Published November, 1973

Recurrent Selection for Lint Percent within a Cultivar of Cotton (*Gossypium hirsutum* L.)[1]

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

ABSTRACT

We conducted this study to determine if a modified form of recurrent selection for lint percent within a cotton (*Gossypium hirsutum* L.) cultivar, 'Deltapine 523,' could improve lint yield. Three cycles of selection, beginning in 1965, were completed, with selection for lint percent being practiced first on a plant basis and then on a progeny-row basis. Plant populations of 430, 828, and 800 plants were used to initiate the S_1, S_2, and S_3 populations, respectively. From each population, 16 progenies were ultimately selected on the basis of high lint percent, and 8 crosses were made among them to initiate the next cycle. In each cycle, an equal number of seeds from each of the 16 selections were combined to form the bulk populations tested in 1971. Eight progenies selected in the S_3 for higher 2.5% span length were bulked and designated as the S_{3L} population.

In 1971, Deltapine 523 (S_0) and the four selected populations were grown in replicated experiments at four locations. Mean lint precent was 33.8, 35.4, 36.6, 38.0, and 37.1 for the S_0, S_1, S_2, S_3, and S_{3L} populations, respectively. The S_2, S_3, and S_{3L} populations produced significantly greater lint yield than did S_0 and S_1. As lint percent was increased by selection, there were concurrent decreases in seed index and 50 and 2.5% span length. Selection for fiber length in the S_3 population restored most of the fiber length previously lost. As lint percent was increased by selection, there were simultaneous increases in lint index, seeds per boll, and Micronaire. No consistent trend or change was observed for boll size, number of bolls per plot, fiber strength, and fiber elongation. The primary cause of the increase in lint yield resulting from selection for lint percent was the association of lint percent with increased number of seeds per boll and higher lint index.

The genetic variability for lint percent within the S_1 and S_2 populations was found to be 188 and 83%, respectively, as compared to that of the S_0 population. The genetic variability for an unselected trait, boll size, was similar, with the S_1 and S_2 populations expressing 233 and 186%, respectively, as much variability as that of the S_0 population.

Additional index words: Cotton breeding, Yield components, Correlated response.

LINT percent is a component of yield routinely determined in most cotton (*Gossypium hirsutum* L.) breeding experiments. It is reported (3, 10, 11) as having variety by environment interactions which are small relative to that for varietal effects. In genetic studies (1, 6, 8, 12), lint percent has been highly correlated with lint yield. Miller et al. (12) calculated genetic correlations of 0.74, 0.79, and 0.87 between lint percent and lint yield in three segregating populations. Al-Jibouri, Miller, and Robinson (1) reported a genetic correlation of 0.84 between lint percent and yield. Miller and Rawlings (8), in populations produced by several generations fo intercrossing, found a genetic correlation of 0.67 between lint percent and yield. In a similar study, Meredith and Bridge (6) obtained a genetic correlation of 0.70. Several studies (1, 6, 12) have reported a negative genetic correlation between lint percent and seed index and lint percent and fiber length, strength, and fineness. Boll size usually had a negative, but small, genetic correlation with lint percent. In summary these genetic studies indicate that if selection in a genetically variable population were practiced only for lint percent, one would expect an increase in yield and decreases in seed index, boll size, and fiber length, strength, and fineness.

Relatively few recurrent-selection studies have been described in the literature for cotton. Manning (5) has reported yield increases from 12 generations of progeny selection in an African cultivar, 'BP 52.'. Selection was practiced for three components of yield: bolls/plant, seed/boll, and lint/seed, and at the end of the 10th generation, yield had been increased 24 to 32%. Miller and Rawlings (9) reported a 29.7% increase in lint yield as a result of three cycles of recurrent selection in a population resulting from a cross between a line of 'Coker 100' and one of 'Acala 1517.' Correlated responses to yield selection were observed to increase lint percent, number of seed/boll, earliness, and fiber elongation. Decreases in boll size, seed index, fiber strength, and fiber fineness accompanied the increase in yield. Bridge and Meredith (4) reported responses similar to those of Miller and Rawlings (7) in commercial breeding programs in the Delta of Mississippi. Improvements in yield of commercial cultivars appeared to have been associated closely with increased lint percent.

The positive genetic association between yield and lint percent in these numerous studies suggests that selection for one component of yield, lint percent, would be an effective procedure to increase yield. The primary objective of this study was to determine if recurrent selection within a cultivar could result in significant yield increases without loss of fiber properties. A second objective was to determine the changes in genetic variance caused by selection within a cotton cultivar.

MATERIALS AND METHODS

We conducted three cycles of a modified form of recurrent selection for higher lint percent in the cultivar 'Deltapine 523.' Deltapine 523 descends from an F_4 plant selection made in 1955. The cultivar has a complex parentage involving a selection from 'Deltapine 14' × 'Bobshaw 1,' crossed with a selection from 'Deltapine 15' × 'Magnolia.' Deltapine 523 is referred to in this study as the base population, S_0. In each cycle, selection for higher lint percent was practiced in two stages: on a plant basis and then on replicated progeny-rows. No selection was practiced for yield or any other traits, except where specified.

First Cycle Selections (S_1). In 1965, 16 blocks with 25 spaced plants/block plus 2 blocks of 15 spaced plants/block were grown. Individual plants in all the studies reported herein were spaced approximately 33 cm apart. Lint percent for the

[1] Contribution from the Cotton Physiology Research Laboratory, Agricultural Research Service, USDA, and the Delta Branch of the Mississippi Agricultural and Forestry Experiment Station, Stoneville, Miss. Published as Journal Paper 2570 of the Mississippi Agricultural and Forestry Experiment Station. Received May 21, 1973.

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

430 plants was measured in the laboratory. An 8-saw gin was used to separate the lint and seed for lint percent determinations. The 23 plants with highest lint percent were retained and planted in progeny rows in 1966. Four replications of one-row plots 12 m long and 1 m wide were grown, and lint percent was determined from 50-boll samples taken from each replication. The open-pollinated seed from the boll samples of the 16 entries with highest lint percent were retaind. Open-pollinated seed are assumed to be selfed as natural crossing of cotton in this locale has been estimated (7) to be 0.2%. The following year, 1967, the 16 individual entries were grown and 200 open-pollinated bolls from 150 to 175 plants were harvested. The seed from these samples were kept in cold storage until 1971. Equal numbers of seed from each of the 16 entries were bulked to form the S_1 population planted in the 1971 test.

Second-Cycle Selections (S_2). A diallel crossing system involving the 23 selected progenies was conducted in 1966. Eight single crosses among the 16 selected entries were retained and sent to Iguala, Mexico. These eight single crosses and those crosses subsequently made were done at random with the stipulation that no S_1 selected progeny would appear more than once in each pedigree. An outline of the crossing procedure is given in Table 1. In 1967, the F_2's of the 8 crosses were each planted in 5 blocks of about 21 spaced plants/block. A total of 828 plants were harvested, and their lint percents were determined. From each cross, the 10 plants with highest lint percent were retained and grown in 1968 as progeny rows in 2 replications. Plot size was again one row 12 m long and 1 m wide. Lint percent was determined from 50-boll samples taken from each replication for each entry. Based on the progeny-row performance, the two selections from each cross with the highest lint percents were retained. The F_4 seed were planted the following year and 200 open-pollinated bolls from 150 to 175 plants were harvested. Equal numbers of F_5 seeds from each of the 16 selections were bulked to form the S_2 population tested in 1971.

Third-Cycle Selections (S_3). Eight crosses were made in 1968 among the 16 S_2 selections. F_2 seed were produced during the winter at Iguala, Mexico and planted in 10 blocks of 10 plants each in 1969. The 10 plants with highest lint percent from each cross were grown as replicated progeny rows in 1970. Two progenies from each of the crosses were again selected. Equal numbers of F_4 seed from each of the 16 selections were bulked to form the S_3 population planted in the 1971 test.

Third-Cycle 2.5% Span-Length Selections (S_{3L}). Fiber-length determinations of the 80 progeny rows grown in 1970 indicated that there had been some loss of fiber length during the 3 cycles of selection. The progeny that had the longest 2.5% span length from each of the 1968 crosses was selected. The bulk of equal numbers of F_4 seed from these eight progenies is designated as the S_{3L} population. None of these eight progenies were the same as those used to form the S_3 population.

Variability within Populations. In 1965, open-pollinated seed from 100 spaced plants of Deltapine 523 were harvested. In 1966, 2 sets of 50 progenies each were grown in 2 replications. Lint percent and boll size in grams were determined from 50-boll samples taken from these plots. This population, taken as a random sample of Deltapine 523, is designated as S_0 in Table 4. In 1967, 12 random F_2 plants from each of the 8 crosses were harvested, and the seed were grown as progeny rows in 1968. Three sets of 32 progenies each were grown with 2 replications. Lint percent and boll size were determined from 50-boll samples. These 96 progenies were taken as a random sample of the variability in the S_1 population and are designated as S_1 in Table 4. This same procedure was repeated with the S_2 population, and 96 random progenies were grown in 1970.

Comparison of Populations. In 1971, S_0, S_1, S_2, S_3, and S_{3L} populations were grown at four locations. A commercial variety, 'Deltapine 16,' was also included in each test, but was not used in the analysis of variance. At each location, six replications of two-row plots 7 m long and 1 m wide were used. Fifty-boll samples from replications 1, 2, and 3 were bulked to form one composite sample and from replications 4, 5, and 6 to form another composite sample. Lint percent was determined from these samples as lint/seed cotton. The average lint percent for each population was multiplied by each plot's seed-cotton yield to obtain the lint yield per plot. The average weight in g/boll was used to estimate boll size. The weight of 100 seeds from each sample was obtained as an estimate of seed index. The number of harvestable bolls per composite sample was determined as total seed cotton in g/boll size. Lint index per composite sample was computed as LI = (lint % × seed index)/(100 − lint %). The number of seed per boll was computed from each composite sample as (100 − lint %) (boll size)/seed index.

Table 1. Crossing outline for producing the various populations.

First Cycle	Second Cycle		Third Cycle	
430 S_0 plants, 16 S_1 Sel.	S_1 crosses 828 S_1 plants	S_2 Sel.	S_2 crosses 800 S_2 plants	S_3 Sel.
A	A × C	A'	A' × C'	A''
B	A × C	B'	A' × C'	B''
C	B × D	C'	B' × D'	C''
D	B × D	D'	B' × D'	D''
E	E × G	E'	E' × G'	E''
F	E × G	F'	E' × G'	F''
G	F × H	G'	F' × H'	G''
H	F × H	H'	F' × H'	H''
.	.		.	
.	.		.	
.	.		.	
P	N × P	P'	N' × P'	P''

Fiber length was measured as 50% and 2.5% span length (SL) on a Digital Fibrograph.[8] The .312-cm (1/8-inch) gauge Stelometer was used to determine fiber strength (T_1) and elongation (E_1). Fiber fineness was expressed in Micronaire units. Fiber determinations were made by the U.S. Cotton Fiber Laboratory of the Agricultural Research Service, USDA, at Knoxville, Tennessee.

RESULTS AND DISCUSSION

The means for lint yield, yield components, and fiber properties for the various Deltapine 523 populations and Deltapine 16 are given in Table 2. The analyses of variance (Table 3) indicate highly significant differences among populations for all traits except lint index, fiber strength, and fiber elongation. No interactions of populations with locations were detected. It is evident that selection was effective in producing populations with higher lint percent (Table 2). The S_3 population had the highest lint percent, 38.0%, compared with 33.8% for the base population. Had the recurrent-selection study been terminated with the S_1 population, one might have concluded that recurrent selection for lint percent within cultivar was not effective in increasing lint yield. However, after intercrossing the 16 selected S_1 progenies, a yield increase was detected in the S_2 population. Although a further increase in lint percent was obtained, no significant differences were detected for lint yield among the S_2, S_3, and S_{3L} populations. Selection for lint percent, therefore, produced three populations, S_2, S_3, and S_{3L}, which produced higher yields than those for the S_0 population.

Examination of the other yield components indicates that the effect of lint percent on yield was of an indirect nature through seed index, lint index, and number of seed/boll. Lint percent can be defined as lint index/ (lint index + seed index). Therefore, lint percent increases can be related to changes in lint index and seed index. Lint index increased from 6.3 in the S_0 population to 6.6 in the S_1 population and essentially did not change during the remaining cycles of selection. Seed index decreases, however, were observed in each cycle of selection. Lint percent increase in the S_0 population was therefore the result of both an increase in lint index and a decrease in seed index. Subsequent increases in lint percent were the

[8] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

14350653, 1973, 6, Downloaded from https://acsess.onlinelibrary.wiley.com/doi/10.2135/cropsci1973.0011183X001300060033x by North Carolina State Universit, Wiley Online Library on [20/07/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 2. Yield, yield components, and fiber properties of Deltapine 523, four selected populations, and Deltapine 16.

Population	Lint, kg/ha	Lint %	Boll size	Seed index	Lint index	Bolls/ plot	Seed/ plot	50% SL	2.5% SL	T_1	E_1	Micro- naire
S_0	1,066 c*	33.8 f	5.38 b	12.5 a	6.3 b	2,458 ab	28.0 b	0.615 a	1.20 b	20.75 a	6.65 b	4.36 b
S_1	1,053 c	35.4 e	5.67 a	12.0 b	6.6 a	2,200 c	30.6 a	0.588 c	1.16 c	20.98 a	6.45 b	4.57 a
S_2	1,144 b	36.6 c	5.36 b	11.1 c	6.5 ab	2,436 ab	30.6 a	0.601 b	1.17 c	20.90 a	6.51 b	4.70 a
S_3	1,134 b	38.0 a	5.33 b	10.9 c	6.6 a	2,352 b	30.5 a	0.586 c	1.17 c	20.40 a	6.66 b	4.58 a
$S_{3\,L}$	1,125 b	37.1 b	5.29 b	11.2 c	6.6 a	2,408 b	30.0 a	0.592 bc	1.19 b	20.77 a	6.46 b	4.63 a
DPL 16	1,207 a	35.7 d	5.64 a	11.7 bc	6.5 ab	2,514 a	31.0 a	0.591 bc	1.24 a	19.52 b	8.57 a	4.23 c

* Means followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

Table 3. Mean squares for yield, yield components, and fiber properties in Deltapine 523 populations.

Source	df	Lint, kg/ha	Lint, %	Boll size	Seed index	Lint index	Bolls/ plot	Seed/ boll	50% SL†	2.5% SL†	T_1	E_1	Micro- naire
Population	4	42,044**	20.95**	0.180**	3.658**	0.131	85,584**	9.62**	1,134**	2,434**	0.375	0.083	0.127**
Pop. × Loc.	12	9,063	0.17	0.055	0.171	0.050	20,869	2.38	274	377	0.040	0.128	0.020
Error‡	16	7,347	0.17	0.026	0.146	0.052	9,530	1.34	164	244	0.234	0.098	0.013

* Statistically significant at the 0.01 level of probability. † Mean squares × 10^6. ‡ Error degrees of freedom, 80 for lint yield.

result of decreases in seed index. An increase in the number of seed/boll accompanied these changes. The result of combined changes in seed index, lint index, and number of seed/boll was that boll sizes of the selected populations remained about the same as those of the base population. There were no consistent differences in number of bolls/plot between the base populations and selected populations.

No significant differences in fiber strength or elonvation were detected among the five populations. This is in contrast to previous genetic studies (1, 6, 8, 12) which implied that a loss in fiber strength and gain in fiber elongation would occur with increases in lint percent. A significant increase in Micronaire was obtained between the S_0 and S_1 populations. Subsequent cycles of selection did not result in any further significant increases. The increase in Micronaire closely parallels the change in lint index, implying that increases in fiber thickness may have been responsible for the increase in lint index. Fiber lengths of the selected populations, S_1, S_2, and S_3, were significantly shorter than those of the base population. Selection in the S_3 cycle was effective in restoring most of the 2.5% span length lost in the earlier cycles. The changes in Micronaire and fiber length agree with the expectations from previous studies (1, 6, 8, 12).

Little information on the change in genetic variances in selected populations of cotton has been reported. The genetic variances for lint percent and boll size within the base population (S_0) and two of the selected populations are given in Table 4. Because each of these populations were grown under different environmental conditions, the variance estimates may contain genotype by environment interaction effects. However, the analyses of variance in Table 3 and previous studies (3, 10, 11) would suggest this is a minor effect. The genetic variance for lint percent for the S_1 population was greater than that of the S_0 or S_2, and there was little difference between the S_0 and S_2 populations. A similar trend was noticed for boll size,

Table 4. Mean squares and genotypic variances for lint percentage and boll size in three populations of Deltapine 523.

Source	Lint percentage			Boll size		
	S_0	S_1	S_2	S_0	S_1	S_2
Progeny	2.7653**	4.6191**	2.2282**	0.1423**	0.3480**	0.3283**
Error	0.5855	0.5233	0.4162	0.0485	0.1290	0.1538
σ^2_g	1.0899	2.0479	0.9060	0.0469	0.1095	0.0873
S.E.†	0.2019	0.9400	0.1662	0.0107	0.0257	0.0266

** Statistically significant at the 0.01 level of probability. † Standard error for genotypic variance estimates.

a trait not directly selected for. Even though strong selection pressure was applied for a very heritable trait, lint percent, the genetic variance in the S_2 population was about the same as that of the base population.

Genetic variability within these populations might originate from four sources: mechanical mixture of seeds, cross-pollination, mutation, and heterozygosity of the original F_4 plant selection to which Deltapine 523 traces. Mechanical mixtures of other strains should be readily distinguishable from Deltapine 523 in several traits other than lint percent. Most strains in breeding nurseries do not possess the fiber strength shown by the selected populations. For this reason. hybrids produced by outcrossing would also tend to have weaker fiber. Recent investgiations by Meredith and Bridge (7) also indicate that cotton is essentially a self-pollinated crop in the Central Delta of Mississippi. While self-pollination is not absolute, mechanical mixtures and cross-pollinations would appear insufficient to explain the variability observed. The mutation rate for quantitative characters in cotton has not been adequately investigated, but based on the rates observed for qualitative traits it is generally believed to be low. One cannot rule out the possibility that micromutations for lint percent have occurred during the several seed-increase generations of this cultivar. However, it is our opinion that much if not most of the present variability was present in the original plant selection. Investigations by Allard, Jain, and Workman (2) have indiacted that many natural populations of inbreeding species contain great stores of genetic variability. Their studies indicated higher frequencies of heterozygosity and heterogeneity than have previously been assumed for predominantly self-pollinated species.

In our study, the several generations of selfing during the seed increases should have resulted in the production of nearly homozygous lines within this cultivar. Selection practiced in the S_0 population was then effective in identifying 16 strains that were phenotypically similar for high lint percent but were obviously genetcially different. Crossing and selfing of those 16 strains resulted in about twice as much variability being expressed in the S_1 generation as in the S_0 base population. The results in Table 2 indicate that this variability was usable, as evidenced by the progress made in each in a practical breeding program selection cycle.

14350653, 1973, 6, Downloaded from https://acsess.onlinelibrary.wiley.com/doi/10.2135/cropsci1973.0011183X001300060033x by North Carolina State Universit, Wiley Online Library on [20/07/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

This study indicates that a modified form of recurrent selection for lint percent, which is also highly correlated with yield, can result in yield increases. It also suggest that deleterious changes in fiber properties need not necessarily accompany the increase in yield. Reselection within cotton cultivars is a common practice and is believed by many breeders to be effective. These results give credence to that position, especially where the trait has a high heritability, and its cost of determination is low. The results also suggest that reselection would probably be even more effective if some intercrossing and selfing preceded selection.

REFERENCES

1. Al-Jibouri, H. A., P. A. Miller, and H. F. Robinson. 1958. Genotypic and environmental variances and covariances in an upland cotton cross of interspecific origin. Agron. J. 50:633-636.
2. Allard, R. W., S. K. Jain, and P. L. Workman. 1968. The genetics of inbreeding populations. Advance. Genet. 14:55-131.
3. Bridge, R. R., W. R. Meredith, Jr., and J. F. Chism. 1969. Variety × environment interactions in cotton variety tests in the Delta of Mississippi. Crop Sci. 9:837-838.
4. ————, ————, and ————. 1971. Comparative performance of obsolete varieties and current varieties of upland cotton. Crop Sci. 11:29-32.
5. Manning, H. L. 1963. Realized yield improvement from twelve generations of progeny selection in a variety of upland cotton. p. 329-351. *In* W. D. Hanson and H. F. Robinson (ed.) Statistical genetics and plant breeding. Publ. 982, Nat. Acad. Sci., Nat. Res. Council, Washington, D.C.
6. Meredith, William R., Jr., and R. R. Bridge. 1971. Breakup of linkage blocks in cotton, *Gossypium hirsutum* L. Crop Sci. 11:695-698.
7. ————, and ————. 1973. Natural crossing in cotton (*Gossypium hirsutum* L.) in the Delta of Mississippi. Crop Sci. 13:551-552.
8. Miller, P. A., and J. O. Rawlings. 1967a. Breakup of initial linkage blocks through intermating in a cotton breeding population. Crop Sci. 7:199-204.
9. ————, and ————. 1967b. Selection for increased lint yield and correlated responses in upland cotton. Crop Sci. 7:637-640.
10. ————, H. F. Robinson, and O. A. Pope. 1962. Cotton variety testing: Additional information on variety × environment interactions. Crop Sci. 2:349-352.
11. ————, J. C. Williams, and H. F. Robinson. 1959. Variety × environment interactions in cotton variety tests and their implications on testing methods. Agron. J. 51:132-134.
12. ————, J. C. Williams, Jr., H. F. Robinson, and R. E. Comstock. 1958. Estimates of genotypic and environmental variances and covariances in upland cotton and their implications in selection. Agron. J. 50:126-131.

14350653, 1973, 6, Downloaded from https://acsess.onlinelibrary.wiley.com/doi/10.2135/cropsci1973.0011183X001300060033x by North Carolina State Universit, Wiley Online Library on [20/07/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License