3.82	21.27	9.36
NIAB-78 x AA-802	49.23	44.57	25.89	23.86	110.05	93.07	2.7	1.5	114.14	98.74	2.17	1.81	2.22	1.40	0.95	-3.20
CIM-496 x MG-06	20.91	0.99	16.72	8.96	111.94	83.29	-0.9	-3.8	110.53	86.70	8.86	6.57	12.26	10.36	8.29	3.64
IR-3701x AA-802	25.74	8.16	21.52	18.11	90.11	63.87	-3.9	-6.4	83.89	56.57	0.96	-0.07	4.81	1.76	27.83	23.01
IR-1524 x AA-802	35.10	22.82	3.18	0.85	71.86	53.83	6.3	3.7	83.12	67.40	4.54	2.24	6.05	4.23	16.21	9.52
FH-113 x AA-802	15.37	4.12	3.75	2.34	87.79	63.64	7.5	4.3	101.73	71.96	3.06	2.63	6.93	4.67	12.35	11.90
MG-06 x FH-113	7.86	1.39	7.09	0.19	55.10	38.07	15.5	7.8	78.57	50.26	4.25	1.83	6.87	4.005	8.85	0.59

RH= relative heterosis, HB = heterobeltiosis.

Regarding heterotic effects in ginning outturn%, the positive mid-parent heterosis ranged from 2.22% to 12.26%, nonetheless, the top scoring hybrid with maximum heterosis over mid parent was CIM-496 x MG-06 and 2nd ranker in relative heterosis was CIM-534 x AA-802. As far heterobeltiosis is concerned, all the ten hybrids showed positive better parent heterosis, yet substantial heterobeltiosis was expressed by CIM-496 x MG-06 (10.36%). For seed index, the hybrids showed a fair percentage of relative heterosis and heterobeltiosis (Table 3). The positive mid-parent heterosis varied from 0.95 to 27.83%, however the maximum mid parent heterosis of 27.83% was exhibited by cross IR-3701 x

AA-802. While considering the heterobeltiosis, it was observed that nine hybrids showed positive better parent heterosis.

The positive heterobeltiosis, nonetheless varied from 0.59% to 23.01% while the maximum better parent heterosis of 23.01% was recorded by IR-3701 x AA-802. It is also evident from the result that one of the hybrids viz. NIAB-78 x AA-802 expressed negative better parent heterosis (-3.20%). Our findings are in line with those of Rajmani *et al.* (2009); Khan *et al*. (2010); Siwach *et al*. (2014) and Tuteja (2014); who also reported positive mid parent and better parent heterosis for lint% in different crosses of cotton.

CONCLUSION

The analysis of variance revealed that significant differences existed in the mean performance of parents, F_1 hybrids and parents vs. hybrids for all the characters studied, except staple length. The mean performance of F_1 hybrids for all the traits was better than the parents and may be due to heterotic effects. On the basis of *per se* performance, parent IR-3701 performed better for setting higher number of bolls, produced more seed cotton yield and ginned higher lint%. While among the hybrids, the crosses CIM-534 x AA-802 produced more sympodial branches, formed higher number of bolls per plant and gave higher seed cotton yield, yet maximum lint% was given by CIM-496 x MG-06 and longer fibre by BH-160 x IR-1524. The heterotic effects of the hybrids revealed that at least three hybrids CIM-534 x AA-802, NIAB-78 x AA-802 and CIM-496 x MG-06 were identified which exhibited relative heterosis above 100% and heterobeltiosis over 80% for both number of bolls per plant and seed cotton yield. However, the same hybrids expressed a fair amount of heterosis for lint% and seed index. The high heterotic effects for sympodial branches, number of bolls and seed cotton yield absolutely favour the exploitation of heterosis breeding due to expression of large number of favourable dominant and over dominant genes at many loci.

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