Published May, 1973

The Relationship Between F_2 and Selected F_3 Progenies in Cotton (*Gossypium hirsutum* L.)[1]

William R. Meredith, Jr. and R. R. Bridge[2]

ABSTRACT

Yield, components of yield, and fiber determinations of five parental lines of cotton (*Gossypium hirsutum* L.) and their 10 F_2 hybrids were made at Stoneville, Mississippi in 1968. These results were then related to the 1969 F_3 performance at the same location of eight random, eight high yield, and eight high strength selections from each cross.

The linear correlation coefficient for the F_2 and mean F_3 yield was .48 and not significant. The F_2 hybrids, therefore, gave little information regarding which cross to use when selecting for lint yield. However, high correlations between the F_2 and F_3 for lint percent, seed index, and fiber length, strength, and elongation were detected. The performance of F_2 was a good indication of these traits.

Differences in yield, lint percent, seed index, fiber length, and fiber strength among the three selection types were observed. The yield selections produced 5.7% more lint than the random and strength selections. However, the increased yield was partially at the expense of fiber properties. The average length and strength of the fiber quality selections were slightly greater (1.0%) than the random entries. There was no significant difference in yield between the random and high strength selections.

Additional key words: **Variety improvement, Correlated response, Yield, Agronomic traits, Fiber properties.**

BREEDERS have an almost unlimited number of possible crosses in cotton (*Gossypium hirsutum* L.) from which to choose. However, practical limitations restrict them from investigating all combinations. Frequently, the decision of which cross or crosses to utilize involves practicing the art as much as the science of cotton breeding. Generally, the major criterion used to select parents is that one or more of the parents possess worthwhile expressions of the traits desired. Miller and Lee (3) reported a close relationship between the yield of cotton varieties per se and their F_1 hybrids. Working with soybeans (*Glycine max* L.), Leffel and Hanson (2) reported that the yield, oil, and protein content of the 45 hybrids were highly correlated with the means of 20 F_3 lines derived from each of the 45 crosses. Little information on the relationship between F_2 performance and later generations has been reported in cotton. The first objective of this study was to investigate the feasibility of using the F_2 of selected crosses as an indication of their F_3 performance.

After the selection of a particular cross, the cotton breeder generally begins making plant selections in the F_2. Selection is based on apparent yield potential or on both yield and fiber properties. The second objective of this study was to investigate the effectiveness of F_2 plant selections for lint yield and fiber strength.

MATERIALS AND METHODS

In 1968, an F_2 diallel utilizing five parental lines was grown at Stoneville, Mississippi. The parents were 'Deltapine 16,' 'Stoneville 508-9117,' 'Coker 4104,' 'NM 9608,' and 'PD 3967.' Two row plots, 16 m long and 1.0 m wide, with eight replications were used in a randomized complete-block design. Individual plants were spaced 32 cm apart within the row. One hundred boll samples were taken from each entry in each replication. Boll samples of the two adjacent replications were bulked to form four 200 boll samples and then ginned on a 8-saw gin. Lint percentage, boll size (grams per boll), seed index (weight in grams of 100 seeds), and fiber properties were determined from the bulked samples. Fiber length was measured as 50% and 2.5% span length (SL) in inches on a digital fibrograph. Strength (T_1) expressed in grams per tex and elongation (E_1) expressed as a percentage were measured with the 1/8-inch gauge stelometer. Fiber fineness was expressed in micrograms per inch on the Micronaire. Fiber determinations were made at Knoxville, Tennessee by the U. S. Cotton Fiber Laboratory of the Plant Science Research Division, ARS, USDA.

Seed from three plants were saved from each replication of each F_2 population. One plant was considered a random (R) selection, and it was the first plant in each replication. Five additional plants were chosen within each replication on the basis of a visual appraisal of their yield. The plant judged to be the best was kept as the high yield (Y) selection. From the remaining four plants, fiber property determinations were made. The plant with the highest fiber strength was designated the high strength (S) selection. Seed from the other three plants were discarded. A total of 24 plants were selected from 10 crosses: 8 (R), 8 (Y), and 8 (S).

In 1969, the 240 F_3 progenies were grown in eight sets of 30 selections each. In each set, the R, Y, and S progeny of the 10 crosses from a given 1968 replication were grown in two replications. A split-plot experimental design was used with the eight sets arranged as whole plots and the 30 progenies within a set as subplots. Deltapine 16 was included twice in each set but was not used for analysis of variance computations. Lint percentage, boll size, seed index, and fiber properties were determined from 50 boll samples taken from each plot. The plot size was one row, 16 m long and 1.0 m wide. All plots were harvested with a mechanical picker, modified to handle small plots. Lint yield per plot was determined by multiplying the lint percentage for each plot by the total seed cotton yield per

[1] Contribution from the Cotton Physiology Research Laboratory, ARS, USDA, and the Delta Branch of the Mississippi Agricultural and Forestry Experiment Station, Stoneville, Miss. Published as Journal Paper 2407 of the Mississippi Agricultural and Forestry Experiment Station. Received Sept. 5, 1972.

[2] Research Geneticist, ARS, USDA; and Plant Breeder, Delta Branch of the Mississippi Agricultural and Forestry Experiment Station, Stoneville, Miss. 38776.

Table 1. Mean squares for nine traits in the 1968 F_2 diallel.

Source	df	Lint yield, kg/ha†	Lint, %	Boll size	Seed index	50% SL‡	2.5% SL‡	T_1	E_1	Mic.
$\bar{P}$ vs $\bar{F}_2$	1	98.7**	0.97**	0.219	0.061	2.43**	4.81**	0.35	0.17**	0.296**
P	4	17.2*	22.49**	0.241*	0.704*	1.40**	4.52**	8.63**	4.47**	0.524**
F_2	9	17.4**	5.41**	0.301**	0.870**	0.93**	0.47	4.70**	1.26**	0.156**
gca	4	19.6	11.50**	0.537**	1.066*	1.42**	0.57	8.72**	2.73**	0.317**
sca	5	15.6*	0.54**	0.112	0.714*	0.54	0.38	1.49**	0.08	0.027
Error§	42	5.2	0.11	0.080	0.291	0.31	0.30	0.45	0.12	0.039

*, ** Statistically significant at the 0.05 and 0.01 level of probability, respectively. † Mean square × 10^{-3}. ‡ Mean square × 10^3. § Error degrees of freedom equal 98 for lint yield.

plot; then plot yields were converted into kg/ha. Statistical tests were made according to the t-test approximation procedure for unequal variances and observations given by Cochran and Cox (1).

RESULTS AND DISCUSSION

Pertinent mean squares for the 1968 diallel cross are given in Table 1. The presence of nonadditive gene action is indicated for some traits by the significance of the one degree of freedom comparison for the parental mean vs the F_2 mean. Specific combining ability, also an indicator of nonadditive gene action, is significant for lint yield, lint percentage, seed index, and fiber strength. Both tests indicate that non-additive genetic effects are present and are large for lint yield. The mean performance of the five parents and their 10 F_2 hybrids are given in Table 2. The parents ranged from 823 to 942 kg/ha for lint yield, 1.10 to 1.18 for 2.5% span length, and 19.1 to 23.1 for T_1. Lint yields of the F_2's ranged from 848 to 1032 kg/ha; 2.5% span length ranged from 1.15 to 1.18; and T_1 ranged from 19.8 to 22.9. The cross of Deltapine 16 × Coker 4104 produced the highest yield of 1032 kg/ha and accounted for 40.6% of the sum of squares estimated for specific combining ability of this trait.

Relationship of F_2 and F_3 performance mean squares for the 1969 F_3 progeny are given in Table 3. Highly significant differences among the three selection types were detected for all traits except boll size, fiber elongation, and Micronaire. Among the 10 crosses, highly significant differences for all traits were detected. Significant specific combining ability was detected only for boll size. The means of the F_3 progeny and Deltapine 16 are given in Table 4. Lint yield of the F_3 ranged from 715 to 1031 kg/ha. This range was much larger than that of the F_2. Since no interactions between selection types and crosses were detected, the relationship of the mean performance of the 24 F_3 progenies from each cross with its F_2 is given in Table 5. The linear correlation coefficient for lint yield was .48 and not significant. The F_2 diallel cross performance was not, therefore, as good an indication of F_3 progeny yield performance as many cotton breeders would desire. Nevertheless, the F_2 diallel cross performance does give some information as to which crosses on the average would produce the higher yielding progenies. Leffel and Hanson (2) reported more positive results with soybeans. They reported a relationship of $r = .85$ for soybean yield between F_2 and F_3 populations.

Table 2. Mean performance of the parents and their F_2 hybrids in the 1968 diallel.

Entry	Lint yield, kg/ha	Lint %	Boll size	Seed index	50% SL	2.5% SL	T_1	E_1	Mic.
DPL 16	942	38.6	5.34	10.4	0.54	1.16	20.4	8.1	4.0
Stv 508	836	34.6	5.62	11.0	0.56	1.18	20.3	7.1	3.9
Coker 4104	862	35.7	5.52	11.0	0.52	1.12	19.1	6.9	3.8
NM 9608	823	36.2	5.51	10.7	0.57	1.14	23.1	5.8	4.2
PD 3967	850	40.5	6.00	11.5	0.53	1.10	21.0	5.5	4.7
DPL × Stv	915	36.3	5.51	10.4	0.57	1.18	20.2	7.5	3.7
DPL × Cok	1,032	37.5	5.66	10.7	0.55	1.15	20.5	7.4	3.8
DPL × NM	945	38.0	5.19	10.8	0.57	1.15	21.2	7.1	3.8
DPL × PD	924	39.2	5.45	10.2	0.55	1.15	20.7	7.1	4.0
Stv × Cok	916	35.7	5.93	11.2	0.55	1.17	20.0	7.1	3.8
Stv × NM	930	36.7	5.91	11.3	0.57	1.15	21.6	6.6	3.9
Stv × PD	907	37.8	5.99	11.1	0.55	1.16	19.9	6.6	4.1
Cok × NM	907	36.2	5.96	11.4	0.56	1.15	22.3	6.2	4.2
Cok × PD	848	38.1	5.73	11.2	0.53	1.15	19.8	6.5	4.1
NM × PD	900	38.8	5.97	11.6	0.59	1.16	22.9	5.7	4.3

Table 4. Mean F_3 progeny and Deltapine 16 progeny performance in 1969.

Entry	Lint yield	Lint %	Boll size	Seed index	50% SL	2.5% SL	T_1	E_1	Micronaire
DPL × Stv	1,031	33.1	5.90	12.1	0.53	1.19	19.0	7.69	3.99
DPL × Cok	1,007	34.5	5.64	11.5	0.54	1.15	18.9	7.74	4.18
DPL × NM	853	34.5	5.55	12.1	0.54	1.15	20.3	7.37	4.13
DPL × PD	897	36.1	5.55	11.7	0.52	1.15	19.7	7.04	4.10
Stv × Cok	963	32.8	5.79	12.5	0.52	1.17	19.3	7.32	3.87
Stv × NM	770	33.0	5.44	12.6	0.55	1.17	21.1	6.58	4.05
Stv × PD	830	34.5	5.65	12.0	0.52	1.17	20.1	6.62	3.96
Cok × NM	736	34.1	5.40	12.5	0.54	1.14	21.0	6.42	4.26
Cok × PD	821	35.7	5.41	11.9	0.53	1.15	19.9	6.60	4.05
NM × PD	715	35.8	5.57	12.4	[illegible]	1.15	21.2	6.02	4.26
DPL 16	1,045	35.0	5.69	11.4	0.53	1.18	19.2	8.13	4.20

Table 5. Linear correlation (r) and regression (b) coefficients between the F_2 and F_3.

Coefficient	Lint yield	Lint %	Boll size	Seed index	50% SL	2.5% SL	T_1	E_1	Micronaire
r	0.478	0.923**	-0.194	0.673*	0.697*	0.802**	0.786**	0.949**	0.475
b	1.142	0.948**	-0.115	0.525	0.495*	1.080**	0.630**	0.978**	0.320

*, ** Statistically significant at the 0.05 and 0.01 level of probability, respectively. Sample size (n) equals 10.

There are several possible reasons why the F_2 performance for lint yield was not more closely related to that of the F_3. First, the genetic variability within F_2 plots would be greater than that within F_3 progeny rows. The effects of plant competition and genetic variability in cotton have not been adequately investigated, but theoretically some special instances could result in low associations between F_2 and F_3 performance. A second factor is that genotype by environment interactions may be of large magnitude. Although the F_2 and F_3 tests were grown on the same site, genotype by environment interactions involving years or years and locations could be involved. A third possibility, and the one we consider most likely, is that considerable dominance gene action, if present, is expressed in an F_2 population.

As indicated in Table 6 for the F_2 diallel study, Deltapine 16 averaged 20 kg/ha more than the mean

Table 3. F_3 progeny mean squares in 1969.

Source	df	Lint yield, kg/ha†	Lint, %	Boll size	Seed index	50% SL‡	2.5% SL‡	T_1	E_1	Micronaire
Sel.	2	117**	31.06**	0.482	7.644**	5.48**	22.37**	18.945**	0.044	0.457
Cross	9	582**	68.44**	1.275**	6.371**	5.65**	10.20**	36.192**	16.021**	0.848**
gca	4	5,055**	153.67**	1.492	12.272**	11.61**	21.67**	79.524**	35.149**	1.736**
sca	5	37	0.25	0.803*	1.650	0.89	1.02	1.526	0.719	0.137
SXC	18	13	1.82	0.328	1.262	1.04	2.26	1.288	0.281	0.086
Prog. × set	203	19	4.06	0.295	1.045	0.90	2.10	1.542	0.662	0.183
Error	232	9	0.32	0.149	0.209	0.49	0.54	0.776	0.199	0.035

*, ** Statistically significant at the 0.05 and 0.01 level of probability. † Mean square × 10^{-3}. ‡ Mean square (SL) × 10^3.

Table 6. Lint yield comparison of Deltapine 16 with the F_2 and with the mean F_3 performance.

Entry	DPL 16 - F_2 hybrid	DPL 16 - F_3 avg	Col. 2 - Col. 1
DPL × Stv	27	14	-13
DPL × Cok	-89	38	127**
DPL × NM	-3	192	195**
DPL × PD	18	148	130**
Stv × Cok	26	82	56
Stv × NM	12	275	263**
Stv × PD	35	215	180**
Cok × NM	35	309	274**
Cok × PD	94	224	130**
NM × PD	42	330	288**
Mean	20	183	163**

** Statistically significant at the 0.05 and 0.01 probability levels, respectively.

of the 10 F_2's. In the F_2 analysis, the magnitude of nonadditive gene action was significant for lint yield (Table 1), and its presence was detected for most of the other traits. In the F_3 study (Table 6), Deltapine 16 averaged 183 kg/ha more lint than the F_3 populations. The difference between test generation-years was highly significant on the basis of a synthetic t-test which does not include genotype by environment interactions. The F_3 analysis did not detect any nonadditive gene action for yield (Table 3), and in general it was not present or of large magnitude for the other eight traits. One cannot discount the possibility that the 1968 season may have been especially suited for the expression of non-additive gene action.

Those F_3 progenies which exhibited superior combinations of yield and fiber strength were further evaluated in the F_4 generation, and plant selections were made at that time. Only three representatives of the original 240 progenies remained in the evaluation program by the F_7. Two were from the cross of Deltapine 16 with Stoneville 508-9117. The yield and fiber properties of these progenies were very similar to that of Deltapine 16. The third progeny remaining was from the cross of Deltapine 16 with Coker 4104. This progeny's average yield, 2.5% span length, and fiber strength from four locations in 1972 was 12, 4, and 1% greater, respectively, than that of Deltapine 16. Thus, the only progeny by the F_7 generation which was superior to Deltapine 16 descended from the highest yielding F_2 hybrid (Table 2). These results suggest that the diallel cross does provide some useful information as to which crosses might tend to produce the most productive progeny. High correlations, for seed index and for fiber length, strength, and elongation are evident in Table 5. This suggests that the F_2's performance is a good indication of these traits.

Effectiveness of F_2 Plant Selection

The means for the three selection types are given in Table 7. Significant differences among the types were detected for all traits except boll size, fiber elongation, and Micronaire. The yield selections were significantly higher (5.7%) in yield than the random or strength entries. However, the yield selections did have slightly shorter and weaker fiber than the other two selection types. The average length and strength of the high strength selections, while significantly greater, were only slightly higher (1.0%) than the random entries. The yield of the strength selections was essentially the same as that of the random entries. These results indicate that visual selection in the F_2 for lint yield was effective. However, the gain in yield was partially at the expense of fiber properties. Miller and Rawlings (4) have reported similar correlated responses for yield in cotton. As selection increased lint yield, decreases were observed in fiber length and strength. On an F_2 plant basis, selection for yield and strength was only slightly better than the random entries. By the F_7 there were 1, 2 and 0 selections remaining that descended from the yield, strength, and random selections, respectively.

Table 7. Mean performance of random (R), high yield (Y), and high strength (S) selections and of Deltapine 16.

Selection	Lint yield	Lint %	Boll size	Seed index	50% SL	2.5% SL	T_1	E_1	Mic.
R	845 b*	34.5 a	5.57 a	12.1 b	0.53 b	1.16 b	20.1 b	6.92 a	4.09 a
Y	893 a	34.8 a	5.55 a	11.9 c	0.52 c	1.15 c	19.7 c	6.94 a	4.12 a
S	849 b	33.9 b	5.65 a	12.4 a	0.54 a	1.17 a	20.4 a	6.96 a	4.04 a
DPL 16	1,045	35.0	5.69	11.4	0.53	1.18	19.2	8.13	4.20

* Progeny means for each trait followed by the same letter are not significantly different at the 0.05 probability level (Duncan's Multiple Range Test).

The possible causes for selection of F_2 plants not being any more effective are similar to those relating F_2 and F_3 performance. First, the environment of an individual plant differs greatly from that of progeny rows. A second factor is that genotype × environment interactions from one year to the next at a single location may be large. A third reason is that dominance gene action in an F_2 population may not be usable in later generations. The large nonadditive gene effects, especially for yield (Table 1), are evidence that this was one factor that influenced our results. A fourth possibility is that the genetic variability for some traits in some crosses may have been low. Any one or combination of these possibilities could result in the meager progress observed. Since nonadditive genetic effects were not detected in the F_3 generation and the lint yield range in the F_3 was much greater than that of the F_2, selection in the F_3 or later generations should be more effective than in the F_2.

REFERENCES

1. Cochran, W. G., and G. M. Cox. 1957. Experimental designs. 2nd Ed. John Wiley, New York. p. 611.
2. Leffel, R. C., and W. D. Hanson. 1961. Early generation testing of diallel crosses of soybeans. Crop Sci. 1:169-174.
3. Miller, P. A., and J. A. Lee. 1964. Heterosis and combining ability in varietal top crosses of upland cotton, *Gossypium hirsutum* L. Crop Sci. 4:646-649.
4. ———, and J. O. Rawlings. 1967. Selection for increased lint yield and correlated responses in upland cotton, *Gossypium hirsutum* L. Crop Sci. 7:637-640.