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Inbreeding Depression of Selected F_3 Cotton Progenies[1]

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ABSTRACT

The objective of this study was to investigate yield inbreeding depression of selected cottons (*Gossypium hirsutum* L.). In 1973, 360 F_3 equivalent progeny rows from the cross and random intercross of 'Deltapine 16' × 'Mo 277-396' were grown at two Delta locations with two replications each. From 50 of the 72 highest lint-producing progenies, F_4 and F_5 seed were produced in 1973 and 1974.

In 1975, the 50 families were grown in five sets of 10 families each at two locations. Families were grown as whole plots; F_3, F_4, and F_5 progenies were grown as subplots. An additional whole plot of Deltapine 16, Mo 277-396, F_1, F_2, and the unselected bulk of F_3, F_4, and F_5 plants was grown in each set. The average lint yields of these seven populations were 633, 899, 859, 751, 725, 709, and 713 kg/ha, respectively. The average yields of selected F_3, F_4, and F_5 progeny were 759, 748, and 710 kg/ha, respectively. Significant inbreeding depression was detected in both selected and unselected populations. These results imply that inbreeding depression is a major factor in the poor yield performance of early generation selections for yield in cotton.

Additional index words: Cotton breeding, *Gossypium hirsutum* L.

WHY do many early generation F_3 progeny rows produce lint yields of cotton (*Gossypium hirsutum* L.) superior to the best commercial cultivar and in later generations (F_5) produce unacceptable yields? The reasons for this inconsistency of yield performance can be classified into three categories.

1. Reselection within progeny rows could result in some selections being retained with a lower-yielding ability than that of the original population. This result could have been caused by random drift, a poor testing environment or by poor selection.
2. Inadequate sampling, either by using too few or atypical replications and environments.
3. Inbreeding depression.

In practice, many characteristics other than yield, such as unacceptable handling and fiber properties, may cause the breeder to discard promising yield selections from his progeny testing program. However, if one confines the problem to yield per se, the three categories listed above are the primary causes of decreasing yield in advanced generations.

The purpose of this study was to investigate the effects of the last two factors on poor performance of advanced generation selections. The role of reselection on yield performance from previous studies will be discussed.

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Table 1. Average lint yield and yield components of seven unselected and three selected populations.

Population	Yield	Yield component					
		Lint	Boll size	Seed index	Lint index	Seed/ boll	Bolls/ plot
	kg/ha	%	——	%	——	—— No.	——
Unselected							
Deltapine 16	633	37.7	6.38	13.6	8.2	29.4	183
Mo277-396	899	37.4	6.19	13.5	8.0	28.8	270
F_1	859	36.6	6.82	14.3	8.3	30.2	240
F_2	751	36.3	6.52	14.1	8.0	29.2	221
F_3	725	36.1	6.36	13.9	7.9	29.2	220
F_4	709	36.3	6.34	14.1	8.1	28.6	215
F_5	713	36.6	6.31	13.6	7.9	29.5	213
L.S.D. 0.05	74	0.5	0.23	0.3	0.3	1.2	20
Selected							
F_3	759	36.5	6.53	14.1	8.1	29.5	221
F_4	748	36.7	6.48	13.8	8.0	29.7	217
F_5	710	36.6	6.51	13.8	8.0	29.4	211
L.S.D. 0.05	27	N.S.	N.S.	0.1	N.S.	N.S.	N.S.

MATERIALS AND METHODS

In 1973, 360 F_3 equivalent progeny rows from the cross and random intercross of 'Deltapine 16' (DPL 16) and 'Mo 277-396' were grown at two Delta locations with two replications each. Ninety progeny rows each were produced by 0, 1, 2, and 3 generations of random intercrossing to produce the 360 progenies. Later, Mo 277-396 (Mo 277) was released as a cultivar under the name Delcot 277. The 360 progenies were grown in 12 sets of 30 progenies each. The six highest yielding progenies (20% selection differential) from each set were retained for future study. Of these 72 highest lint producing progenies, sufficient remnant F_3 seeds of 50 were available for future plot experiments. The F_3 seeds were produced in 1972 and were stored in a freezer until needed in 1975. Open-pollinated F_4 and F_5 seeds from the 50 selected progenies were produced in 1973 and 1974, respectively, by randomly harvesting one boll from approximately 200 plants.

In 1975, the 50 families were grown in five sets of 10 families each. Four of the sets were grown at two locations and the remaining set was grown at only one location because of insufficient F_3 seed. Families were grown as whole plots; F_3, F_4, and F_5 progenies were grown as subplots. An additional whole plot of DPL 16, Mo 277, F_1, F_2, and the unselected bulk of F_3, F_4, and F_5 plants were grown in each set. The seeds were produced in 1974, 1974, 1974, 1971-72, 1972, 1973, and 1974, respectively. All these seeds were produced as open-pollinated seed at Stoneville from a large number (in excess of 2,000) of unselected plants except for the F_1 and F_2. The F_1 seeds were produced by hand crossing and the F_2 seeds were produced in Iguala, Mexico in 1971-72. All seeds were stored in a freezer until needed for the 1975 plantings.

All plots used in 1973 and 1975 were one row, 1 $\times$ 6.9 m. Plant densities were about 120,000 plants/ha except for five selected F_3 progenies which, due to limited seed, were approximately 100,000 plants/ha.

RESULTS

The average lint yields of DPL 16, Mo 277, and the 360 F_3 progeny rows grown in 1973 were 1,170, 1,018, and 1,052 kg/ha, respectively. The heritability of yield was 0.376 and the predicted genetic advance by selecting the highest yielding 20 percentile was 62 kg/ha. In a previous gene action study, Meredith and Bridge (6) reported considerable heterosis in the cross of DPL 16 $\times$ Mo 277. In theiry study, the yields of DPL 16, Mo 277, F_1, and F_2 were 813, 783, 936, and 870 kg/ha, respectively. An analysis of generation means indicated that very large dominance effects were involved in yield expression.

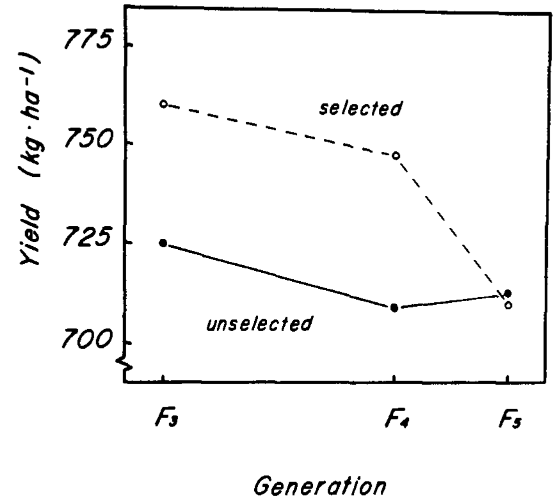

Fig. 1. Average yield performance of selected and unselected F_3, F_4, and F_5 populations. Unequal spacing of generations reflects their relative heterozygosity.

The results of the 1975 study are given in Table 1. The productivity of DPL 16 was not as high relative to other populations based on previous studies. The season was one in which many of the late-season bolls of full-season cultivars such as DPL 16 did not mature.

Results from the seven unselected populations indicate a significant inbreeding depression with yields decreasing from 859 to 713 kg/ha, respectively, for the F_1 and F_5 populations. Greatest loss in yield was from F_1 to F_2. Little loss in yield from F_3 to F_5 was detected, 12 kg/ha.

In the selected populations there was a significant loss of yield from F_3 to F_5 of 49 kg/ha. Using the F_3 as a base population, the inbreeding depression was 1.7 and 6.5% for the unselected and selected populations, respectively. Therefore, these results suggest that inbreeding depression of the selected F_5 progenies was equal to or greater than that of the average unselected population.

The lack of stability in advanced-generation plants selected for yield may also be related to inadequate or atypical sampling of the initial environments. That such an interaction could occur is demonstrated by comparing the yields of the parents. DPL produced a 15% greater yield than Mo 277 in 1973, but a 30% lower yield in 1975.

However, the question remains, could part of the loss of yield observed in 1975 be related to sampling? The discriminant function analysis of the 1973 populations indicates that the 20% selection differential for yield should result in a selected population advantage of 5.9% over the average or unselected population. In 1975, average F_3 yield of the selected populations was 4.7% greater than that of the unselected population. Thus, the yield advantage shown by selected F_3 progenies in 1973 was consistent with that observed in 1975.

Average performance of selected and unselected F_3, F_4, and F_5 populations are indicated in Fig. 1. For this study, it is evident that the loss in yield in advanced generations was not primarily due to poor initial identification of superior yield progenies, but

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was due to inbreeding depression. In theory, inbreeding depression is caused by a decrease in heterozygosity which conditions strong dominance or over-dominance gene action. This one study does not imply that all problems involved with the inefficiency of early generation selections are due to inbreeding depression. However, the widespread detection of dominance gene action in cotton inheritance suggests that inbreeding depression is a major complicating factor in early generation yield evaluations.

Inbreeding depression of yield components was more evident in the unselected than in the selected populations. In general, in the unselected populations there was a decrease in boll size, seed index, lint index, seed per boll, and bolls per plot with increased inbreeding. The only component in the selected population in which significant differences were detected was smaller seed index in the F_4 and F_5 than the F_3 generation.

Several breeders have investigated the possibility of reselecting within progeny rows. Feaster and Turcotte (4) and Culp and Harrell (1) both concluded that generally little progress for lint yield could be expected from selecting within promising progeny rows. Their conclusion is contrary to the views and practice of many cotton breeders. The review by Ramey (8) and the reports by Ewing (3) and Turner (9) indicate that many cultivars developed before 1965 involved considerable reselection from outstanding progenies or were developed from highly inbred populations. The review presented by Lewis (5) also indicates that cotton cultivar maintenance programs involve much reselection and testing. The practice of pure line breeding in cotton has changed little in the last 60 years. The successful approaches used in earlier cotton breeding times may now need some modifications.

One of the changes that has evolved is that cotton has changed from an often cross-pollinated crop to an essentially self-pollinated crop (7). In earlier cotton breeding history, the frequent outcrossing within and among progeny rows resulted in populations with high heterozygosity, heterogeneity, and increased breakup of unfavorable linkage blocks. It is quite reasonable to understand why the practice of reselection within progeny rows among earlier cotton breeders was so popular and successful. These earlier breeders were, in essence, practicing selection for general combining ability with earlier generations. Reselections within these progeny rows followed for both general and specific combining ability.

Could some of the recent decline in cotton yields be related to cotton breeders no longer making use of specific combining ability? What modifications can breeders make to combat this prbolem?

First, these results indicate that increasing the number of replications and environments for yield testing in the early generations is unlikely to alleviate the problem. In practice, the breeder within the limits of his resources would have greater probability of selecting a superior yielding progeny in the F_3 generation by increasing the number of strains tested and decreasing the number of replications. When parents from widely different genetic backgrounds are used in a cross, such as in this study, both heterosis and bountiful genetic variability are usually observed. In these situations, strong yield selection in the F_3 generation would tend to be ineffective due to the large influence of dominance gene action. However, selection in the F_3 generations for traits that usually show little dominance, such as lint percentage, fiber properties, handling characteristics, disease and pest resistance could be effective. The traits, as indicated in earlier research (6), tend to have high heritability and low cost per determination.

Second, breeders might explore the use of bulk breeding. Large numbers of plants could be maintained by harvesting one boll per plant each generation. Selection could be delayed until F_5 or F_6 where the effects of dominance would be small and the additive genetic variance considerably greater than in the F_3.

A third approach not frequently used by cotton breeders would be recurrent selection. El-Adl and Miller (2) have demonstrated the effectiveness of this method. After three cycles of selection, the mean of their selected population exceeded the parental F_1 by 5.5%. The F_1 had previously exhibited much heterosis, 32.6% more than the midparent and 13.3% more than the higher yielding parent. Recurrent selection would then utilize effectively the additive genetic variance among families, broaden the genetic base of the breeding populations, and provide greater opportunities for transgressive segregation and recombination. The commonly used pure-line approach to cotton breeding is frequently criticized on all four of these breeding characteristics.

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