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Combining Ability of Yield Components in Half Diallel Crosses of Cotton

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ABSTRACT

Combining ability estimates were studied for seed cotton yield and its components in eight cotton cultivars (four *Gossypium hirsutum* and four G. *barbadense*) in half diallel crosses in 2000 and 2001 seasons, at the Gezira Research Station, Wad Medani, Sudan. Combining ability analysis revealed that both additive and non-additive types of gene action were important in the studied traits. The G. *hirsutum* parents, Acala(93)H, Barac(67)B and Shambat-B, were best combiners for seed cotton yield, and the G. *barbadense* parents, Barakat-S and B-Pima، combined best for increased number of bolls and improved fiber quality. These results suggest the use of three-way crosses, modified backcross or recurrent selection to improve yield, yield components and fiber quality، The intraspecific crosses, gave low specific combining ability (SCA) effects, suggesting that, with few exceptions, parents within each species would not be useful in single cross combinations to produce progeny having high yields and improved yield components and fiber quality، Simple linear correlation coefficients revealed positive association of seed cotton yield with number of sympodia, lint index, boll weight and 100-seed weight suggesting that emphasis should be laid on these traits when selecting for increased yield.

INTRODUCTION

Cotton used to be the major cash crop in Sudan. It is grown in both irrigated and rainfed areas of varying climatic, soil and ecological conditions. In the last two decades, Sudan witnessed a pronounced decline in cotton area and production amounting to more than 50%

Petroleum and sesame in export earnings. Generally, cotton improvement (Mursal, 2003). As a result, cotton recently ranked the third after program in Sudan is centered around yield and quality improvement, resistance to prevailing diseases, earliness and extension of quality range. Cotton yield and fiber, quality are the primary traits targeted for improvement. Hence, testing of the available material for combining ability mode of inheritance of particular traits and correlation between components is a prerequisite for its utilization in a successful breeding program.

Yield and its components in cotton are complex and mostly controlled By additive, dominance and epistatic gene actions (Singh and Raut, 1983) . Estimates of genetic variation and combing ability are useful in determining the breeding value of some populations and the appropriate procedures in the breeding program. The objective of this study is to assess general and specific combining ability effects among seven cultivars and a prospective cultivar and to provide guidelines for improvement of cotton yield and fiber quality characters in Sudan.

MATERIALS AND METHODS

Eight cotton cultivars were hand crossed in a half diallel mating design 1999 and 2000 at the Gezira Research Station (GRS), Wad Medani, Four of them, Albar(57)12, Barac(67)B, Acala(93)H and Shambat-B, are G. *hirsutum* L., while the other four, Barakat-90, Huda, at-S, and B-Pima, a prospective cultivar, are G. *barbadense* L. Baraket -90, Barakat-S and B-Pima are extra long staple; Huda and Shambat-B are long staple; Barac(67)B and Acala(93)H are medium staple and Albar(57)12 is a short staple cotton. Parents and their 28 F_l hybrid combinations were planted in plots of three 5 x 0.8 m rows and 0.5m between holes on 22 July 2000 and 31 July2001 in a randomized complete block design with three replications.

Data were collected on number of sympodia and of bolls per plant (averge of ten random plants in each plot), boll weight (average of 30 bolls), seed cotton yield (kg ha^{-1}), ginning out-turn (calculated as percentage of lint of 30 bolls), 100-seed weight, lint index (lint of 100 seeds), fiber length, fiber fineness and fiber strength. Seed cotton yield was hand harvested, two picks for the G. *hirsutum* parents and their intraspecific F_l hybrids, and three picks for the G. *barbadense* parents intraspecific intra- and interspecific F_l hybrids. The fiber properties were tested at the Fiber, Spinning and Stickiness Laboratory, Cotton Research Program, Agricultural Research Corporation, Wad Medani, Sudan.

The data were analyzed for each year, and the analysis of variance Was performed on plot data for all traits. The diallel system was used to obtain analysis of variance, and general and. specific combining ability estimates, based on Griffing's (1956) Model l, Method 2.

RESULTS AND DISCUSSION

Combining ability analysis

Analysis of variance revealed highly significant (p≤0.01) differences among parents and hybrids for all the studied traits (Table l). This indicated that an adequate amount of variability is present in the parental material, and thus suggested the effectiveness of selection for the development of new genetic lines possessing improved traits.

Table l. Mean squares for combining ability of yield of 28F_1 cotton hybrids and their parents grown at Gezira Research station, in 2000 and 2001.

		Seed cotton yield		No. of sysmpodia /plant		No. of bolls /plant	
Source	Df	2000	2001	2000	2001	2000	2001
Genotypes	35	9026070.40***	7385275.50***	10.79***	8.05***	169.34***	61.61***
GCA	7	7073221.40**	7666750.00**	2.81*	3.74**	101.14**	43.69**
SCA	28	1992557.80**	1160511.00**	3.79**	2.42**	45.58**	14.75**
Error	70	57502.60	129725.70**	1.12	0.56**	2.58	0.69
GCA:SCA		0.36	0.73	0.06	0.17	0.23	0.31

Table 1. (continued)

Source	Df	Boll weight		100-seed weight		Lint index		Ginning out-turn	
		2000	2001	2000	2001	2000	2001	2000	2001
Genotypes	35	5.32**	4.41***	8.67***	5.18***	1.65**	1.52***	18.84***	16.56***
GCA	7	16.12**	6.49**	4.69**	2.77**	21.13**	1.88**	11.51**	15.55**
SCA	28	0.69**	0.21**	2.44**	1.47**	0.16**	0.17**	4.97**	3.01**
Error	70	0.03	0.06	0.25	0.26	0.07	0.09	1.04	1.12
GCA:SCA		I .93	1.09	0.20	0.21	2.33	2.26	0.27	0.76

Table 1. (continued)

Source	Df	Fiber length		Fiber fineness		Fiber strength	
		2000	2001	2000	2001	2000	2001
Genotypes	35	26.82***	16.07***	1.02***	0.82***	33.18***	37.59***
GCA	7	16.80**	10.94**	0.81**	0.77**	40.91**	43.10**
SCA	28	6.97**	03.96**	0.23**	0.15**	3.60**	4.89**
Error	70	0.46	0.36	0.03	0.02	0.66	0.81
GCA:SCA		0.25	0.29	0.29	0.56	1.37	1.04

* ** *** Significant at 0.05, 0.01 and levels of probability. Respectively
GCA, SCA General and specific combing ability respectively

The significant genotypic variance was further partitioned into variance due to general combining ability (GCA) and specific combining ability (SC A) (Table l). Variances due to GCA and SCA were highly significant (pf0.01) for all the studied traits in both seasons, except for number of sympodia where GCA was significant ($p \leq 0.05$) in 2000; and lint index where SCA was significant ($p \leq 0.05$) in 2001. This indicated both additive and non-additive gene actions were responsible for the inheritance of the studied traits. This suggests the use of reciprocal recurrent selection for exploiting both types of genetic variance. Basu *et* (1993) and Coyle and Smith (1997) reported the importance of both additive and non-additive gene actions for yield, yield components and fiber quality traits in G. *barbadense* and G. *hirsutum*, which agrees with present results.

The average of the two seasons of GCA: SCA ratio of variances for boll weight, lint index and fiber strength were more than one (Table l). indicating that the inheritance of these traits was largely controlled by additive gene action. Therefore; progeny selection would be effective for genetic improvement of these traits. Similar results were obtained by other researchers (Patel *et al*.- 1991: Tomar and Singh, 1992; Carvarlho، 1995) However, the ratio of GCA: SCA variances for number of sympodia and bolls per plant. 100-seed weight, ginning-out-turn, seed cotton yield, fiber length and fiber fineness were less than one indicating the predominance of non-additive gene action in these traits. This suggests the use of these traits in hybridization breeding. These results are comparable to the findings of Percy and Turcotte (1988) and Patel *et al* . (1991)who reported the predominance of non-additive genetic variance for seed cotton yield, lint cotton and fiber length.

Estimates of GCA effects for the measured traits are presented in Table .2. The best general combiners with maximum GCA effects for seed cotton yield were Acala(93)H, Barac(67)B and Shambat-B. Barakat S and B-Pima combined well for bolls per plant: Acala(93)H and Barac (67)B for boll weight, lint index and ginning out-turn; and Shumbat-B and Barac(67)B for 100-seed weight. The *G. barbadense* parents (Barakat-90, Huda, Barakat-S and B-Pima) were good combiners for increased fiber length, reduced fiber micronaire values (finer fibers) and increased fiber strength (stronger fibers), whereas the *G. hirsutum* parents [Albar(57)12, Barac(67)B, Acala(93)H and Shambat-B} were good combiners for short. coarse and weak fibers.

Table 2. Estimates of general combining ability effects of seed cotton yield and its components in eight cotton cultivars grown at Gezira Research Station, in 2000 and 2001.

	Seed cotton yield		No. of sympodia Plant		No. o bolls/plant	
Parent	2000	2001	2000	2001	2000	2001
Albar(57) 12	589.07	981.60**	-0.97*	0.02	-3.25**	-0.91**
Barac(67)B	312.77**	769.90**	-0.41	-0.79* *	-4.24**	-2.31**
Acala(93)B	1362.18**	985.15**	-0.19	-0.77**	-1.98**	-1.56**
Shambat-B	640.50**	442.29**	-0.09	-0.55	-0.38	-1.92**
Huda	-134.50**	-1074.49**	0.25	0.52	0.56	1.54**
Barakat-S	-626.65**	-619.45**	0.64	0.56	3.33**	1.54**
B-Pima	-578.89**	-701.25**	0.51	0.42	4.12**	2.19**
S.E.±	-664.91**	-783.77**	0.27	0.59	2.83**	2.44**

Table 2. (continued)

	Boll weight		100-seed weight		Lint index		Ginning out-turn	
Parent	2000	2001	2000	2001	2000	2001	2000	2001
Albar(57) 12	0.53**	0.70**	-0.77**	-0.58**	-0. 14	0.02	0.65	1.04**
Barac(67)B	0.90**	0.88**	-0.92**	0.59**	0.87**	0.55**	I .45	1.58**
Acala(93)B	0.91**	0.74**	-0.35	0.22	0.42**	0.55**	-1.14**	1.09**
Shambat-B	0.74**	0.69**	-0.97**	0.91**	0.10	0.29**	-1.18**	-0.11
Barakat-90	-0.78**	-0.73**	-0.35	-0.22	-0.37**	-0.17	-0.53	0.08
Huda	-0.80**	-0.77**	-0.58**	-0.22	0.00	-0.21	0.55	-0.78
Barakat-S	-0.80**	-0.76**	-0.56**	-0.23	-0. 49**	-0.59**	-0.83	-2.26**
B-Pima	-0.70**	-0.74**	-0.01	-0.47**	-0. 39**	-0.45**	-I .25**	-0.63
S.E.±	0.08	0.11	0.22	0.23	0.12	0.13	0.46	0.47

Table 2. (Continued)

	Fiber length		Fiber fineness		Fiber strength	
Parent	2000	2001	2000	2001	2000	2001
Albar(57) 12	-1.87**	-0.97**	4.07**	0.42**	-2.17**	-1.76**
Barac(67)B	-0.73**	-1.63**	0.03	0.06	-1.81**	-2.05**
Acala(93)B	-0.69**	-0.77**	4.17**	0.35**	-2.01**	-2.30**
Shambat-B	-0.10	-0.30	0.14	0.09	-1.56**	-1.61**
Barakat-90	0.89**	0.80**	-1.20**	-0.24**	1.82**	2.17**
Huda	0.98**	0.89**	-0.8**	-0.10**	1.82**	1.88**
Barakat-S	1.11**	0.95**	-3.2**	-0.34**	1.89**	2.01**
B-Pima	1.38**	1.02**	-3.20**	-0.23**	2.02**	1.66**
S.E.±	0.30	0.27	0.07	0.06	0.36	0.40

* ** Significant at 0.05 and 0.01 levels of probability. respectively.

The performance of single-cross progenies can be predicted from the performance of their parents only if GCA is significant (Baker, 1978). In this experiment, the significant GCA effects exhibited by most of the parents for the measured traits suggested that these properties could be easily transferred into a line with good agronomic background. The *G. hirsutum* parents showed positive GCA effects for seed cotton yield, boll weight, 100-seed weight lint index and ginning out-turn but negative GCA effects for number of sympodia and bolls per plant; whereas the *G. barbadense* parents showed the opposite. This was attributed to the observation that *G. hirsutum* has few sympodia and bolls per plant but heavy boll weight، which contributed to increased seed cotton yield. The presence of positive

GCA effects indicates that continued progress should be possible through breeding for yield and yield components in cotton with these parents.

Generally, significant SCA effects were exhibited by the interspecific hybrids for most of the measured traits in both seasons (data not shown). When *per se* performance of these hybrids was considered, the hybrids Barac(67) x Barakat-90, Acala(93)H x Huda, Acala(93)H x B-pima, Albar(57)12 x Barakat-90 and Shambat-B x B-pima showed highly significant SCA effects for increased seed cotton yield, number of bolls per plant, fiber length, fiber strength and reduced fiber micronaire values (finer fibers). The hybrids Albar(57)12 x Barakat-S and Albar(57)12 x B-Pima were good for fiber length and fiberness.

The presence of SCA effects in F_1 hybrids is a consequence of fluctuations in the dominance relationship among the parents. The best hybrid combination with high SCA effects exhibited by the interspecific hybrids may be due to contribution of favorable alleles by their parents. Singh and Narayanan (1993) stated that unrelated inbreds derived from different open-pollinated varieties will generally combine to produce high yielding single crosses than inbreds derived from related parents, which may have more of the same genes in common. This might be the case with this result. where some of the cultivars have common parents. Wilson and George (1980) and Tomar and Singh (1992) reported significant SCA effects for yield components and fiber properties in cotton.

The intra-*hirsutum* and intra-*barbadense* hybrids showed positive highly significant SCA effects for boll weight and fiber fineness (coarse fibers); and negative for seed cotton yield, number of sympodia and bolls per plant, fiber length and strength (reduced fiber length and strength) (data not shown). The cultivars of each species, used in this study, have part of their genetic background in common which resulted in the low SCA effects exhibited by the intraspecific hybrids for yield and yield components. The *G. hirsutum* parents were all derived from a common source (Acala cotton from USA), except

Albar(57)12 which was introduced from Uganda. Likewise, the G. *barbadense* parents were selections resulting from crosses having the variety Barakat (Sakel cotton introduced from Egypt). Shrivastava and Seshu (1983) indicated that, depending upon the nature of genes. when both parents belong to the same group their F_IS will be nearer to mid-parental value resulting in low SCA effects.

Trails association

The analysis of simple correlation coefficients, using the means of entries over the two seasons (Table 3), showed that seed cotton yield was significantly ($p \leq 0.05$) and positively correlated with number of sympodia and lint index, and highly significantly($p \leq 0.01$)) and positively associated with boll weight and I00-seed weight. Such positive association would cause selection in one trait to simultaneously and positively affect the other. Elsiddig *et al* (2004). reported similar results. Contrarily، Abdelrahlnan and Abdalla (1995) obtained significant negative association of seed cotton yield boll size and 100-seed weight in *G. hirsutum.* Seed cotton yield was non-significant and positively correlated with number of bolls per plant, fiber length and fiber fineness, but significantly and negatively associated with liber strength. Since it expected that increase in boll number would cause increase in seed cotton yield. it seems that this trait has contributed to yield indirectly through number of sympodia. The non-significant association may be due to other influences that caused boll loss before harvest. Butany *el al.* (1968) reported the indirect effect of boll number and boll weight on yield. The non-signilicant correlation between seed cotton yield and fiber length and fineness obtained in this study is in agreement with the findings of Tyagi (1987) who studied bi-parental progenies; however، Abdelralunan and Abdalla (1995) reported significant positive correlation of these traits with seed cotton yield in G. *hirsutum*

Table 3. Simple linear correlation coefficients (r) among various pairs of 10 yield components of eight cotton cultivars and their 28 F_1 hybrids grown at Gezira Research Station, in seasons 2000 and 2001

Trait	2	3	4	5	6	7	8	9	10
l. Nuniber of sympodia/plant	0.80**	-0.53**	-0.48**	-0.24	-0. 50	0.29**	0. 80 **	-0. 69 **	0. 62 **
2.Number of bolls/plant		0.73**	0. 30*	-0.46**	-0.56**	0.10	0. 88 **	-0. 77 **	0. 77 **
3. Boll weight			0.05	0.72**	-0.56**	0.41**	-0. 71 **	0. 72 **	-0. 95 **
4. 100-seed index				0.39**	-0.35*	-0.46	0. 41 **	-0. 39 **	0. 07
5. Lint index					0.58**	0.30*	-0. 48	0. 43 **	-0. 65**
6. Ginning-out-turn						0.02	-0. 71 **	0. 69 **	-0. 58 **
7. Seed cotton yield							0. 07	0. 06	-0. 35*
8. Fiber length								-0. 80 **	0. 53 **
9. Fiber fineness									-0. 80 **
10. Fiber strength									

* ** Significant at 0.05 and 0.01 levels of probability, respectively.

The negative association of seed cotton yield with fiber strength indicated that selection for increased yield might result in simultaneous reduction in fiber strength (Abdelrahman and Abdalla 1995: Elsiddig *et a*l. 2004). Scholl and Miller (1976) indicated that negative association of yield with fiber strength was probably due to pleiotropic effects. Fiber length was highly significantly and positively correlated with fiber strength and negatively associated with fiber fineness. Tyagi (1987) and Abdelralunan and Abdalla (1995) reported similar results. Negative association was also observed between yield components and between fiber properties and some of the yield components indicating that selection for simultaneous improvement of these traits would not be effective. Meredith (1984) attributed such negative association to undesirable linkages.

Yield is a complex character controlled by a number of genes. Thus selection based on simple linear correlation without taking into consideration the interaction between the genes may not prove fruitful.

CONCLUSIONS

The *G. hirsutum* parents Acala(93)H, Barac(67)B and Shambat-B were best combiners for seed cotton yield, and the *G. barbadense* parents. Barakat-S and B-Pitna, combined best for increased number of bolls and that yield, yield improved fiber quality. These results suggest components and fiber quality characters can be improved through the use of three-way crosses, modified backcross or recurrent selection methods. Based on the performance of the intraspecific crosses, with low SCA effect it seems that the parents included in this study are suitable for use in single cross combinations to. produce progeny having high yields، improved yield components and fiber quality. The *per se* performance exhibited by the interspecific crosses suggests the presence of sufficient heterosis which can be exploited in hybridization breeding. The positive association of seed cotton yield with number of sympodia, lint index, boll weight and 100-seed weight suggests that emphasis should be laid on these traits when selecting for increased yield.

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