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Natural Selection in a Bulked Hybrid Population of Upland Cotton[1]

J. E. Quisenberry, Bruce Roark, J. D. Bilbro, and L. L. Ray[2]

ABSTRACT

A bulked hybrid population of upland cotton (*Gossypium hirsutum* L.) was grown without artificial selection for 10 generations in a nonirrigated, semiarid nursery at Lubbock, Texas. In 1972 and 1976, seeds from all generations were grown in replicated tests to estimate the effects of natural selection on several traits in the population and to compare the responses of seed trait to the more vauable traits of lint yield and fiber quality. Traits measured were seeds/m, seeds/boll, seed size, lint yield, fiber length, strength, and micronaire. Data were evauated by anaysis of variance and regression techniques. Seeds/m, lint yield, and coarseness of the fiber increased while seed size and fiber strength decreased over the 10 generations. Significant differences were not detected for seeds/boll or fiber length. Bulk population breeding appeared to be a useful method for improving climatic adaptation of upland cotton in environments where moisture is limiting.

Additional index words: Gossypium hirsutum L., Bulk population breeding, Lint yield, Seed traits, Fiber properties.

THE bulk population breeding method presumes that natural selection will, over time, evolve superior genotypes of self-pollinated crop plants (2, 3, 8). The system is a relatively simple and inexpensive method to improve climatic adaption of self-pollinated crops. The procedure allows natural selection to increase the frequency of genotypes well adapted to prevailing conditions at the expense of more poorly adapted kinds. The rate of reduction depends on the degree of selection pressure applied, the consistency of that pressure, and the heritability of the trait, or traits, under selection. In an annual plant species, the most highly adapted genotype is defined as the one that produces the most propagules (or seeds) per unit of time. The primary assumption underlying the rationale for use of bulk population breeding is that the most competitive genotypes in the bulk will be the most productive in pure or semipure cultures. However, tests of that assumption have produced varied results (1, 4, 5, 9, 10).

Most workers who have studied bulk population breeding have used annual crop species that produce seed as their main agricultural product. Upland cotton (*Gossypium hirsutum* L.) is a perennial species, although it is grown commercially in the USA as an annual, and its primary saleable product is fiber, not seed. The role of fiber in promoting fitness in wild cotton can be debated. The large amount of lint, however, on the seed of present-day cultivars is a man-developed trait and would not be expected to be advantageous in a wild population. The purpose of this study was to detect and evaluate effects of natural selection on several agronomic traits in a bulked hybrid population of upland cotton, and to compare the responses of seed traits to the more economically valuable characteristics of lint yield and fiber quality.

MATERIALS AND METHODS

The bulked hybrid population was started in 1960 at the Texas A&M Univ. Agric. Research and Extension Center at Lubbock. The initial bulk consisted of approximately equal

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[2] Research geneticist, plant physiologist, and research agronomist, Cotton Production Laboratory, Oklahoma-Texas Area, Southern Region, SEA, USDA; and professor, Texas Agric. Exp. Stn., Texas A&M Univ. Research and Extension Center, Route 3, Lubbock, TX 79401.

Table 1. Analyses of variance and orthogonal polynominals for seven traits over years and generations.

		Mean squares						
Source	df	Seeds/m	Seeds/boll	Seed size	Lint yield	Fiber length	Fiber strength	Micronaire
Year test grown (Y)	1	699,624*	54.91	112.07	392,365**	0.0065	0.0096	3.083**
Reps/Y	4	82,884**	12.18**	34.93	21,467**	1.3323**	61.8413	0.117
Generations (G)	9	103,657*	2.77	96.36*	22,831*	0.4903	118.3030*	0.122*
Linear	1	716,415**	2.66	667.93**	142,037**	0.8774	829.0257**	0.877**
Quadratic	1	29,621	0.09	30.33	182	0.6323	43.8644	0.003
Cubic	1	5,426	7.11	0.59	8,235	0.1097	24.7231	0.033
Residual	6	30,242	2.51	28.07	9,171	0.4656	27.8523	0.031
G × Y	9	32,407*	3.46	26.99	8,802*	0.3491	26.5819	0.026
Linear × Y	1	26,268	1.53	27.18	1,629	0.1871	77.0611	0.045
Quadratic × Y	1	63,633*	22.17**	20.37	25,705*	0.0064	78.3939	0.027
Cubic × Y	1	39,786	0.86	64.40	2,165	0.0064	4.4885	0.029
Residual × Y	6	26,996	1.06	21.83	8,287	0.4903	13.2156	0.023
G × Reps/Y	36	14,348	2.20	21.99	3,761	0.2776	24.7416	0.042

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

amounts of F_2 seeds from all possible crosses among the following: five experimental strains (NR-AHA, H 257, CA 396, CB 3106A and GL 249-2) representing a diverse group of material that included an experimental Acala-type (NR-AHA), a nematode tolerant line (H 257), an early maturing stormproof strain (CA 396), a foreign introduction (CB 3106A), and an early generation glandless line (GL 249-2), and the cultivar 'Gregg 35' (6). Successive generations stemming from this population were grown for 10 seasons in a nonirrigated, semi-arid nursery without artificial selection. Rainfall averaged 47 cm and ranged from 33 to 60 cm during those 10 seasons. Plot size varied from 4 to 6 rows wide and from 122 to 213 m long with 1 m between rows. The entire plot was harvested each year, and a random sample of seed was saved from each generation and stored for subsequent testing.

During the 10 seasons, the material was not artificially self-pollinated nor were insecticides applied. Although no pollination records were kept for this material, checks in earlier years at other locations have shown the amount of natural outcrossing at Lubbock to be less than 5% (7).

In an attempt to equalize seed quality among generations, seeds from each generation (F_3 to F_{12}) were planted in 1971 in plots four rows wide and 100 m long and harvested (advanced one generation). In 1972, and again in 1976, fresh seeds from each generation (F_4 to F_{13}) were planted in randomized complete-blocks with three replications per generation. Plots were two rows, 10 m long, with 1 m between rows. After seedling emergence, each plot was thinned to approximately 64,000 plants/ha. During both years, soil moisture was sufficient for plant establishment, and no irrigation was applied during the growing season. Recommended cultural and tillage practices were followed during the two seasons.

The following traits were measured:

seeds/m — number of bolls per meter of running row × the number of seeds/boll;

seeds/boll — average number of seeds per boll from a 25-boll sample;

seed size — average weight (mg) of a seed from a 25-boll sample;

lint yield — plot weight of lint in kg/ha;

fiber length — length of the longest 2.5% of the lint fibers in mm;

fiber strength — the breaking strength of a fiber bundle in mN/tex;

micronaire — resistance of a given quantity of fiber to air flow in micronaire units, i.e., μg/in. A high micronaire value suggests coarse fibers. whereas, a low value suggests finer fibers.

Data from the traits were evaluated with analysis of variance procedures. A mixed model was assumed with year the test was grown and replications within years considered to be random and generations considered to be a fixed effect. Means were compared among generations. Orthogonal polynominals were calculated to determine the type of relationships that existed across generations and the interaction of these relationships between years. Regression coefficients were determined and used to quantify the across-generation relationships.

Table 2. Means and regression coefficients for both years for seeds/m and lint yield.

	Seeds/m		Lint yield	
Generation	1972	1976	1972	1976
	no.		kg/ha	
F_4	649	1,042	334	561
F_5	630	943	342	548
F_6	603	996	326	569
F_7	982	1,029	494	615
F_8	1,049	1,014	548	560
F_9	965	1,047	481	577
F_{10}	836	1,084	410	567
F_{11}	991	1,178	509	683
F_{12}	832	1,270	417	714
F_{13}	1,151	1,243	554	684
Regression coefficients				
Linear	123.27**	−46.54**	65.08*	−24.00**
Quadratic	−5.25	5.20*	−3.09	2.61

*,** Significantly different from zero at the 0.05 and 0.01 probability level, respectively.

RESULTS AND DISCUSSION

Mean squares from the analyses of variance are shown for each trait in Table 1. Seeds/m, lint yield, and micronaire were significantly different in the 2 years. Mean seeds/m was 869 in 1972 and 1085 in 1976. Mean lint yield was 441 kg/ha in 1972 and 603 kg/ha in 1976. Micronaire was 3.5 in 1972 and 4.0 in 1976. The other four traits did not differ significantly between 1972 and 1976. Significant differences were detected among generations for all traits measured except seeds/boll and fiber length. Test of orthogonal polynaminals across years showed that the response of generations was entriely linear for all traits except seeds/boll and fiber length. Generations interacted significantly with year the test was grown for seeds/m and lint yield. This interaction was partitioned into orthogonal polynominals by year components to determine if the same trends were evident in 1972 and 1976. The linear × year interaction was not significant for any trait. The interaction associated with seeds/m and lint yield was due to a quadratic × year interaction. The interactions were caused by differences in the relative magnitudes of the generation means rather than by changes in mean ranking among generations (Table 2). The quadratic × years interactions occurred because the 1972 curve was concave downward and the 1976 curve was concave up-

Table 3. Means for the seven traits by generation averaged over years.

Generation	Seeds/m	Seeds/boll	Seed size	Lint yield	Fiber length	Fiber strength	Micronaire
	no.	no.	mg	kg/ha	mm	mN/tex	μg/in
F_4	845 cd*	32.2 a	105 abc	447 c	26.2 a	173 ab	3.6 b
F_5	786 d	32.2 a	107 a	445 c	25.9 a	174 ab	3.7 ab
F_6	799 d	33.5 a	106 ab	447 c	25.9 a	171 abc	3.7 ab
F_7	1,006 bc	32.9 a	105 abc	554 abc	26.7 a	175 a	3.8 ab
F_8	1,031 b	33.9 a	102 abcd	554 abc	26.4 a	172 ab	3.7 ab
F_9	1,006 bc	31.8 a	101 bcd	529 abc	26.4 a	173 a	3.9 a
F_{10}	960 bc	32.7 a	99 d	488 bc	25.9 a	169 bc	3.8 ab
F_{11}	1,085 ab	33.0 a	101 bcd	574 ab	26.2 a	168 bc	3.7 ab
F_{12}	1,051 b	32.9 a	100 cd	565 ab	25.7 a	165 c	3.8 ab
F_{13}	1,197 a	33.6 a	93 e	619 a	25.9 a	168 bc	3.9 a

* Means within columns not followed by any letters in common are significantly different at the 0.05 probability level based on a Duncan's multiple range test.

ward. This same type of interaction occurred in the seeds/boll data; however, the generation and generation × year sources of variation were not significant.

Generation means for the seven traits averaged over years are shown in Table 3. As the generations progressed from the F_4 through the F_{13}, seeds/m and lint yield increased, seed size decreased, and fiber tended to be weaker and coarser. Seeds/boll and fiber length were essentially unchanged.

Linear regression coefficients are shown in Table 4. These coefficients suggested that seeds/m, seed size, lint yield, fiber strength, and fiber fineness changed significantly in response to natural selection pressure encountered over the 10 seasons the population was grown. Seeds/m increased by an average of 38 seed/generation. This increase represented an average selection response of 3.8%/generation. Seed size decreased 1.2 mg/generation, with an average selection response of 1.1%/generation. Lint yield increased 17 kg/ha/generation for an average selection response of 3.3%/generation. Fiber strength decreased and fiber fineness increased about 0.5%/generation. For these two traits, a consistent response was noted between the 1972 and 1976 data; however, the coefficients were not statistically significant in 1972 for either trait. Seeds/boll and fiber length displayed no significant differences among generations (Table 1); therefore, the lack of significant coefficients was not unexpected.

These results suggest that natural selection in a bulked hybrid population of upland cotton increased the frequency of genotypes producing more seeds during the growing season. The average selection response/generation was greater for seeds/m than for the other traits measured, especially the fiber quality traits. The increase in the number of seeds was accompanied by a reduction in seed size and an increase in lint year. Because seeds/boll did not change and the numbers of plants/m of row was kept constant, the number of bolls/plant must have also increased. Seeds/m and lint yield were highly correlated ($r = 0.97$); therefore, the ratio between seed number and fiber production must have remained relatively constant. The response of the fiber-quality traits varied, but apparently fiber tended to become slightly weaker and coarser over the 10 seasons.

Table 4. Linear regression coefficients for the seven traits across generations.

Traits	1972	1976	Average
Seeds/m, no.	44.55*	31.55**	31.12**
Seeds/boll, no.	0.12	0.02	0.07
Seed size, g	−1.42**	−0.90*	−1.22**
Lint yield, kg/ha	18.79*	16.44**	16.97**
Fiber length, mm	−0.03	−0.06	−0.03
Fiber strength, mN/tex	−0.54	−1.09*	−0.85**
Micronaire, μg/in	0.01	0.03**	0.02*

*,** Significantly different from zero at the 0.05 and 0.01 probability levels, respectively.

Results from this study suggest that bulk population breeding is a useful method to improve the adaptation of upland cotton under such climatic conditions.

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