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Yield and Fiber-Quality Potential for Second-Generation Cotton Hybrids

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ABSTRACT

Due primarily to the difficulty of producing F_1 seed, use of heterosis in cotton (*Gossypium hirsutum* L.) has been limited. The objective of this study was to evaluate the potential of using F_2 hybrids by comparing them with parents and F_1's for yield, fiber quality, and interaction with environments. The genetic design was a half-diallel consisting of seven mid-South parents, 21 F_1's, and 21 F_2's. The 49 genotypes were grown in 1987 and 1988 at three sites near Stoneville, MS. At each site, April and May planting was made, resulting in a total of 12 environments. Yield, yield components, and fiber length, strength, and micronaire reading were determined from four replications. Yarn tenacity was determined from two 1987 tests, and short-fiber content from three 1987 tests. Average first-harvest yield was 594, 688, and 643 kg ha^{-1} for the parents, F_1's and F_2's, respectively; total yield was 953, 1065, and 1025 kg ha^{-1}, respectively. Average yarn tenacity was 130, 134, and 132 kN m kg^{-1} for the parents, F_1, and F_2 hybrids, respectively. Both F_1 and F_2 hybrids had significantly fewer short fibers than the parents. The highest-yielding parent was 'DES 119', which averaged 1031 kg ha^{-1}, while 'Deltapine 50', the most commonly grown cultivar in the USA, averaged 959 kg ha^{-1}. The highest-yielding F_1 hybrids DES 119 × 'Delcot 344' and DES 119 × 'Coker 81-613' averaged 1145 and 1143 kg ha^{-1}, respectively, ~15% higher than the average of DES 119 and Deltapine 50; their F_2 hybrids averaged 8% higher. No differences in adaptive ability between parents, F_1's, and F_2's were detected. The results indicate that F_2 hybrids have the genetic potential for increasing cotton yields and fiber quality.

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THE USE OF HETEROSIS in the form of F_1 hybrids has long been an objective of cotton breeders. That sufficient magnitudes of heterosis are present in cotton to result in significant increased yields has been established (3,4,6,7). In a review of 14 studies (3), the average increase in yield of F_1 hybrids over the mid-parent was 18% and was due primarily to increases in number of harvestable bolls, 13.5%, and boll weight, 8.3%. Heterosis for fiber properties was small, averaging from 0 to 2% for most characteristics. The discovery of a male-sterile cytoplasm (5) and restorer factor (8) gave encouragement to breeders that hybrid cottons are obtainable. However, the complexities of developing good combiners with dependable fertility restoration present major problems for hybrid production. One method of circumventing this problem is to use male gametocides (6); however, due to the lack of a dependable and economic method of controlling the insect pollen carriers, it still has not been practical to produce F_1 hybrids.

Similar problems in obtaining sufficient quantities of F_1 seed occurred in the early history of developing hybrid corn (*Zea mays* L.). This problem in corn was solved initially by using double-cross hybrids. The yield performance of some F_2 cotton hybrids suggested to some (4,6) that there exists a potential for the successful use of these hybrids. The F_2 hybrids are expected to express only 50% of the heterosis (F_1–mid-parent) expressed in the F_1 hybrid, and even less when heterosis is defined in terms of the highest-yielding parent. Meredith and Bridge (4) reported that one of six F_2 hybrids yielded 10% more lint than the best yielding parent, 'Deltapine 16', and equaled the F_1 hybrid. Olvey (6), after a 3-yr study in Arizona, concluded that some F_2 hybrids showed significant increases in seedling vigor and fiber properties, with yields 10 to 24% greater than the best-yielding parents.

The F_2 hybrids, besides having only 50% of the F_1 heterozygosity, consist of a very heterogeneous population. This heterogeneity might result in a greater range of adaptation for F_2's, relative to their parents or F_1 hybrids. Conversely, this heterogeneity might result in reduced fiber quality, such as increased short-fiber (<12.7 mm) content and reduced yarn tenacity.

The objectives of this study were to compare the yield and fiber properties of F_1 and F_2 hybrids and their interactions with environments. Of particular interest was the potential of F_2 hybrids to be competitive with high-yielding cultivars across a range of environments.

MATERIALS AND METHODS

In a half-diallel genetic design, seven cultivars and strains, with 21 F_1 and 21 F_2 hybrids, were grown on three sites near Stoneville in 1987 and 1988. The F_1 seed were produced by hand crosses at Stoneville; F_2 seed were produced by selfing the F_1 hybrids in Mexico during the 1986–1987 winter. The parents were 'Deltapine 8018', Deltapine 50 (DPL 50), Coker 81-613, DES 119, MD 65-11 Subne, MD 82ne, and Delcot 344. At each site-year, an early and late planting was made to give 12 test environments. The three soil types were a Beulah fine sandy loam (coarse-loamy, mixed thermic Typic Dystrochrepts); Dundee silty clay (fine-silty, mixed, thermic Aeric Ochraqualf); and a Dubbs silt loam (fine-silty, mixed thermic Typic Hapludalf). Planting dates were 20, 21, and 27 April and 3, 16, and 16 May in 1987 and 21, 21, 29, 29 April, and 19 and 19 May in 1988. The experimental design was a randomized complete block with four replications. The parents and environments were treated as random effects. Standard cultural methods for the Mississippi Delta were used.

The 49 genotypes were grown in one-row plots; rows were 1.02 × 5.55 m. Seeding rate was 18 seed m^{-1} of row. Fifty-boll samples were hand-harvested from each replication. The samples from the first two replications and last two replications were combined to form two 100-boll bulk samples from which yield components were determined and lint was obtained for fiber quality determinations. The yield components were lint percentage, boll weight (sample seed-cotton weight, g/50 boll), and seed weight. Lint yields were determined as seed-cotton weight × lint percentage. Span length (50 and 2.5%), fiber strength (T_1), elongation (E_1), and micronaire were determined from all tests. However, short-fiber content was determined from only three 1987 tests, and yarn tenacity was determined from two 1987 tests. Short-fiber content was determined by the Peyer Al101-Almeter[1] at the USDA-ARS Ginning Laboratory, Stoneville.

RESULTS AND DISCUSSION

The yield superiority of F_1 hybrids over the F_2 and their parents' yield is evident (Table 1, Fig. 1). For F_1 and F_2 hybrids, first-harvest yield averaged 15.8 and 7.6% higher, and total yield 11.8 and 7.6% higher, respectively, than the parental averages. It is evident, as in a previous study (9), that significant heterosis in cotton is initiated early in fruiting development. Selection of seven parents from mid-South breeding programs exhibiting good productivity was the cause of the lower heterosis expression of 11.8%, compared with the average of 18.0% from 14 studies reported by Meredith (3). Of major interest in the present study was the yield comparison of F_2 hybrids with established cultivars. The highest-yielding cultivar, DES 119, averaged 1031 kg ha^{-1}; DPL 50, the cultivar most planted in the USA, averaged 959 kg ha^{-1}(1). It is evident from Fig. 1 that several F_2 hybrids were superior in yield to well-established cultivars. The highest-yielding F_1 hybrids, DES 119 × Delcot 344 and DES 119 × Coker 81-613, averaged 1145 and 1143 kg ha^{-1}, respectively, or ~15% higher than the average of DES 119 and DPL 50; their F_2 hybrids averaged 8% higher.

Assuming that a dominance gene action causes heterosis, the F_2 yield was expected to lose 50% of the heterosis expressed by the F_1. However, for total yield, the F_2 produced significantly more than expected. Also, a significant F_1 vs. F_2 × cross interaction (F = 2.0) was detected (Fig. 1). The F_2 hybrids involving the lowest-yielding parent, MD 65-11 Subne, tended to have the largest deviation from the 50% expected reduction in heterosis. The inbreeding depression of the highest-yielding F_1 hybrids was about what was expected based on a 50% decrease in dominance from

[1] Mention of a proprietary product does not constitute endorsement by the USDA, nor does it imply approval to the exclusion of other suitable products not mentioned.

Table 1. Average parental, F_1, and F_2 yield and yield components in cotton, from a seven-parent half-diallel across 12 environments.

Generation	Lint yield: Total	Lint yield: First harvest	Lint	Weight: Boll	Weight: Seed
	kg ha^{-1}	kg ha^{-1}	%	mg	mg
Parents	953c†	594c	35.7a	500a	104a
F_1	1065a	688a	35.9b	541c	106c
F_2	1025b	643b	35.7a	522b	105b

† Within columns means followed by the same letter are not significantly different at the 0.01 probability level, as indicated by a t-test.

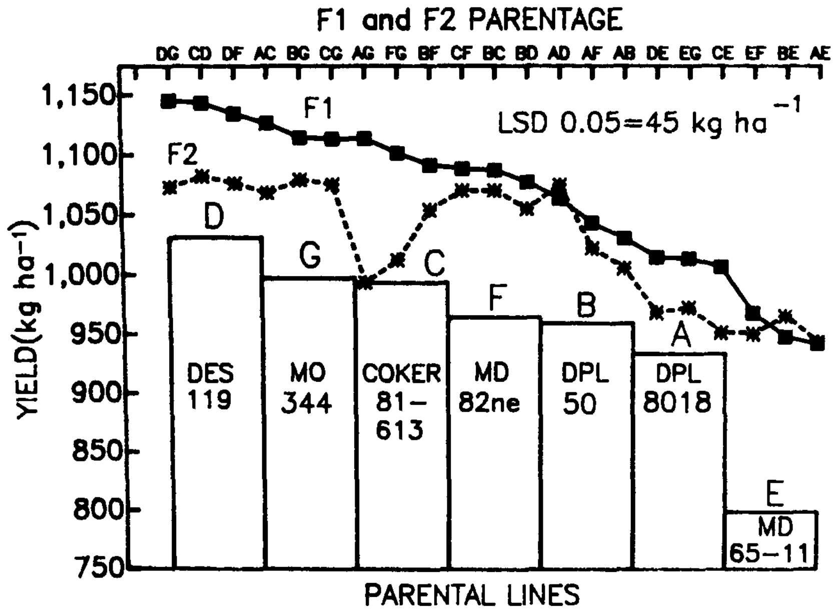

Fig. 1. Average yield of cotton parents and F_1 and F_2 hybrids across 12 environments.

the F_1 to F_2. Several crosses, however, showed little inbreeding depression (Fig. 1). Other authors (4,6) have reported high-yielding F_2 hybrids that produced greater yields than expected on the basis of their F_1 and parental performance. Significant deviations of the F_2 from expected could be due to nonadditive gene action other than dominance, or plant competition within the F_2 population. These results do show that for earliness and total yield, F_2 hybrids can be competitive with established cultivars.

Heterosis for yield components was 0.6, 8.2, and 1.9% for lint percentage, boll weight, and seed weight, respectively. This is similar to the average of several studies summarized previously (3).

A second objective was to compare the consistency of performance of the parents, F_1's and F_2's across environments. To aid in summarizing the data, the two years, three soil types, and two planting dates were combined into 12 environments for analysis. Large mean squares for environments for yield and its components are evident (Table 2). Total yield ranged from an average of 691 to 1384 kg ha^{-1}. Since F_2 populations have 50% of the heterozygosity of the F_1 and are very heterogeneous, it might be assumed that they would be more adaptable or stable to variable environments than the homogenous parents and F_1's. The results in Table 2 show significant interactions for first-harvest and total yield for parents vs. hybrids and

Table 2. Yield and yield component mean squares for seven-parent F_1 and F_2 half-diallels, in cotton.

		Mean squares†				
Source	df	Total yield	First-harvest yield	Lint %	Boll wt.	Seed wt.
Environments (E)	11	12 333**	15 021**	8657**	668**	5685**
P vs. Hybrids (Hyb.)	1	3 749**	1 717**	35	1408**	333**
Hyb.	1	1 229**	1 194**	379	787**	173**
Parents (P)	6	428**	643**	4368**	1012**	578**
F_1	20	300**	590**	1491**	743**	283**
F_2	20	191**	425**	1234**	788**	326**
P vs. Hyb. × E	11	67**	62**	51	345**	38*
Hyb. × E	11	178**	96**	149	16	17
P × E	66	22	34**	66	12	28*
F_1 × E	220	38**	37**	53	20	29*
F_2 × E	220	30**	27**	217**	18	28*
Error	1728	19	18	127	18	21
Combining ability‡						
F_1 GCA	6	918**	1 855**	4351**	168**	845**
F_2 GCA	6	548**	1 363**	2927**	101**	885**
F_1 SCA	14	357**	49**	265**	34**	43**
F_2 SCA	14	37**	23	508**	34**	87**
F_1 GCA × E	66	64**	57**	90	32**	44**
F_2 GCA × E	66	39**	47**	213**	29**	40**
F_1 SCA × E	154	12	29**	33	16	22
F_2 SCA × E	154	26**	19	219**	13	22

*,** Significant at the 0.05 and 0.01 probability levels, respectively, by an *F*-test.
† For lint %, boll and seed weight, df = 588 for error. Environments for first-harvest yield were nine (8 df), and the df involving E interactions should be adjusted accordingly.
‡ GCA = general combining ability; SCA = specific combining ability.

Table 3. Average parental, F_1, and F_2 cotton fiber properties† from a seven-parent half-diallel across 12 environments.

Genotype	Span length 50%	Span length 2.5%	T_1	E_1	Mic.	Yarn tenacity	Short fiber no.	Short fiber wt.
	mm	mm	kN m kg^{-1}	%		kN m kg^{-1}	%	%
Parents	14.4b‡	29.4c	21.1c	7.8a	4.02a	130c	7.3a	3.5a
F_1	14.5b	29.9a	21.5a	7.6b	3.97c	134a	6.2b	2.9b
F_2	14.5b	29.7b	21.3b	7.6b	4.00b	132b	5.8b	2.8b

† T_1 = fiber strength; E_1 = elongation; mic. = micronaire reading.
‡ Within columns, means followed by the same letter are not significantly different at the 0.01 probability level, as indicated by a *t*-test.

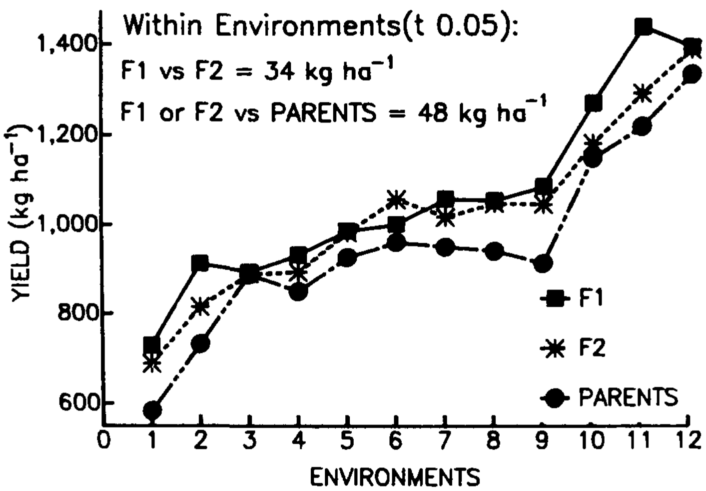

Fig. 2. Average yield in each of 12 environments for the cotton parents and 21 F_1 and 21 F_2 hybrids in a seven-parent half-diallel crossing design.

between F_1 and F_2 performances. Significant interactions within the 21 F_1 and 21 F_2 hybrids were also detected for first-harvest and total yield. The parent × environment interaction was significant for first harvest only. No consistent differences in performance comparing the parents, F_1, and F_2 hybrids are evident for yield (Fig. 2). The question concerning the stability across environments of parents, F_1, and F_2 remains open, as it probably will require a greater range of climates, soils, pests, and management environments to determine whether F_2 hybrids are more adaptable than their parents or F_1 hybrids. In general, the interactions of yield components with environments were of lesser magnitude than for total yield.

The genetic design of the present study also allows for the partitioning of the F_1 and F_2 sources of variability to general (GCA) and specific combining ability (SCA) (Table 2). The genetic expectations for the F_1 and F_2 are the same, except that the dominance component in the F_2 SCA is 25% of that in the F_1 (2). Large effects due to SCA are evident for yield in the F_1, but are generally smaller, although still significant, for yield components. The environmental interactions of F_1 and F_2 yield components are similar in magnitude except for lint percentage, which has large GCA and SCA × environment interactions. The combining ability analyses reinforce the analysis of means, as they indicate significant nonadditive gene action for yield.

The last objective of this study was to investigate the influence of F_2 hybrids on fiber quality. Previous gene action and heterosis studies (3) have indicated that there is little nonadditive gene action for fiber length, strength, and fineness involved within upland cotton crosses. The measurements of fiber quality characteristics in this study reinforce the previous studies (Table 3). While the F_2 hybrids had significantly longer, stronger, and finer lint than the parents, the improvements were too small to be of much practical value. The concerns of using F_2 hybrids are that, since there is great genetic variability within an F_2 population, the resulting lack of uniformity may result in reduced spinning efficiency and greater short-fiber content. The F_1 produced the highest yarn tenacity, followed by the F_2 and the parents. Both the F_1 and F_2 had significantly lower short-fiber content than the parents.

This study shows that F_2 hybrids have the potential of competing with successful pure-line cotton cultivars for yield and fiber quality, and that their stability of yield performance is at least equal to that of established cultivars. The commercial use of F_2 hybrids is most likely to depend upon the logistics of seed production and the willingness of the cotton industry to accept change.

REFERENCES

1. Mather, K., and J.L. Jinks. 1971. Biometrical genetics. 2nd ed. Cornell Univ. Press, Ithaca, NY.
2. Meredith, W.R., Jr. 1984. Quantitative genetics. p. 131–150. *In* R.J. Kohel and C.F. Lewis (ed.) Cotton. Agron. Monogr. 24. ASA, CSSA, and SSSA, Madison, WI.
3. Meredith, W.R., Jr., and R.R. Bridge. 1972. Heterosis and gene action in cotton, *Gossypium hirsutum* L. Crop Sci. 12:304–310.
4. Meyer, V.G. 1975. Male sterility from *Gossypium harknessii*. J. Hered. 66:23–27.
5. Olvey, J.M. 1986. Performance and potential of F_2 hybrids. p. 101–102. *In* T.C. Nelson (ed.) Beltwide Cotton Prod. Res. Conf., Las Vegas, NV. 4–9 Jan. 1986. Natl. Cotton Council of Am., Memphis, TN.
6. Sheetz, R.H., and J.E. Quisenberry. 1986. Heterosis and combining ability effects in upland cotton hybrids. p. 94–98. *In* T.C. Nelson (ed.) Beltwide Cotton Prod. Res. Conf., Las Vegas, NV. 4–9 Jan. 1986. Natl. Cotton Council of Am., Memphis, TN.
7. U.S. Department of Agriculture. Cotton varieties planted 1988. USDA Agric. Marketing Serv., Cotton Div. Memphis, TN.
8. Weaver, D.M., and J.B. Weaver, Jr. 1977. Inheritance of pollen fertility restoration in cytoplasmic male-sterile upland cotton. Crop Sci. 17:497–499.
9. Wells, R., and W.R. Meredith, Jr. 1986. Heterosis in upland cotton: I. Growth and leaf area partitioning. Crop. Sci. 26:1119–1123.