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Breeding Methods for Improving Pima Cotton and Their Implications on Variety Maintenance[1]

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ABSTRACT

Three commercial varieties of cotton (*Gossypium barbadense* L.) — 'Pima S-1,' 'Pima S-2,' and 'Pima S-4' — and selections from each variety were included in this study. Crosses among varieties and strains followed by selection resulted in greater improvement than selection within a variety. The potential of a strain was established in a few generations after a cross, making further selection ineffective. Thus, maintaining the established variety in the simplest manner possible, such as storing breeders seed for periodic release, and a separate program of improvement by hybridization and selection are suggested.

Additional index words: ***G. barbadense,*** **Variety improvement, Variety maintenance.**

ONCE a variety has been released, the breeder is confronted with deciding where to search for further improvement. He may choose between selecting within the newly released variety or selecting from variants generated through hybridization. Both approaches are usually utilized with varied emphasis on each approach.

A series of Deltapine cotton (*Gossypium*) varieties was developed by selection initiated within the original release and continued within each subsequent variety (2). Turner (6) showed progressive improvement of 'Acala 4-42' by continued selection within the variety. Manning (5) and Walker (7) gave different interpretations to the improvement realized by selecting within an established variety in Uganda. Walker's estimate of improvement was lower than Manning's. These improvements, obtained by selecting within material which had been inbred for several generations, may relate to their amphidiploid origin (5). More recently, most commercial Upland cottons have been developed by selecting within hybridized material. (USDA cooperative variety release notices and personal communication with commercial cotton breeders.)

The early development of Pima cotton, *Gossypium barbadense* L., in the United States followed the line selection method (3). The 'Yuma' variety was selected from 'Mit Afifi,' an introduction from Egypt. 'Old Pima' in turn was selected from Yuma. Subsequent Pima varieties have resulted from selection within hybridized materials. The hybridization program involved a relatively narrow germ plasm base through the development of the varieties 'SxP,' 'Amsak,' and 'Pima 32.' With the development of 'Pima S-1,' the genetic base was broadened to include a complex ancestry involving 'Sea Island,' 'Tanguis,' 'Pima,' and 'Stoneville' (*G. hirsutum* L.). Since the release of 'Pima S-1' in 1951, three additional Pima varieties — 'Pima S-2,' 'Pima S-3,' and 'Pima S-4' — have been developed by selection within hybridized materials (3, 4).

Selection with various modifications has been utilized in cotton varietal maintenance (Lewis, C. F. 1963. Concepts of varietal maintenance in cotton. Proc. of Fifteenth Ann. Cotton Improvement Conf., Dallas, Texas). These modifications include roguing off-type plants, type selection, mass selection, evaluation of progeny-rows followed by yield testing, and line composites. The method used by a breeder depended upon his objective. The objectives varied from preventing deterioration of the variety to improving the variety.

In this paper we *(1)* compare Pima varietal improvement by selection within a given variety with hybridization followed by selection, and *(2)* discuss the implication these results have on varietal maintenance and improvement.

MATERIALS AND METHODS

This study included three commercial varieties — Pima S-1, Pima S-2, and Pima S-4 — and strains selected from each variety. The lint yield, fiber length (2.5% span), and yarn strength (22-

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count) for the three varieties were obtained from Pima Regional Tests grown at low (up to 457 m), intermediate (457 to 762 m), and high (above 762 m) elevations from 1964 through 1966. The strains from Pima S-1 were tested in 1956, those from Pima S-2 in 1963, and those from Pima S-4 in 1966 and 1969 at Phoenix. The data reported for the strains from a given variety were adjusted to the 3-year (1964-66) average performance of their respective parent varieties at Phoenix, except for the strains included in the 1969 test. Yield of a given strain was adjusted by dividing the yield of the strain by the yield of the variety from which it was selected and multiplying that by the 1964-66 average yield of that variety. Fiber length and yarn strength were adjusted similarly.

The breeding procedure varied for each variety, as did the method of selection within each variety. Pima S-1 was developed by selection from a complex series of crosses involving Sea Island, Pima, Tanguis, and Stoneville (1). Selection within Pima S-1 began in 1951. In 1952, 104 progeny rows were grown and the best 35 progenies were combined on the bases of appearance and fiber properties. This bulked seed nucleus was increased in 1953 and compared with commercial Pima S-1 in 1954. The performance of the 35-strain nucleus and commercial Pima S-1 was similar. Additional selections were taken from commercial Pima S-1 in 1954, and 155 progenies were grown in 1955. Twenty-three of these strains were compared with commercial Pima S-1 in 1956. Data from the Pima S-1 strains reported in this paper are from this test (Fig. 1 and 2).

Pima S-2 originated as an F_3 plant selection from the cross Pima S-1 and experimental strain 3-79. This selection had been maintained by bulking self-pollinated seed from 200 to 1,500 plants each year from 1953 to 1960. In 1960, the strain was released as a commercial variety. Also, in 1960, 200 plants were selected from Pima S-2. These selections were grown in progeny rows, and evaluated for boll and fiber properties in 1961. In 1962, 63 of these strains and Pima S-2 were included in a replicated yield test. Eleven of the most promising strains and Pima S-2 were further evaluated in a yield test in 1963. Data on the Pima S-2 strains reported in this paper are from this test (Fig. 1 and 2).

Pima S-4 originated as an F_4 plant selection from the cross of experimental strains P32 × S1 10-8 and 3-79 × S1 22-12-22. Its development followed the plant-to-row method through F_4. In 1963, 30 F_6 plants were selfed and harvested individually. The plants then were stubbed in the field, transplanted to the greenhouse, and mass-crossed. Seed from the mass-cross provided the nucleus from which breeders seed of Pima S-4 was grown. The selfed seed harvested from the individual plants in 1963 was grown in progeny rows in 1964. In 1966 the 30 strains and Pima S-4 were included in a yield test. Data on these strains are included in this paper (Fig. 1 and 2). One thousand selections were made in 1965 from the F_2 of the mass-cross nucleus and evaluated in progeny rows in 1966 and 1967. Several of these strains were selected for yield testing in 1968 and 1969. The data from 1969 are reported in this paper (Table 2).

RESULTS

The release of each succeeding variety — Pima S-1 in 1951, Pima S-2 in 1960, and Pima S-4 in 1966 — resulted in more productive cottons (Table 1). Pima S-2 gave a considerable increase in yield over Pima S-1 at all elevations; however, its fiber was slightly shorter and gave weaker yarn than Pima S-1. Under certain stressed growing conditions, the fiber length of Pima S-2 was too short to meet the official minimum length standards for extra-long staple cotton. Thus, at that time, longer fiber along with higher production became our major objectives in varietal improvement. The release of Pima S-4 provided a variety with longer fiber than either Pima S-1 or Pima S-2. Likewise, Pima S-4, as compared with Pima S-2, gave a considerable increase in yield at low elevation, a slight increase at intermediate elevation, but no increase at high elevation. Also, Pima S-4 had stronger yarn than Pima S-2.

After the development and release of each Pima variety, an effort was made to improve it by selection within the variety. Fig. 1 shows the yields and fiber lengths of three varieties at Phoenix over a 3-year period, and the yields and fiber lengths of the selections adjusted to the 3-year average of the variety

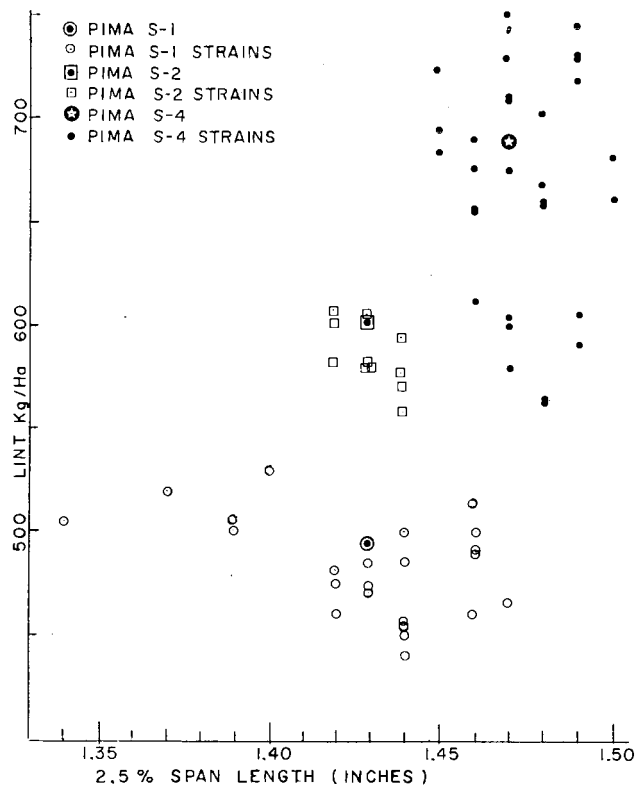

Fig. 1. Yield vs. fiber length for Pima S-1, Pima S-2, Pima S-4, and strains selected from each variety.

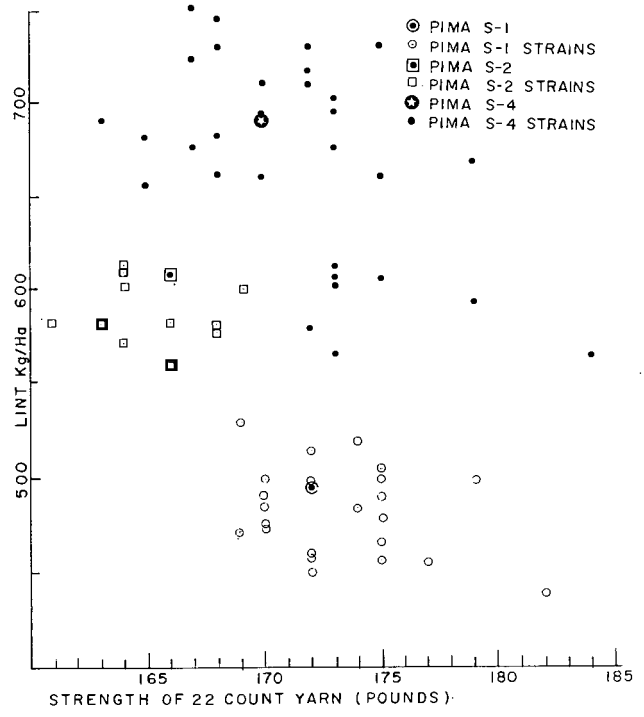

Fig. 2. Yield vs. yarn strength for Pima S-1, Pima S-2, Pima S-4, and strains selected from each variety.

Table 1. Lint yield, fiber length, and yarn strength, expressed in percent, of three Pima cotton varieties grown at low elevation (8 tests), intermediate elevation (3 tests), and high elevation (6 tests), 1964-66.

Variety	Lint yield			Fiber length			Yarn strength		
	Low	Inter-mediate	High	Low	Inter-mediate	High	Low	Inter-mediate	High
Pima S-1	100	100	100	100	100	100	100	100	100
Pima S-2	119	120	117	99	99	99	97	94	96
Pima S-4	133	124	117	102	101	103	98	96	96

from which they were selected. The fiber yield and length performance of the selections tended to cluster around the variety from which they were selected. For a given length, the yield of the most recently developed variety and its selections surpassed that of the earlier developed variety and its selections.

Fig. 2 includes similar data for yield and yarn strength. For a given yarn strength, the most recently developed variety and its selections yielded higher than the earlier developed variety and its selections.

Table 2 includes Pima S-4 and 21 strains derived from Pima S-4 material. P15-14 and P15-27 are the two most desirable Pima S-4 strains included in Fig. 1 and 2. The other strains are the most promising of those derived from the 1,000 selections from the F_2 of the Pima S-4 mass-cross nucleus. None of the strains was significantly superior to Pima S-4 in yield, fiber length, or yarn strength. Yields of P15-14 and P15-27 were high in this test; however, results from the Pima Regional Test at six locations in 1968 indicated them to be more specific in their adaptation than Pima S-4. In these tests, the strains yielded slightly more than Pima S-4 at low elevation, but yielded less at high elevation.

DISCUSSION

The data presented in this paper provide information for establishing guide lines in cotton improvement and maintenance programs. Minor improvements were realized by selection within a variety, but greater improvements were realized from hybridization and selection.

In Pima S-1, selections were made when plant variability was quite evident. In fact, the first selections were taken in an effort to purify the variety. A composite of 35 of the most promising progenies resulted in a more uniform appearing variety, but the fiber quality and yield of the composite were no better than the material from which it was selected. Selections taken in later generations performed similarly.

Although Pima S-2 originated as an F_3 plant selection, it was maintained by bulk-selfing through F_{11}, when 200 plants were selected. Presumably, these selections represented relatively homozygous biotypes, none of which had a more desirable combination of fiber yield and quality than Pima S-2.

Pima S-4 originated as an F_4 selection which was maintained by bulk-selfing through F_5 and F_6 before being reselected. Here again, no appreciable improvement was realized by further selection. The 30 F_6 selections were mass crossed in an effort to increase heterogeneity. Selections from the F_2 of this mass-cross population likewise resulted in no improvement over Pima S-4.

Table 2. Lint yield, fiber length, and yarn strength of Pima S-4 and 21 selections, Phoenix, Az., 1969.

Variety or strain	Lint per acre	Fiber length	Yarn strength
	kg/ha	2.5% span, inches	22-count, pounds
P15-14	719 a*	1.42 bc	183 a-f
P15-1165	712 a	1.45 abc	187 a-d
P15-27	682 ab	1.44 abc	184 a-e
P15-1513	628 abc	1.42 bc	176 ef
Pima S-4	623 abc	1.44 abc	179 def
P15-1222	586 bcd	1.45 abc	184 a-e
P15-1834	581 cd	1.44 abc	179 def
P15-1016	575 cd	1.44 abc	187 a-d
P15-1238	558 cd	1.45 abc	183 a-f
P15-1391	537 cde	1.45 abc	180 c-f
P15-1243	535 cde	1.41 c	180 c-f
P15-1985	535 cde	1.45 abc	191 ab
P15-1944	523 de	1.45 abc	185 a-e
P15-1785	511 def	1.43 abc	173 f
P15-1474	509 def	1.46 ab	190 abc
P15-1521	491 def	1.42 bc	180 c-f
P15-1711	482 def	1.45 abc	189 a-d
P15-1249	474 efg	1.44 abc	181 b-f
P15-1355	447 efg	1.47 a	182 a-f
P15-1509	436 efg	1.42 bc	189 a-d
P15-1907	412 fg	1.46 ab	181 b-f
P15-1304	374 g	1.46 ab	192 a

* In a given column, values followed by the same letter are not significantly different at the 5% level.

It appears that the potential of a strain is established in relatively few generations after a cross. This was evident with the two varieties developed from within *G. barbadense*. The final plant selection in developing Pima S-2 and Pima S-4 was taken in the F_3 and F_4 generations, respectively. Further selection within either variety proved to be futile. Pima S-1 was developed from an interspecific cross, and many generations were involved in its development. However, once it was stabilized sufficiently for release, further improvement by selection was negligible.

These results suggest that crossing among varieties and strains followed by selection is likely to be the most satisfactory breeding method for varietal improvement. The established variety should be maintained in the simplest manner possible since further selection resulted in no appreciable improvement. Storage of breeders seed for periodic release provides a simple, efficient means of controlling varietal deterioration which can result from mechanical mixing, natural crossing, mutation, or selection pressure. In addition to storing breeders seed of Pima S-4, we have maintained in the greenhouse the original 30 plants which formed the nucleus for the production of the original breeders seed.

LITERATURE CITED

1. Bryan, W. E. 1955. Prospects for Pima S-1 cotton. Progressive Agr. in Arizona 7:6.
2. Ewing, E. C., Jr. 1965. Deltapine 15, Deltapine Staple, Deltapine Smooth Leaf, Fox 4, and Deltapine 45 cottons. Crop Sci. 5:199.
3. Feaster, Carl V., and E. L. Turcotte. 1962. Genetic bases for varietal improvement of Pima cotton. Crops Res., ARS 34-31.
4. Feaster, Carl V., E. L. Turcotte, and E. F. Young, Jr. 1967. Pima cotton varieties for low and high elevations. Crops Res., ARS 34-90.
5. Manning, H. L. 1963. Realized yield improvement from twelve generations of progeny selection in a variety of Upland cotton. Res. Mem. 50. Empire Cotton Growing Corp.
6. Turner, John H. 1963. Breeding methods used in maintenance and improvement of the Acala 4-42 variety of cotton. Crops Res., ARS 34-51.
7. Walker, J. T. 1965. Modal selection in Upland cotton. Res. Mem. 55. Empire Cotton Growing Corp.