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Development of Short and Coarse-Fibered American Pima Cotton for Use as Parents of Interspecific Hybrids

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ABSTRACT

Short, coarse-fibered Pima (*Gossypium barbadense* L.) cotton strains may be desirable as parents of interspecific F_1 hybrid cottons. This study was conducted to determine if selective advance toward short, coarse-fiber types could be accomplished within a subset of Pima strains while maintaining adequate fiber strength, uniformity, and lint percentage. The fiber selection criteria of extra-long length and fineness used for American Pima cotton were reversed within the subset. Two diallel tests were conducted at Maricopa and Marana, AZ in 1985. Significant (0.01 level) genotype mean squares and general combining ability (GCA) estimates indicated useful variability for shorter, coarser fiber. Comparisons of GCA and specific combining ability (SCA) sums of squares (SS) with the total sums of squares indicated that greater additive genetic variability was available for fiber micronaire ($\bar{x}$ GCA SS/total SS = 0.70) than for fiber length ($\bar{x}$ GCA SS/total SS = 0.34). A single best parent could not be identified based upon GCA effects due to the necessity of simultaneous selection for several traits. Population variances and ranges, estimated from individual plant data from F_1 and F_2 generations grown in 1985 and 1986, were consistent with genetic segregation in the F_2 generation for fiber length and micronaire. Broadsense heritability estimates ranged from 0.20 to 0.52 for 2.5% span length and from 0.51 to 0.69 for micronaire in the F_2 populations. Transgressive segregation was observed in F_2 populations for shorter and coarser fiber. Selective advance toward Pima cotton with short, coarse fiber appears possible, but progress is expected to be slow.

THE GOAL OF FIBER SELECTION within *G. barbadense* L. germplasm grown commercially as American Pima or Pima cotton has been to increase or maintain an extra-long, strong, fine fiber for maximum spinning efficiency and enhanced end-use suitability. The fiber type present within the Pima germplasm represents the upper end of the fiber quality scale. Modern Pima germplasm, which had a broad genetic base when synthesized by W.E. Bryan (2,4), has been selected intensively for high quality fiber. During the more than 30 yr of selection, new sources of genetic variability have been introduced into the germplasm pool; but these sources possessed to a great degree the same fiber characteristics as the Pima germplasm. In addition, the natural tendency of cotton to self-pollinate has been intensified within the Pima breeding program by forced self-pollination of advanced strains used as parental materials. Therefore, when it became apparent that a short, coarse-fibered Pima phenotype might have some application, the question arose as to how much variability for those traits resides in the present Pima germplasm.

The desire to produce a short, coarse-fibered Pima cotton derives from the potential use of Pima cottons as parents in interspecific (*G. barbadense* × *G. hirsutum* L.) F_1 hybrids (ISH). Numerous advantages have been attributed to ISH, including increased seedling vigor, yield, and pest resistance (6,7,8,9). Among problems encountered in ISH, which offset their potential, is a genetic incompatibility between parent species (1,3). This incompatibility has been held responsible for the high levels of seed abortion observed in F_1 ISH (1). Seed abortion, in turn, results in reduced fiber quality and yield due to underdeveloped fiber, seed coat fragmentation, and lower seed numbers. Another difficulty associated with ISH cottons has been the complex and costly methods of producing F_1 seed. For reasons that include seed abortion in the F_1 ISH, greater seed production costs of ISH, and the wider marketability of upland cotton fiber; we have deemed it desirable to investigate the potential of interspecific hybrids having fiber properties characteristic of an upper-end *G. hirsutum* cotton such as an Acala cultivar. To produce ISH with this fiber type requires that the Pima parent possess shorter and more coarse fiber than found in standard Pima cultivars.

The objectives of this study were to determine (i) genetic variability for the short, coarse fiber traits present in a select set of the Pima germplasm, and (ii) whether these fiber characteristics could be selected while maintaining current levels of fiber strength, uniformity, and lint percentage.

MATERIALS AND METHODS

Two diallel sets (excluding reciprocals) of American Pima cotton were grown in the field in 1985. Strains selected as parents for the diallel sets displayed fiber and plant traits outside the normal range of commercial Pima cotton. One set, which included the experimental strains 7801-163-8-1 (7801), 7907-8-13-2 (7907A), 7907-38-5-4 (7907B), 7804-38-38-1-2 (7804), 7909-13-3-2 (7909), and 8004-95-5 (8004), and their 15 F_1 progeny, was grown in a randomized block design with four replicates at Maricopa, AZ. A second set, which included the experimental strains 7907A, 7907B, 7804, 7909, and 8004, and their 10 F_1 progeny, was grown in a randomized block with four replicates at Marana, AZ. The soil type at the Maricopa location is a Casa Grande silty clay loam (fine-loamy, mixed, hyperthermic Typic Haplargid); and that at Marana is a Prima clay loam (fine-silty, mixed, thermic Typic Torrifluvent).

At both locations, a plot consisted of a single row 9.1 m long with 30 plants spaced at 0.3 m intervals. Rows were spaced 1 m apart. Due to small seed quantities, all seed were germinated in peat pellets in the greenhouse and transplanted to the fields using a mechanical transplanter.

At maturity, 50-boll samples were hand picked at random from each plot for determination of ginning and fiber properties. Seedcotton from the 50-boll samples was cleaned, weighed, ginned, and the lint was weighed to determine lint percentage. A 13 g sample of lint from each 50-boll sample was blended in preparation for fiber property determinations. Measurements of 2.5% and 50% span fiber lengths were made on a fibrograph, fineness was measured by a mi-

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cronaire instrument, and fiber strength was determined with a stelometer. Uniformity of fiber length was calculated by using the formula: 50% span fiber length/2.5% span fiber length × 100. Data were analyzed by analysis of variance, and means were compared with an LSD test. Strain and replicate (block) effects were assumed to be fixed (model I). Combining ability analysis was done using method 2 of Griffing (5). Expected genetic response for selection among F_1 families was calculated using the formula $R_f = i_f h^2 f$ where i_f (selection intensity) = 0.20.

In 1985, five individual F_1 plants from the crosses 7907B × 7804, 7907B × 8004, and 7804 × 8004 were harvested from each replicate of the Maricopa diallel and their fiber traits measured as described above. In 1986, F_2 populations from the above crosses were grown as block plantings at Maricopa, AZ. The blocks were subdivided into single row plots 9.1 m long, spaced 1 m apart. Each plot contained approximately 30 plants spaced at 0.3 m intervals. Each plot contained the progeny of a single plant from the F_1 generation. Random F_2 individuals were harvested from the plots within each block and their fiber traits determined as previously described. Population means, ranges, and variances were determined from the individual plant data. In both 1985 and 1986 a set of 11 non-selected check strains were grown in adjacent plots, with the plant spacing and plot length previously described, harvested with the F_1 and F_2 individual plants, and fiber traits measured. The range, mean, and variance of the 11 check strains were compared for the 2 yr to determine if environment significantly influenced these parameters.

Degree of genetic determination, or broadsense heritability estimates were calculated from F_1 and F_2 data assuming the F_1 populations to be uniformly heterozygous-homogeneous and the 1985 and 1986 environments to be equivalent. Under these conditions the F_1 variances were assumed to represent environmental variance.

RESULTS AND DISCUSSION

Micronaire and fiber length—traits in which selective advance was desired, showed highly significant genotype effects (Table 1). Fiber length uniformity, fiber strength, and lint percentage—traits in which maintenance of the parental phenotype was desired, also displayed significant genotype effects. Within locations, fiber length, strength, and micronaire showed significant (0.01 level) general combining ability (GCA) mean squares. Fiber micronaire displayed significant specific combining ability (SCA) mean squares at both locations. The relative importance of GCA and SCA in determining progeny performance, as determined by a ratio of their sums of squares (SS) to the total SS, indicated large GCA contributions for micronaire ($\bar{x}$ GCA SS/total SS = 0.70) and lint percentage ($\bar{x}$ GCA SS/total SS = 0.61) at both locations. Smaller GCA contributions to progeny performance for 2.5% and 50% span fiber length, as indicated by GCA SS/total SS ratios and comparison of the above ratios with the SCA SS/total SS ratios, indicated less usable variability for those traits.

Simultaneous selection for a number of traits made it difficult to identify a best parent strain among the six tested for use as a donor source of genetic variability (Table 2). Estimates of GCA effects for 2.5% and 50% span fiber length indicated that strain 7804 was the best parent to use to shorten fiber length. On the other hand, strains 7907B and 8004 were the best parents for increasing micronaire. The negative GCA estimates for fiber strength of 7804 and 8004, and for lint percentage of the latter, indicated potential problems with maintaining these two traits. Despite undesirable GCA estimates associated with 7907B, 7804, and 8004, some parental combinations of these strains appeared to have the greatest potential for selecting the desired combination of shorter fiber length and increased fiber micronaire.

Comparisons of individual plant data from F_1 and F_2 populations involving the 7907B, 7804, and 8004 parents continued to produce evidence of useful variability for selective advance (Table 3). Although the F_1 and F_2 generations were grown in different seasons, ranges and variances of non-selected check strains over the 2 yr indicated that the two generations could be compared. Variances for fiber length and micronaire of F_2 populations exceeded those of F_1 populations. Broadsense heritability estimates, calculated for the individual F_2 populations, indicated a higher degree of heritability for 2.5% span fiber length within the

Table 1. Mean squares of fiber traits and lint percentage from diallel tests of cotton grown at Maricopa and Marana, AZ.

		Analysis of variance						
		Mean squares						
			Fiber length					
Source	df	Micronaire	2.5% span	50% span	Fiber length uniformity	Fiber strength	Lint percentage
				Maricopa			
Genotype	20	0.110**	0.0013**	0.0013**	4.02*	3.96**	8.54**
GCA†	5	0.383**	0.0038**	0.0025**	2.81	10.97**	31.62**
SCA	15	0.019**	0.0005*	0.0010	4.43*	1.62	0.84
Error	60	0.005	0.0002	0.0006	2.11	0.79	1.37
GCA SS/Total SS		0.755	0.438	0.196	0.066	0.419	0.621
SCA SS/Total SS		0.110	0.170	0.232	0.313	0.186	0.049
				Marana			
Genotype	14	0.118**	0.0014**	0.0014**	4.09**	4.62**	5.23**
GCA	4	0.316**	0.0026**	0.0024**	5.66**	13.34**	16.42**
SCA	10	0.042**	0.0010	0.0011**	3.85*	1.26*	0.83
Error	42	0.006	0.0005	0.0003	1.42	0.51	0.77
GCA SS/total SS		0.649	0.241	0.269	0.175	0.585	0.600
SCA SS/total SS		0.196	0.218	0.277	0.268	0.124	0.069

*,** Significant at the 0.05 and 0.01 levels, respectively. † GCA and SCA are general and specific combining ability, respectively.

7907B × 7804 F_2 population than within the other F_2 populations. The 7804 × 8004 F_2 population, with a broadsense heritability of 0.20, suggested considerably less opportunity for advance through selection. Broadsense heritability estimates for micronaire ranged between 0.51 and 0.69. The 7907B × 8004 F_2 population produced the highest micronaire heritability estimate. It appeared that confining further selection to within the 7907B × 7804 and 7907B × 8004 F_2 populations would yield the greatest probability of simultaneous advance for fiber length and micronaire.

The expected genetic advance due to family selection of the 7907B × 7804, 7907B × 8004, and 7804 × 8004 populations from among the 15 F_1 populations of the diallel was −0.36 mm for 2.5% span fiber length and 0.28 for micronaire. Observed advance, calculated as the shift in phenotypic means between the 15 F_1 families and the 3 selected F_2 populations was −2.59 mm for 2.5% span fiber length and 0.33 for micronaire. The discrepancy between predicted and observed fiber length response may have been due to environment, although statistical parameters of check strains between 1985 and 1986 argue against this explanation.

Results of this study suggest that selective advance toward the desired genotype can be made within the subset of Pima germplasm, but progress can be expected to be slow. Further progress toward a short fiber length may become minimal and introduction of new sources of variability from outside the Pima germplasm may become necessary. A positive association (r = 0.30) of fiber length with strength, observed within F_1 populations, may further complicate selection for short fiber. The reported fiber lengths for parent, F_1, and F_2 populations do represent an accomplished reduction in fiber length. The above mentioned populations were shorter than the 35.3 and 35.0 mm 2.5% span fiber lengths obtained for commercial Pima S-6 at Maricopa in 1985 and 1986. The GCA/SCA ratios obtained from diallel analysis and the broadsense heritability estimates obtained from individual plant data indicate few problems in manipulating fiber micronaire. One consideration in manipulating fiber micronaire is recent information from the textile industry indicating a future need for finer fiber. It should be possible to meet this new criterion, as transgressive segregation for both coarse and fine fiber was observed in this study.

The identification of a subset of Pima lines possessing variability for short, coarse-fibered cotton was somewhat unexpected; considering the self-pollinating nature of cotton, the intensive selection for longer,

Table 2. General combining ability (GCA) effects and means of parents for fiber traits and lint percentage measured in tests grown at Maricopa and Marana, AZ.

Parent strain	Micronaire		2.5% span Fiber length		50% span Fiber length		Uniformity		Fiber strength		Lint percentage	
	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean
		units		mm		mm		%		kN m kg^{-1}		%
						Maricopa						
7801	−0.09**	4.19	0.002	33.3	−0.004	16.2	−0.36	49.0	−0.53**	326	1.42**	39.3
7907A	−0.06**	4.29	0.010**	33.5	0.006	16.5	0.07	48.8	0.27*	331	0.90**	35.4
7909	−0.03**	4.21	0.006**	33.5	0.006	16.2	0.27	48.3	1.07**	348	−0.53**	34.5
7907B	0.15**	4.73	−0.004*	32.8	0.004	15.7	0.32	47.2	0.10	334	0.14	35.9
7804	−0.09**	4.17	−0.018**	31.7	−0.014**	14.7	−0.43	46.1	−0.55**	319	0.91**	37.7
8004	0.12**	4.59	0.002	33.0	0.002	15.7	0.12	47.8	−0.35**	328	−1.03**	34.0
LSD (0.05)		0.10		0.5		0.8		2.0		13		1.7
						Marana						
7907A	−0.01	4.46	0.000	32.5	−0.002	15.0	−0.21	46.4	0.33**	315	−0.65**	37.7
7909	−0.05**	4.22	0.011**	33.5	0.012**	16.2	0.49**	48.4	0.73**	318	−0.45**	37.6
7907B	0.12**	4.74	−0.000	32.2	0.005*	15.2	0.44*	47.4	0.16	312	−0.08	38.3
7804	−0.14**	4.21	−0.012**	31.5	−0.012**	15.0	−0.49**	47.3	−1.25**	290	1.26**	41.6
8004	0.08**	4.56	0.001	32.5	−0.002	14.7	−0.22	44.9	0.01	307	−0.09	69.3
LSD (0.05)		0.11		0.8		0.8		1.7		10		1.2

*,** Significant at the 0.05 and 0.01 levels, respectively.

Table 3. Fiber length and micronaire population variance estimates (σ^2), ranges, means ($\bar{X}$), and broadsense heritability estimates (H) calculated from individual plant measurements of the F_1 and F_2 populations of 7907B, 7804, and 8004 parents.

Population	N	2.5% span fiber length				Micronaire			
		σ^2	Range	$\bar{X}$	H	σ^2	Range	$\bar{X}$	H
			mm				mm		
F_1 (1985)									
7907B × 7804	19	0.44	31.5–33.8	32.5		0.018	4.05–4.60	4.28	
7907 × 8004	20	0.64	31.5–33.8	32.0		0.018	4.05–4.60	4.24	
7804 × 8004	20	0.67	31.0–33.5	32.4		0.029	4.03–4.50	4.24	
Checks	11	0.59	31.2–34.0	32.2		0.040	4.17–4.60	4.30	
F_2 (1986)									
7907B × 7804	50	0.92	27.9–34.0	30.7	0.52	0.037	3.82–4.57	4.26	0.51
7907B × 8004	77	1.07	26.9–33.5	30.9	0.40	0.058	3.97–5.12	4.61	0.69
7804 × 8004	53	0.84	28.4–32.8	30.8	0.20	0.072	3.60–4.90	4.27	0.60
Checks	11	0.57	30.2–32.8	31.4		0.044	4.20–4.70	4.35	

finer fiber practiced within Pima, and the restricted entry of new sources of variability into the Pima germplasm pool in recent years. However, these factors appear to have been mitigated by a broad initial germplasm pool (2,4) and by the maintenance of variability through frequent intercrossing of divergent strains within the germplasm.

Results from the present study show that development of short coarse-fibered Pima parents for use in ISH is possible. Following their development, the next logical step will be to determine whether these modified Pima strains favorably influence the targeted traits of ISH and thus increase their commercial potential.

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