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HETEROSIS MANIFESTATION LEADING TO HYBRID DEVELOPMENT IN UPLAND COTTON

S. I. Mastungi and B. A. Ansari

Department of Plant Breeding and Genetics, Faculty of Crop Production, Sindh Agriculture University Tandojam, Pakistan

ABSTRACT

Considerable interest exists among cotton breeders in the expression of heterosis within intraspecific *Gossypium hirsutum* L. or *Gossypium barbadense* L. or interspecific between both species. Positive heterosis generally exhibits vigor, uniformity and additional yield and yield components of crops. A study of 8 X 8 diallel cross in upland cotton was conducted during 2009 to see the heterotic effects of F_1 hybrids. Eight inbred strains of upland cotton were crossed in 2008, to obtain superior hand-produced hybrids to be utilized in cotton cultivar development program with the objective of producing broad based genetic material. Twenty eight F_1 hybrids were grown along with their eight parents in randomized complete block design with four replications in an experimental field. The hybrids Malmal X LA-G18 (161.44%), NIAB-78 X LA-G18 (135.76%) and Sindh-1 X Acala-63-74 (123.60%) were obtained with high heterotic effects for seed cotton yield over better parents. The highest heterobeltiosis was displayed by the hybrids Malmal X LA-G18 (123.82%), Malmal X Acala-63-74 (104.39%), and Sadori X Sindh-1 (99.52%). It is recommended that these hybrids may be incorporated in cotton variety maximization program as a tool to improve the cotton yield. The traits studied were mostly expressed over dominant inheritance pattern in F_1 diallel.

Keywords: Cotton, dominance, heterosis, heterobeltiosis, hybrid, trait.

INTRODUCTION

The importance of cotton crop cannot be denied as it is an important cash crop of Pakistan that plays a vital role in its economy. It fetches 60% foreign exchange earnings and contributes 8% value added in agriculture and 2% to GDP. On global basis, Pakistan ranks fourth in area and production for cotton. However, the yield per unit area is low and ranks 8th in position as compared to 10 major cotton growing countries of the world (Anonymous, 2013). This situation is not favorable and requires immediate attention. In order to achieve high quality yields, the factors that decrease the yield should be worked out with appropriate solutions.

Corresponding author: mastungi3@gmail.com

The cotton production has reached a plateau because of narrow genetic base (Rehman and Malik, 2008). Therefore, it is very important to develop new hybrid cotton varieties with higher heterosis having potential yield. Heterosis has a vital role in variety development; it is the difference between the hybrid and the mean of two parents (Falconer and Mackay, 1996). This difference is known as mid parent heterosis and is expressed in percentage. For heterosis over better parent value, the term useful heterosis/ heterobeltiosis was coined by Meredith and Bridge (1972). Genetic variability in *Gossypium hirsutum* L. is limited particularly among the elite germplasm and even more so among commercial varieties (Bowman, 2000). Heterosis has been observed in many crop species and has been the objective of considerable importance to study as means of increasing productivity of crops and plants. Heterosis or hybrid vigor is defined as increase of a hybrid over the average of its parents (F_1 – P_1 + P_2; here F_1 stands for first filial generation, P_1 for parent 1 (Female) and P_2 for parent 2 (Male)). The amount of heterosis expressed by the hybrid has been considered indicative of the degree of genetic diversity between its parents.

The use of F_1 heterosis has long been one of the objectives of cotton breeders. Intraspecific as well as interspecific heterosis has been reported in cotton (Galanopoulou-Sendouca and Roupakias, 1999; Yuan *et al.,* 2002, and Zhang *et al.,* 2002). Babar *et al.* (2001) analyzed 4-parental upland cotton of diallel cross for heterosis and heterobeltiosis. The traits studied were number of sympodia plant^{-1}, bolls plant^{-1}, boll weight, and seed cotton yield plant^{-1}. The results manifested that seed cotton yield was positively dependent on number of bolls plant^{-1}. Four hybrids showed more than 70% heterosis of all types. Abro *et al.* (2009) analyzed 4 X 4 complete diallel cross of upland cotton varieties. Traits considered were plant height, sympodia plant^{-1}, bolls plant^{-1} and seed cotton yield plant^{-1}. All the crosses showed positive magnitude of heterosis over mid and better parental mean for plant height. Two hybrids revealed positive higher heterosis and heterobeltiosis for number of bolls plant^{-1} and seed cotton yield plant^{-1}. Campbell *et al.* (2008) revealed in an experiment that significant heterosis was found in seed cotton yield, ginning out turn % and boll weight. Pakistan is facing a number of yield decreasing factors, in these, narrow genetic base of commercial cotton varieties is a prominent factor that is effecting cotton yield. The present research was carried out with the objective to produce new cotton material with high heterotic estimates and having broad genetic base. For this purpose eight parents were used to develop twenty eight hybrids. These hybrids and parents were used to investigate the performance and heterosis of F_1s in upland cotton under inland environmental conditions to explore the yield and fiber potential in subsequent generations.

MATERIALS AND METHODS

The experimental material used in the present study comprised of eight upland cotton cultivars and their 28 F_1 hybrids. The cotton cultivars, NIAB-78, Chandi-95, Sadori, Malmal, Sindh-1, Acala-63-74, LA-G 18 and GL-6, were selected on the basis of their performance and broad range of genetic diversity. The breeder's seed of these eight cultivars was grown during Kharif 2008, in crossing block at the experimental field of the Department of Plant Breeding and Genetics, Sindh Agriculture University Tandojam. At the time of flowering, crossing was done by emasculating the buds in the evening and pollinating those buds in the next morning by freshly opened flower and desired pollinator parent. In this way all possible 28 cross combinations were obtained. During Kharif 2009, replicated trial of 8 X 8 diallel cross of 64 entries was conducted in a Randomized Complete Block Design with four replications at the same experimental field. Two lines of each entry were ridge planted manually by dibbling two seeds per hill at the distance of 12 inches plant to plant, on the water mark of the ridge. Each ridge was 25 feet long and 2.5 feet apart. After one month of planting, experimental plots were thinned leaving one healthy plant per hill. All the agronomical practices and plant protection measures were carefully adopted in the experimental plots. At the time of harvest, 10 plants were randomly selected and tagged various observations i.e. sympodial branches plant^{-1}, boll weight, number of bolls plant^{-1}, seed cotton yield plant^{-1}, number of seeds boll^{-1} and seed index. From the average performance of the F_1 hybrids and their parents, heterosis and heterobeltiosis values were worked out by simple calculations as:

$$[\{(F_1 - MPV) / MPV\} \times 100]$$
$$[\{(F_1 - BP) / BP\} \times 100]$$

Where:

F_1 stands for first filial generation, MPV stands for mid parent value

BP stands for better parent

Statistical data from F_1 and F_2 diallel crosses for each of the character was computed for heterosis estimates, following the procedure described by Hayman (1954). Mid parent value (MPV) was calculated as $\{[P_1 + P_2] / 2\}$; where P_1 and P_2 are average performance of two respective parental lines for a particular character. Therefore, mid-parent heterosis or useful heterosis (also termed as heterobeltiosis by Fonseca, 1965) was considered as the deviation of F_1 hybrid from its better parent expressed in percentage. Thus it gives the formula of $[\{(F_1-BP)/BP\} \times 100\}$. F_1 stands for first filial generation, and BP stands for better parent. Signification of heterotic values was tested by using “t” test suggested by Wynne *et al.* (1970) and calculated from “Statistix” software program.

RESULTS AND DISCUSSION

The degree of heterosis for six important characters i.e. number of sympodial branches plant^{-1}, boll weight, number of bolls plant^{-1}, seed cotton yield plant^{-1}, number of seeds boll^{-1} and seed index was computed for each 28 hybrids. In the analysis of variance for entries in Table 1, highly significant differences were recorded for all the characters. This implies the presence of adequate genetic variability in the experimental material. Estimation of genetic parameters from component of variation of 8 X 8 cotton diallel cross for six quantitative traits has been given in Table 2. To calculate the magnitude of heterosis and heterobeltiosis, 28 hybrids were compared with mid parents (Table 3). The important information obtained from different characters was as follows:

Number of sympodial branches plant^{-1}

Sympodia are fruiting branches arising from axillary buds of the main stem and from buds on the vegetative branches. According to Table 2, the character sympodia plant^{-1} inherited as over-dominant trait (1.86). It is apparent from the data (Table 3) that most of the hybrids expressed significant amount of heterosis over the mid parent which ranged from -25.61% to 32.80% in all crosses. Maximum heterosis (32.80%) as well as heterobeltosis (26.83%) for this character was recorded in the hybrid Sindh-1 X Acala 63-74. These results are in conformity with Rauf *et al.* (2005); Abbas *et al.* (2008); Abro *et al.* (2009); Hong and Jun (2010). Khan and Hassan (2011) reported partial dominance of sympodial branches plant^{-1} in their results; our results do not agree with these studies due to different experimental material under studies.

Table 1. Mean Squares from the analysis of variance of F_1 cotton diallel crosses for six quantitative traits.

Character	Blocks DF = 3	Entries DF = 63	Error DF = 189	F- Value
Sympodia plant^{-1}	0.54	27.58**	0.09	293.96
Boll weight	0.02	0.10*	0.00	26.55
Bolls plant^{-1}	0.45	122.36**	2.57	47.65
Yield plant^{-1}	11.52*	2457.65**	10.46	234.99
Seeds boll^{-1}	1.61	37.84**	0.56	67.83
Seed index	1.22	20.33**	0.08	241.61

*Significant at 5 % probability level; ** Significant at 1 % probability level

Table 2. Estimation of genetic parameters from component of variation of 8 X 8 cotton diallel cross for six quantitative traits.

Genetic parameter	Sympodia plant^{-1}	Boll weight	Bolls plant^{-1}	Seed cotton yield plant^{-1}	Seeds boll^{-1}	Seed index
Average degree of dominance.	1.86	1.75	1.74	2.23	1.64	2.47
Proportion of dominant and recessive genes in parents.	0.74	0.78	0.66	0.68	0.77	0.69
Number of effective factors controlling a particular trait.	0.02	0.91	0.64	2.12	1.24	0.02
Proportion of genes with positive and negative effects in parents.	0.19	0.16	0.22	0.22	0.17	0.19

Boll weight

Boll weight is the weight of seed cotton taken from each boll. The trait as shown in Table 2, the degree of dominance (1.75) revealed over-dominance inheritance pattern. From the results (Table 3) it is clear that most of the hybrids manifested highly significant positive heterosis over mid parent and better parent (values ranged from -2.98% to 13.77%). Table 3 compared with better parent values, and the hybrids revealed heterobeltiosis ranging from -7.32% to 12.62%. The cross NIAB-78 X Acala 63-74 proved best by giving second highest heterosis (13.65%) and highest heterobeltiosis (12.62%). Earlier workers such as Campbell *et al.* (2008); Mueen *et al.* (2008) and Zangi *et al.* (2010) had already reported a fair degree of heterosis and heterobeltiosis for this character and the present results are in conformity with these studies. On the other hand, Ali and Khan (2007), and Abbas *et al.* (2008), interpreted partial dominance for this trait, as their studies do not tally with our studies due to different experimental material of parental lines and their crosses.

Number of bolls plant^{-1}

The number of open bolls on a single plant represents the boll number of that plant. This character also showed over-dominance inheritance pattern (1.74) in Table 2. From the results (Table 3) it is obvious that extent of heterosis in different hybrids varied from -18.58% to 76.05% for boll number. The hybrids showed heterobeltiosis values ranging from -18.67% to 64.83%. The hybrid Sadori X Acala 63-74 exhibited highest heterosis and heterobeltiosis. The results are supported by the findings of Khan *et al.* (2003) and Nadeem and Azhar (2004); Campbell *et al.* (2008); Pole *et al.* (2008) and Zangi *et al.* (2010), reported that number of bolls plant^{-1} inherited as partial dominance trait, and present results do not tally with these researchers.

Seed cotton yield plant^{-1}

This is weight of seed cotton (in grams) collected from each plant. It is obvious from Table 2 that there was over degree of dominance (2.23) for this character. The data (Table 3) showed that the character displayed significant amount of heterosis over the mid parents which ranged from -22.12% to 161.44% in all hybrids. Similarly, the hybrids revealed heterobeltiosis from -20.77% to 123.82%. Maximum mid-parent heterosis (161.44%) as well as heterobeltiosis (123.82%) for seed cotton yield was recorded in the hybrid Malmal X LA-G18. Yield is the ultimate objective of most of the breeding programs and a large number of researchers conducted experiments on cotton yield, like Abro *et al.* (2009); Karademir and Gencer (2010); Zangi *et al*. (2010) and Zeng *et al.* (2011). These researchers also reported mid-parent heterosis and heterobeltiosis for seed cotton yield in their experiments. Therefore, present results are in complete agreement with these researchers. Murtaza *et al.* (2006) reported genetic studies for yield of seed cotton and plant height in 8 X 8 diallel cross of upland cotton cultivars. The inheritance pattern for these traits was within the range of incomplete dominance and the present results are in partial agreement with these workers.

Table 3. Mid-parent heterosis and heterobeltiosis estimates from 8 X 8 F_1 diallel cross for six quantitative traits.

Genotypes	Sympodia plant^{-1}		Boll Weight		Bolls plant^{-1}		Seed cotton yield plant^{-1}		Seeds boll^{-1}		Seed Index	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
NIAB-78 X Chandi-95	-10.39	-21.66	12.39	8.55	45.64	24.32	-3.27	-20.78	-10.39	-21.68	6.93	5.66
NIAB-78 X Sadori	-3.10	-6.78	10.09	10.19	10.23	8.94	30.83	29.20	-3.10	-6.78	-5.27	-11.17
NIAB-78 X Malmal	3.08	2.44	7.42	6.53	21.87	16.29	26.48	19.15	3.08	2.46	5.39	4.28
NIAB-78 X Sindh-1	4.78	1.39	10.01	9.02	21.29	9.49	49.79	36.14	4.79	1.40	8.56	2.45
NIAB-78 X Acala-63-74	12.39	10.87	13.65	12.62	24.94	18.26	95.44	86.74	12.39	-10.57	21.42	18.59
NIAB-78 X LA-G18	27.32	20.77	7.77	1.63	52.86	54.67	135.76	92.09	6.22	11.79	49.74	36.28
NIAB-78 X GL-6	20.08	11.17	4.86	0.94	34.02	15.57	114.29	77.96	6.88	-16.85	37.29	19.52
Chandi-95 X Sadori	6.21	-3.92	7.09	3.43	28.58	10.85	46.16	20.88	6.21	-3.92	-9.35	-14.02
Chandi-95 X Malmal	-15.02	-26.12	2.68	-1.71	40.58	15.52	10.03	-13.97	-15.03	-26.12	-2.29	-4.47
Chandi-95 X Sindh-1	-16.89	-29.38	2.64	0.01	12.53	-11.69	15.43	-12.19	-16.89	-29.38	-5.59	-11.91
Chandi-95 X Acala-63-74	-25.61	-34.21	3.51	0.86	8.04	-11.87	8.26	-14.43	-25.61	-34.21	-23.82	-24.72
Chandi-95 X LA-G18	-23.91	-36.43	-2.50	-4.88	-1.31	-14.92	13.89	-20.19	-34.89	-36.43	-19.99	-27.98
Chandi-95 X GL-6	-13.72	-29.38	-2.98	-3.31	-18.58	-19.76	9.59	-22.12	-21.88	-29.38	2.25	-11.91
Sadori X Malmal	-9.45	-13.39	8.34	7.45	18.51	11.91	29.54	-21.11	-9.45	-13.39	-16.09	-22.10
Sadori X Sindh-1	26.29	17.75	10.00	9.02	22.75	9.68	122.01	99.52	1.74	-5.17	45.64	29.38
Sadori X Acala-63-74	2.39	-0.17	3.64	2.71	76.05	64.83	20.38	13.65	-2.89	-19.60	4.04	-0.23
Sadori X LA-G18	3.71	-5.17	-0.87	-6.51	14.49	14.52	53.48	23.85	-16.59	-9.05	6.53	-8.49
Sadori X GL-6	11.39	3.71	6.67	1.79	-0.28	-17.09	68.08	46.86	12.58	17.87	21.28	6.58
Malmal X Sindh-1	2.18	-0.54	10.09	8.12	23.53	16.45	56.95	51.06	24.87	21.58	3.93	-0.91
Malmal X Acala-63-74	15.49	13.25	13.77	11.72	30.05	14.52	107.43	104.39	16.54	14.25	26.92	22.67
Malmal X LA-G18	27.41	21.56	-0.88	-7.32	21.39	-14.51	161.44	123.82	15.28	2.32	50.16	38.05
Malmal X GL-6	27.71	18.91	7.56	2.64	22.63	56.69	119.74	91.99	-0.59	-4.85	51.77	33.37
Sindh-1 X Acala-63-74	32.80	26.83	3.61	3.61	61.77	34.22	123.61	112.19	-1.34	-5.79	-0.43	-8.10
Sindh-1 X LA-G18	12.19	9.89	-1.71	-6.51	66.72	11.10	74.74	54.65	-20.38	-30.97	22.86	18.22
Sindh-1 X GL-6	8.39	3.55	3.06	0.09	2.39	8.94	74.09	218.94	-13.94	-19.71	16.11	6.54
Acala-63-74 X LA-G18	-8.62	-14.44	-2.57	-7.32	14.09	6.83	82.79	54.58	-17.82	-25.77	-15.49	-24.71
Acala-63-74 X GL-6	-7.71	-15.63	2.19	-0.77	3.69	-14.42	73.35	49.56	-9.77	-11.96	-14.14	-26.75
LA-G18 X GL-6	8.19	5.45	-2.08	-4.07	-6.83	-18.67	100.23	95.52	-35.66	-40.56	16.02	10.37

MP stands for Mid-parent, and BP stands for Better parent

Number of seeds boll^{-1}

It represents the number of seeds picked from individual boll. With reference to Table 2, the character, number of seeds boll^{-1} manifested over dominance inheritance pattern (1.64). The data in Table 3 indicated that 11 hybrids manifested significant positive heterosis over mid parents and better parents. While the hybrid Malmal X Sindh-1 revealed highly significant heterosis (24.87%) and heterobeltiosis (21.58%) for this trait. Therefore, this hybrid may be brought under consideration during varietal development programs, Campbell *et al.* (2008); Zangi *et al.* (2010) and Zeng *et al.* (2011), also reported positive heterosis and heterobeltiosis for number of seeds boll^{-1} in upland cotton. Subhan *et al.* (2002) and Khan *et al.* (2007) reported that number of seeds boll^{-1} inherited as partial dominant trait in F_1 and F_2 diallels. Therefore, present results are in partial agreement with these researchers due to different experimental field and research material.

Seed index

Seed index is a technical term given to the weight of 100 fuzzy seeds in grams. This character also exhibited over dominance inheritance pattern in the F_1 hybrids (2.47) as shown in Table 2. Data indicated in Table 3, that more than half of the hybrids displayed positive heterotic effects for the character. The positive heterotic magnitude varied from 2.25% to 51.77%. On the other hand, more than half hybrids expressed positive heterobeltiosis for this character. The highest heterosis and heterobeltiosis values were revealed by the hybrids Malmal X GL-6 (51.77%) and NIAB-78 X LA-G18 (36.28%) respectively. Rauf *et al.* (2005); Campbell *et al.* (2008), Abro *et al.* (2009) and Wankhada *et al.* (2009), have also reported heterosis and heterobeltiosis in seed index percentage in upland cotton. Where as, some workers like Murtaza (2005), and Khan *et al.* (2007) reported partial dominance inheritance pattern of seed index, and the present results are in partial agreement with these workers due to changed environmental factors.

CONCLUSION

From the present research it is evident that the magnitude of heterosis from F_2 to subsequent generations shows inbreeding depression. Therefore, the best performing hybrids with highest heterosis must be tried up to F_5 generations. Based on heterosis and heterobeltiosis, the F_1 hybrids Sindh-1 X Acala-63-74 for sympodial branches plant^{-1}, Malmal X Acala-63-74 as well as NIAB-78 X Acala 63-74 for boll weight, Sadori X Acala-63-74 for number of bolls plant^{-1}, Malmal X LA-G18 for seed cotton yield plant^{-1}, Malmal X Sindh-1 for number of seeds plant^{-1}, and Malmal X LA-G18 for seed index can be utilized in future breeding endeavors. The use of schemes like bi-parental mating design, diallel selective mating, followed by recurrent or reciprocal recurrent selection can be beneficial.

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