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HETEROSIS IN INTERSPECIFIC COTTON HYBRIDS

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Abstract

Both F_1 and F_2 hybrids of cotton manifested considerable amount of heterosis against the parents. The F_2 hybrids which produce more quantity of seed as compared to F_1 may be considered for hybrid cotton production. The average heterosis of F_2s over the parents recorded was 16.44% in yield, 9.68% in bolls/plant, 16.21% in seed index, 1.34% in lint and 3.45% in staple length. In all the crosses, observed inbreeding depression was greater than what was expected based on coefficient of inbreeding. The discrepancy between the observed and expected depression could be due to factors like linkage disequilibrium, epistasis and ploidy level.

Introduction

The manifestation of heterosis largely depends on the genetic divergence of parental lines. The lines are considered diverse if they manifest relatively high heterosis than those that manifest little (Hallauer & Miranda, 1986). In this context, interspecific crosses are expected to manifest more heterosis than intraspecific ones. Thus commercial potential of interspecific cotton hybrids (*Gossypium hirsutum* L. x *G. barbadense* L.) is greater than intraspecific hybrids. Interspecific F1 hybrids had been found to be heterotic for plant height and vegetative growth (Marani, 1967) and yield heterosis ranged from 7% (Christidis, 1955) to 50% (Marani, 1967) greater than the yield of best parent. Selfing increases homozygosity as a result of which the vigour and productiveness reduces by 50% in each selfing generation due to inbreeding depression (Falconer, 1989). According to theory proposed by Cowan (1943), the more the divergence between the parents of crosses the less is the inbreeding depression. Less inbreeding depression in interspecific hybrids and problems in obtaining sufficient quantities of F_1 seed has motivated the cotton breeders to consider F_2 hybrids. Problems to obtain sufficient quantitities of F_1 corn seed was also noticed in the early history of hybrid corn which was solved initially by using double-cross hybrids (Jones, 1918). The yield performance of some F_2 cotton hybrids (Meyer, 1975; Sheetz & Quisenberry, 1986) showed that there exists a potential for the successful use of F_2 hybrids. The F_2 hybrids are expected to express 50% reduced heterosis to what is present in F_1. Meredith & Bridge (1972) reported that one of six F_2 hybrids yielded 10% more lint than the best yielding parent and equaled the F_1 hybrid. Olvey (1986) after a 3 year study in Arizona, USA concluded that some F_2 hybrids showed significant increase in seedling vigour, fibre properties with yields 10 to 24% greater than the best yielding parent. Baloch *et al.*, (1991) in intraspecific crosses reported that some F_2 hybrids gave 21.16% increased yield, 54.25% more bolls/plant, 2.07% longer staple over mid-parent and 4.5, 27.09 and 0.84% respectively over high parent. The F_2 hybrids offer heterogeneous population which might result in a greater range of adaptation of F_2's as compared to their parents or F_1 hybrids. In the present study the yield and yield components of F_1 and F_2 hybrids were compared to assess the genetic diversity of the parents used in crosses.

Table 1. Yield and yield component mean squares of parents, F_1s and F_2s cotton hybrids.

Source	Degrees of freedom	Yield/ plant	Bolls/ plant	Seed index	Lint %	Staple length
Replication	3	40.86	40.14	0.97	0.09	0.18
Parents, F_1s & F_2s	25	3597.23**	910.07**	3.94**	2.46 N.S	13.11**
Error	75	14.84	23.25	0.33	3.28	0.16
Total:	103					

** Significant at 1% probability levels, N:S = Nonsignificant.

Materials and Methods

A set of 9 interspecific F_1 and F_2 hybrids (*G. hirsutum* x *G. barbadense*) and their 8 parental strains/cultivars of *G. hirsutum* (NIAB-78, Coker 100 Wilt-A, Rajhans and Stoneville-73IN) and *G. barbadense* (Karnak-NL, Tadla-12, Ashmouni-NL, and Pima-S2) were evaluated. The F_1 hybrids and their F_2 population alongwith parents, were grown in a randomized complete block design consisting of 4 replications. The standard distances between row to row (2.5') and plant to plant (9.0") were followed. Thirty F_1 plants in 2 rows and 3 rows of F_2 hybrids and parental lines were accommodated in each replication. Twenty plants at random from each replication of each genotype were tagged and treated as index plants for recording the data. The standard method of analysis of variance according to Steel & Torrie (1980) was used to work out the statistical differences among the parents, F_1 and F_2 hybrids for various traits. Heterosis over the mid-parent and high-parent were calculated using the formulae suggested by Fehr (1987). Similarly the F_2 hybrid heterosis was determined as percentage increase (+) or decrease (-) of F_2 over respective mid-parent and high-parent (Fehr, 1987). The inbreeding depression in F_2 hybrids was calculated as % decrease of F_2 as compared with F_1 hybrids as under:

$$\text{Inbreeding depression} = \frac{F_2 - F_1}{F_1} \times 100$$

The expected inbreeding depression of F_2 hybrids was also calculated with the formula developed by Hallauer & Miranda (1986).

Expected inbreeding depression in $F_2 = (1/4)\ (P_1 + P_2 + 2F_1)$ where P_1, P_2 and F_1 respectively are parent one, parent two and F_1 hybrid performance. The important traits under this investigation were, yield of seed cotton per plant, number of bolls per plant, seed index, lint percentage and staple length.

Results and Discussion

Analysis of the data indicated significant differences among parents, F_1 and F_2 hybrids for all the traits except lint % (Table 1). The mean performance of parents, F_1s

Table 2. Mean performance of parents, F_1 and F_2 hybrids.

Sr. No.	Parent/Hybrid	Bolls/ plant	Yield of seed-cotton (gm)	Seed index (gm)	Ginning outturn %	Staple length (mm)
1.	NIAB-78	88.2	129.34	8.24	33.68	26.27
2.	Karnak	48.6	96.75	7.70	32.20	30.00
3.	Tadla-12	50.3	91.85	8.50	34.00	32.01
4.	Coker 100 Wilt-A	74.3	167.94	8.79	32.96	27.50
5.	Ashmouni	48.0	108.63	11.76	32.23	31.03
6.	Rajhans	65.7	161.23	9.40	32.43	26.50
7.	Stoneville-731N	65.6	120.84	9.80	32.20	27.20
8.	Pime-S2	55.0	100.00	9.90	33.63	29.13
9.	F_1 = NIAB-78 x Karnak	89.5	221.83	8.90	33.20	30.33
10.	F_2 = NIAB-78 x Karnak	75.9	160.25	8.20	33.00	29.05
11.	F_1 = NIAB-78 x pima S2	92.2	160.18	11.17	34.84	32.50
12.	F_2 = NIAB-78 x Pima S2	78.2	135.14	9.88	33.00	29.50
13.	F_1 = NIAB-78 x Tadla-12	77.0	179.33	11.03	34.80	33.83
14.	F_2 = NIAB-78 x Tadla-12	70.2	138.00	9.44	34.05	29.75
15.	F_1 = Coker 100 Wilt-A x Karnak	73.6	177.46	10.04	34.01	31.72
16.	F_2 = Coker 100 Wilt-A x Karnak	64.3	150.00	8.89	33.20	30.18
17.	F_1 = Coker 100 Wilt-A x pima-S2	70.7	169.49	9.52	34.11	29.83
18.	F_2 = Coker 100 Wilt-A x pima-S2	63.7	145.00	9.30	32.90	28.99
19.	F_1 = Coker 100 Wilt-A x Ashmouni	116.0	175.37	10.83	34.25	31.19
20.	F_2 = Coker 100 Wilt-A x Ashmouni	80.6	140.90	10.20	33.70	29.88
21.	F_1 = Coker 100 Wilt-A x Tadla-12	70.7	171.40	9.07	34.33	32.37
22.	F_2 = Coker 100 Wilt-A x Tadla-12	63.9	143.80	8.70	34.02	31.00
23.	F_1 = Rajhans x pima S2	72.0	175.70	10.15	34.01	30.75
24.	F_2 = Rajhans x pima S2	62.5	142.00	9.60	33.30	29.05
25.	F_1 = Stoneville-731N x Ashmouni	65.0	143.00	10.87	34.62	30.87
26.	F_2 = Stoneville-731N x Ashmouni	52.9	124.20	9.70	33.08	29.87
	Average of parents	62.0	122.07	8.02	32.92	28.71
	Average of F_1s	80.7	174.86	10.18	34.24	31.49
	Average of F_2s	68.0	142.14	9.32	33.36	29.70

and F_2s (Table 2 & 3) showed that all the F_1s formed more bolls/plant than their respective parents. On the average F_1s produced 30.16% and 18.68% more bolls than parents and F_2s respectively whereas F_2s set 9.68% higher bolls than the parents (Table 3). The heterosis for boll number in F_1s and F_2s was also obvious. It varied over mid and better parents from 9.3 to 89.5% and -12.7 to 56.1% respectively whereas F_2s heterosis over mid and better parents ranged from -9.6 to 31.7% and -20.4 to 8.5%, respectively. The maximum heterosis for both F_1s and F_2s however was expressed by Coker 100 Wilt-A x Ashmouni, suggested more diverse pedigree of these parents than the others.

Table 3. Average of parental, F_1 and F_2 hybrids' yield and yield components from interspecific crosses.

Generation	Yield per plant (gm)	Bolls per plant	Yield components: Seed index (gm)	lint %	Staple length (mm)
Parents	122.07	62.0	8.02	32.92	28.71
F_1s	174.86	80.7	10.18	34.24	31.49
F_2s	142.14	68.0	9.32	33.36	29.70
% age increase of					
F_1 over: 1) parents	43.25	30.16	26.93	4.01	9.68
2) F_2s	23.02	18.68	9.23	2.64	6.03
% age increase of F_2s over parents	16.44	9.68	16.21	1.34	3.45

The yield data (Table 2 & 3) indicated 43.25% and 23.02% yield increase of F_1s over the parents and F_2s respectively whereas F_2s gave 16.14% more yield as compared to parents. The yield heterosis was also obvious in F_1s and F_2s over mid and better parents. It varied from 24.63 to 96.22% and 0.22 to 41.75% respectively while over better parents, the corresponding heterosis ranged from 0.92 to 71.51% and -16.18 to 23.90%. The highest heterosis among the F_1 and F_2 (NIAB-78 x Karnak), depicted more parentage diversity. Our yield results agree with those of Percy & Turcotte (1991) and Meredith (1990) who also noted considerable yield increase of F_1 and F_2 hybrids over their parents whereas Baloch *et al.*, (1991) recorded more yield in F_1 and F_2 hybrids against their parents.

Both F_1 and F_2 hybrids gave mean seed index of 10.18 and 9.32 as compared with 8.02 of the parents (Table 2). Further, results shown in Table 3 demonstrate that F_1s gave 26.93 and 9.23% more seed index against the parents and F_2s respectively whereas F_2s gave 16.21% higher seed index over the parents. The heterotic responses (Table 4) of F_1 and F_2 hybrids over mid parents varied from 0.83 to 31.78% and -10.02 to 12.78% whereas corresponding heterosis over better parents ranged from -7.91 to 29.76% and -17.52 to 11.06%. However, the cross NIAB-78 x Tadla- 12 manifested the maximum heterosis which concludes that parents of this cross belong to diverse pedigree.

Regarding ginning outturn percentage (GOT%) and staple length, both F_1 and F_2 hybrids gave higher values as compared with the parents (Table 2). The GOT % of F_1s and F_2s were respectively 34.24 and 33.36% as compared with 32.92% of the parents. Thus, both the hybrids on an average gave 4.01 and 1.34% more lint against the parents (Table 3) whereas F_1 hybrids ginned 2.64% more lint as compared to F_2 hybrids. These results suggest that F_1s gin better than the parents but their F_2s also expressed sufficient superiority over the parents which demonstrates the need of F_2 hybrid production. The heterotic responses in GOT% (Table 4) demonstrate variation of 0.78 to 5.83% and -1.43 to 4.41% of F_1 over mid and better parents respectively whereas the corresponding heterosis in F_2s varied from -1.96 to 3.37% and 2.17 to 2.63%. Among the F_1 hybrids,

Table 4. Yield and yield components of first and second generation interspecific cotton hybrids.

Character	Sr. No.	Cross	Mother Parent	Pollen parent	Mid parent	F_1 hybrid	F_2 hybrid	% age increase + or decrease - of F_1 over Mid parent	% age increase + or decrease - of F_1 over Better parent	% age increase + or decrease - of F_2 over Mid parent	% age increase + or decrease - of F_2 over Better parent	% age of inbreeding depression in F_2 hybrid observed	% age of inbreeding depression in F_2 hybrid Expected
Bolls per plant	1.	NIAB-78 x karnak	88.2	48.4	68.6	89.5	75.9	30.8	1.5	11.0	-13.9	-15.2	-11.8
	2.	NIAB-78 x Pima S2	88.2	55.0	71.6	92.2	78.2	28.8	4.5	9.2	-11.3	-15.2	-11.2
	3.	NIAB-78 x Tadla-12	88.2	50.3	69.3	77.0	70.2	11.1	-12.7	1.3	-20.4	-8.8	-5.0
	4.	Coker 100 Wilt A x Karnak	74.3	48.6	61.5	73.6	64.3	19.7	-0.9	4.6	-13.5	-12.6	-8.3
	5.	Coker 100 Wilt A x pima S2	74.3	55.0	64.7	70.7	63.7	9.3	-4.8	-1.5	-14.3	-9.9	-4.3
	6.	Coker 100 Wilt A x Ashmouni	74.3	48.0	61.2	116.0	80.6	89.5	56.1	31.7	8.5	-30.5	-23.6
	7.	Coker 100 Wilt A x Tadla-12	74.3	50.3	62.3	70.7	63.9	13.5	-4.8	-9.6	-14.1	-9.6	-5.9
	8.	Rajnans x Pima S2	65.7	55.0	60.4	72.0	62.5	19.2	9.6	3.5	-4.9	-13.2	-8.1
	9.	Stoneville 73IN x Ashmouni	65.6	48.0	56.8	65.0	52.9	14.4	-0.9	-6.9	-19.4	-18.6	-6.3
Yield of seed cotton per plant (gms)	1.	NIAB-78 x Karnax	129.34	96.75	113.05	221.83	160.25	96.22	71.51	41.75	23.90	-27.23	-24.52
	2.	NIAB-78 x Pima S2	129.34	100.00	114.67	160.18	135.14	57.13	39.31	17.85	4.48	-15.63	-14.26
	3.	NIAB-78 x Tadla-12	129.34	91.85	110.60	179.33	138.00	62.14	38.65	0.22	6.70	-23.95	-19.16
	4.	Coker 100 Wilt A x Karnak	167.94	96.75	132.35	177.46	150.00	34.08	5.67	13.34	-10.68	-15.47	-12.71
	5.	Coker 100 Wilt A x Pima S2	167.94	100.00	133.97	169.49	145.00	26.51	0.92	8.23	-13.66	-14.45	-10.48
	6.	Coker 100 Wilt A x Ashmouni	167.94	108.63	138.29	175.37	140.90	37.08	4.42	1.89	-16.18	-19.66	-10.57
	7.	Coker 100 Wilt A x Tadla-12	167.94	91.85	129.90	171.40	143.80	31.95	2.06	10.70	-14.37	-16.10	-12.11
	8.	Rajhans x pima S2	161.23	100.00	130.62	175.70	142.00	34.51	8.97	8.71	-11.93	-19.18	-12.83
	9.	Stoneville 73IN x Ashmouni	120.84	108.63	114.74	143.00	124.20	24.63	18.34	8.24	2.78	-13.15	-9.88

Table 4 (Cont'd)

	1.	NIAB-78 x Karnak	8.24	7.70	7.97	8.90	8.20	11.67	8.01	2.89	-0.49	-7.87	-5.22
	2.	NIAB-78 x Pima S2	8.24	9.90	9.07	11.17	9.88	23.15	12.83	8.93	-0.20	-11.55	-9.40
	3.	NIAB-78 x Tadla-12	8.24	8.50	8.37	11.03	9.44	31.78	29.76	12.78	11.06	-14.42	-12.06
Seed	4.	Coker 100 Wilt A x Karnak	8.79	7.70	8.25	10.04	8.89	21.70	14.22	7.76	1.14	-11.45	-8.94
index	5.	Coker 100 Wilt A x Pima S2	8.79	9.90	9.35	9.52	9.30	1.82	-3.84	-0.53	-6.06	-2.31	-0.92
	6.	Coker 100 Wilt A x Ashmouni	8.79	11.76	10.28	10.83	10.20	5.35	-7.91	-0.78	-13.27	-5.82	-2.35
	7.	Coker 100 Wilt A x Tadla-12	8.79	8.50	8.65	9.07	8.70	4.86	3.19	0.58	-1.24	-4.08	-2.34
	8.	Rajhans x Pima S2	9.40	9.90	9.65	10.15	9.60	5.18	2.53	-0.52	-3.03	-5.41	-2.46
	9.	Stoneville 731N x Ashmouni	9.80	11.76	10.78	10.87	9.70	0.83	-7.57	-10.02	-17.52	-1.72	-0.41
	1.	NIAB-78 x Karnak	33.68	32.20	32.94	33.20	33.00	0.78	-1.43	0.18	-2.02	-0.60	-0.39
	2.	NIAB-78 x Pima S2	33.68	33.63	33.66	34.83	33.00	3.48	3.41	-1.96	-2.02	-5.25	-1.69
	3.	NIAB-78 x Tadla-12	33.68	34.00	33.84	34.80	34.05	2.84	2.35	0.62	0.15	-2.16	-1.38
Genning	4.	Coker 100 Wilt A x Karnak	32.96	32.20	32.58	34.01	33.20	4.67	3.46	1.90	0.73	-2.64	-2.23
Outturn	5.	Coker 100 Wilt A x Pima S2	32.96	33.63	33.30	34.11	32.90	2.43	1.42	-1.20	-2.17	-3.55	-1.19
%	6.	Coker 100 Wilt A x Ashmouni	32.96	32.23	32.60	34.25	33.7	5.83	3.49	3.37	2.25	-2.32	-2.76
	7.	Coker 100 Wilt A x Tadla-12	32.96	34.00	33.96	34.33	34.02	1.09	0.97	0.17	0.06	-0.90	-1.24
	8.	Rajhans x Pima S2	32.43	33.63	33.03	34.01	33.30	2.96	1.13	0.82	-0.98	-2.09	-1.44
	9.	Stoneville 731N x Ashmouni	32.20	32.23	32.22	34.62	33.08	4.44	4.41	2.67	2.63	-4.45	-3.47
	1.	NIAB-78 x Karnak	26.27	30.00	29.14	30.33	29.05	4.08	1.1	-0.31	-3.17	-4.22	-3.62
	2.	NIAB-78 x Pima S2	26.27	29.13	28.20	32.50	29.50	15.25	10.92	4.61	1.27	-9.23	-7.28
	3.	NIAB-78 x Tadla-12	26.27	32.01	29.64	33.83	29.75	14.14	5.69	0.37	-7.06	-12.06	-6.93
Staple	4.	Coker 100 Wilt-A x Karnak	27.50	30.00	29.75	31.72	30.18	6.62	5.73	1.45	0.60	-4.85	-4.68
Length	5.	Coker 100 Wilt-A x Pima S2	27.50	29.13	28.82	29.83	28.99	3.50	2.40	0.59	-0.48	-2.82	-2.54
(mm)	6.	Coker 100 Wilt-A x Ashmouni	27.50	31.03	29.83	31.19	29.88	4.56	0.52	0.17	-3.71	-4.20	-3.09
	7.	Coker 100 Wilt-A x Tadla-12	27.50	32.00	30.25	[illegible]	31.00	5.27	1.16	-0.81	-3.13	-4.23	-4.05
	8.	Rajhans x Pima S2	26.50	29.13	28.32	30.75	29.05	8.58	5.56	2.58	0.27	-5.53	-4.77
	9.	Stoneville 731N x Ashmouni	27.20	31.03	29.68	30.87	29.87	4.01	-0.52	0.64	-3.74	-3.24	-2.60

the cross Coker-100 Wilt-A x Ashmouni manifested maximum heterosis over mid parent and the cross Stoneville-731 NL x Ashmouni over better parents suggesting that the parents of both the crosses belong to different origin and are useful for either F_1 or F_2 hybrid cotton production. For staple length, F_1s and F_2s gave respectively 31.49 and 29.70 mm fibre as compared with 28.71 mm of the parents (Table 3), thus on an average, F_1s and F_2s produced 9.68 and 3.45% longer staple than the parents (Table 3) whereas F_1s gave an average of 6.03% longer fiber than the parents. The heterotic effects in staple length of F_1 hybrids varied from 3.50 to 15.25% over mid-parents and -0.52 to 10.92% over better parents. The corresponding effect in F_2 ranged from -0.81 to 4.61% over mid-parents and from -7.06 to 1.27% over better parents suggested fair degree of F_2 heterosis and its possible use in F_2 hybrid cotton production. The cross NIAB-78 x Pima-S_2 which manifested highest degree of heterosis in F_1 and F_2 hybrids indicated their parentage diversities. For both GOT and staple length Baloch *et al.*, (1991) and Meredith (1990) reported potentiality in the use of F_1 or F_2 hybrids over the parents.

Generally, for all the traits, F_2 hybrids suffered from considerable amount of inbreeding depression. In all the crosses, observed depression was greater than expected. This discrepancy between the observed and expected inbreeding depression could be explained by several factors that involve: linkage disequilibrium, epistasis, and ploidy level. Comstock & Robinson (1948) observed that the estimate of dominance may be biased upward if only two factor interactions were present. Repulsion phase linkages can cause positive biases in the estimation of dominance variance in F_2 where linkage effects are expected minimum (Gardner *et al.*, 1953, Gardner, 1963). Inbreeding depression in polyploids has been noted to exceed what is predicted by the co-efficient of inbreeding (Aycock & Wilsie, 1968).

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