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Performance of Cotton (*Gossypium hirsutum* L.) Lines Selected for High Productivity in Three Environments

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Summary. Three groups of cotton (*Gossypium hirsutum* L.) selections that had been screened in separate climatic zones within the San Joaquin Valley were tested for a 2-year period. Selection pressure had been applied solely upon productivity.

Seven production attributes and eight fiber properties were influenced by the selection pressure on this material. The increase in number of bolls per m^2 virtually account for the genetic gains in yield.

Environmental influences accounted for the larger part of the variability with both production and quality attributes. Years (seasons) and years × zone mean square values were highly significant for all production attributes except boll size. Fiber length was increased for one group of selections and decreased for the other two groups. Coarser fiber (micronaire increase) resulted from the selection effort with two groups.

Genetic × environmental interactions encountered with major fiber properties have significant implications. The cryptic variability revealed indicates breeding procedures could be modified to exploit more fully the genetic potential of breeding material. Identifying and utilizing the "optimum selection enviroment" for specific attributes is suggested.

Introduction

Progress has been made in developing more productive cultivars of cotton (*Gossypium hirsutum* L.) over the past 50 years. As genetic advances become less frequent, however, more precise objective methodology needs to be developed. The specific attributes that contribute to production, the environmental influences upon such attributes, and the extent to which genotype × environment interactions influence selection procedures need to be identified.

This paper is a report on the second phase of a breeding method study conducted in the San Joaquin Valley of California. A previous paper reported the results from selection pressure applied solely upon productivity (seed cotton yield) in three zones of the valley (Turner *et al.*, 1974).

Results from replicated yield tests in the three zones are examined with these questions in mind: Are selections superior to the parental check for productivity only in the zone of origin? Have yield and fiber quality been altered? If so, were the changes of different nature for the groups of selections derived from the separate zones?

Literature Review

Various breeding methods have been explored by geneticists; the results vary considerably. Harland (1934) made progress in yield of Sea Island cotton (*Gossypium barbadense* L.) by applying selection pressure solely on lint index. However, Simpson and Duncan (1953) found yield was reduced when a pure line selection method was used to select within four cultivars.

In recent years, Allard and Bradshaw (1964) proposed that breeders need to distinguish between predictable and unpredictable parts of the environment. Lewis and Kerr (1967) reported that cotton fiber quality parameters are influenced by environmental factors as well as by the varietal differences. Feaster *et al.* (1965, 1967) discovered that fruiting habit was correlated with yield when Pima cotton was grown where night temperatuures remained high.

Hughes (1966) unsuccessfully applied selection pressure to increase the number of seeds per boll in a cultivar of *G. barbadense*. Manning (1963) has been successful in making genetic advances for yield by using a selection index. Riggs (1967), however, found by further studies in Uganda that selective indices had definite limitations. Miller and Rawlings (1967) found that selecting for lint yield was effective but the selection decreased boll size, seed size, fiber length and strength. Boll per unit area was the major attribute contributing to yield increases in studies conducted by Turner (1953) in Georgia, and also by Culp and Harrell (1973) in South Carolina and Ramey and Worley (1973) in Mississippi.

Materials and Methods

Individual plant selections were made in 1965 from an F_7 generation strain of cotton that later became the Acala SJ-1 cultivar (Turner and Cooper 1968). In each of three climatic zones of the San Joaquin Valley eighty selections were made, progenies were screened in 1966 and the forty more productive lines tested in their zone of origin in 1968 (Turner et al. 1974).

The eight top yielding lines from each zone were used in this study to form three groups, designated as *N group* (selections from the northern zone), *W group* (from the western zone) and *S group* (from the southern zone). The parental cultivar, Acala SJ-1 served as a check to give nine entries in each group. In the experimental design the groups were the main plots and selected lines the subplots. Selections were randomized within groups, and the three groups randomized. Plots were two rows, 17 m long and 2 m wide, and were replicated 4 times in each of the zones in 1969 and 1971.

Previous to machine harvest, 10-boll samples were hand picked. Seed cotton yield was obtained from the machine harvest of each plot.

Laboratory determinations were made on the following:

Boll size (B.S.) = grams of seed cotton per boll, Seed Index (S.I.) = grams per 100 seeds, Lint Percent (L.P.) = the weight of lint ginned, expressed as a percentage of the weight of seed cotton. Calculations provided the following:

Bolls/m^2 (B.M.) = seed cotton yield (kg/ha) ÷ (boll size (g) × 10)

Seeds/boll (S/B) = B.S. (g) × (100 – L.P.) ÷ S.I. (g)

Lint/seed (L/S) = seed cotton (g) × lint percent ÷ S/B.

In the fiber laboratory the following attributes were determined:

2.5% span length (2.5 SL) = the length, in inches, (measured on the Digital Fibrograph) on a specimen spanned by a 2.5-percent of the fibers scanned at the initial starting point.

50% span length (50 SL) = the length in inches spanned by 50-percent of the fibers scanned.

Uniformity Index (U.I.) = the ratio of 50 SL to 2.5 SL, expressed as a percentage.

Mean Length (M.L.) = the average length, in inches, of all fibers longer than one-fourth inch.

Uniformity Ratio (U.R.) = the ratio of M.L. to upper half mean (length of half of the fibers, by weight that contain the longer fibers).

Fiber strength (T_1) = the strength of a bundle of fibers measured on the Stelometer with the two jaws holding the bundle separated by a 3 mm spacer, expressed in grams-force per tex.

Elongation (E_1) = the percentage elongation at break of the fiber bundle measured on the Stelometer.

Micronaire (M) = the fineness of the fiber sample, measured by the Micronaire and expressed in standard (curvilinear scale) micronaire units. The higher the reading, the coarser the fiber.

Computations were made at the University of Tennessee Computer Center.

Results

Productivity

Seed cotton yield is the best measure of productivity in cotton, because both the seed and fiber are marketable products. The mean square values obtained from the analysis of variance (Table 1) indicate that seed cotton yields were influenced by both genetic and environmental factors. By far, the magnitude of years and years × zone means squares exceed that of other sources of variance.

The selections within group (Swg) source of variance detects the variability due to selected lines. Highly significant yield differences exist within each group. The mean square values for groups, groups × zones, and zones × selections within groups were non-significant, indicating the yield performance of these lines was similar in the three test zones. The mean seed cotton yields (Table 2) show that yield gains were made by selections in all three groups.

The zones accounted for a minor part of the environmental variance with seed cotton yields, but years and years × zones greatly influenced productivity. Yield differences from unexpected sources were extreme. The western and southern zones are the more productive sections of the valley, but insect damage in 1971 caused western zone yields to be only half those of 1969. Similar damage occurred in the southern zone in 1969. In contrast, the northern zone test received excellent management and yields were high. A late planting season and early frost in the western and southern zones in 1971 may also explain the relatively good yield performance of the earlier maturing N group in these zones.

Yield Attributes

Six attributes that relate to yield were studied. All attributes were influenced by the selection pressure for productivity, as shown by the highly significant selections within group source of variance (Table 1).

Table 1. *Mean square values for production attributes*

Sources of Variance	D. F.	Yield Seed Cotton × 10^{-4}	Bolls per m^2	Boll Size	Seeds per boll	Seed Index	Lint per seed	Lint Percent
Years	1	7.142.3**	14.963.1**	.01	176.5**	1.2*	1.2	168.9**
Zones	2	34.9	58.4	1.35	669.8**	576.7**	95.6**	246.5**
Y × Z	2	15.029.9**	26.386.7	5.32	109.6**	.2	28.6**	20.3**
Groups	2	7.1	308.8*	5.22	39.9	7.2	.9	4.8
Y × G	2	25.6	106.3	.43	4.3	.02	.5	1.3
Z × G	4	4.2	20.7	1.39	39.1	8.2**	4.7	.8
Y × Z × G	4	26.2	103.8	1.18	16.0	.6	2.5	3.8
Selections within groups	24	98.4**	425.9**	3.20*	48.4**	11.8**	5.0**	11.3**
Y × Swg	24	34.9	74.4	.92	20.6	.4	3.2	3.7
Z × Swg	48	16.5	67.0	.87	25.1	5.7	1.5	2.6
Y × Z × Swg[1]	48	20.3**	93.0**	1.82**	16.9**	.44	2.1**	2.4**
Pooled Error	486	4.9	4.6	.06	.9	.17	.14	.25

[1] Used as Error term

Table 2. *Yield of seed cotton for selections within groups*

N group		W group		S group	
Selection No.	Kg/ha	Selection No.	Kg/ha	Selection No.	Kg/ha
60	3583	74	3353	80	3403
50	3316	70	3317	18	3350
12	3267	48	3264	23	3320
71	3236	20	3215	45	3276
53	3160	54	3196	43	3275
23	3150	61	3109	41	3136
19	3136	3	3086	26	3039
51	3130	7	3083	36	3022
Check	2714	Check	2756	Check	2789

L.S.D. at 1% level = 402

Table 3. *Mean square values for fiber properties*

Source of Variance	D. F.	Span Length $2.5 \times 10^{+3}$	Span Length 50	Strength $T_1 \times 10^{+3}$	Elongagation E_1	Micronaire	Mean Length $\times 10^{-3}$	Uniformity ratio	Uniformity index
Years	1	−.7	203.3**	3.5	15.2**	7.34**	.81**	553.6**	138.2**
Zones	2	372.3**	2.548.6**	1.295.4**	10.2**	1.64**	10.19**	1,601.4**	398.9**
Y × Z	2	1.5	33.9	23.6	.8**	1.78**	.14	50.6	12.7
Groups	2	33.3**	182.3**	7.7	.4*	.85**	.73**	76.8	19.0
Y × G	2	.6	14.1	1.9	.3	.02	.57	29.5	7.5
Z × G	4	2.5**	10.1	115.1**	1.2**	.01	.41	27.2	6.8
Z × G × Y	4	.2	7.9	7.1	.1	.01	.31*	18.2	4.5**
Selections within groups	24	13.3*	70.6**	130.8**	1.0**	1.00**	.28**	31.9**	7.9**
Y × Swg	24	.3	3.2	11.5	.2*	.36**	.01	5.0	1.3
Z × Swg	48	6.9**	33.1**	53.5**	.5**	.09	.13**	13.4**	3.3
Y × Z × Swg[1]	48	.64**	2.5	10.2**	.1**	.09**	.012**	3.1**	.79*
Pooled Error	486	.12	.6	.004	.01	.006	.002	.59	.14

[1] Used as Error Term

Boll production (B/m²) increases were larger than those of other attributes, indicating that a major part of productivity gains came as a result of selecting plants and progenies that produced more bolls per unit area. Boll size (B.S.) played a secondary role in yield. Boll size is a product of seed number (S/B), seed size (index — S/I), and lint per seed (L/S). Seeds per boll were increased for selections within a group over the parental check, but seed size was decreased in the N and S groups. Lint per seed was decreased in all three groups of selections. Therefore, it was the number of seed per boll that accounts for boll size gain in the S group, but both seed number and seed size contributing to the boll size gain in the W group. Seed size was the only production attribute that responded in a differential manner for the selection groups at the zone sites.

Fiber Properties

Eight fiber parameters were included in the analysis of variance (Table 3). The magnitude of the zone source of variance was greater than that of other sources for all fiber properties except the micronaire measure of fineness. Years and years × zone influences were far less than they were with production attributes.

Genetic differences resulted from the selection pressure upon this material as shown by the significant mean square values for groups and for selections within groups (Swg). The differential responses of groups over the three zones were, however, the most revealing information. The selections made in the North (N Group) produced shorter and weaker fiber than selections made in the West or South when grown in the Northern zone, but the fiber of the N Group was the strongest of the three groups when grown in the Southern zone. The W group had the longest fiber, but was virtually the same length as that of the S Group when grown in the Southern zone. Fiber elongation is closely related to fiber strength and can be expected to increase as strength decreases, and vice-versa. These results emphasize the need for breeders to give special consideration to where early-stage breeding material should be grown if specific traits are important. For example, if fiber length is more important in certain breeding material, selecting in the western zone (W group) might lead to more progress.

The zone × selection within groups (Swg) interactions was a significant source of variance for all measures of fiber length, strength, and elongation. The extent of zone influence upon selections within groups was greater than expected. Part of this differential response of individual selections across zones may be related to sampling. It is difficult to obtain samples that are representative of the entire crop produced. All plots in a single test were harvested the same date, but genetic differences for crop maturity were evident. Fiber development occurred in a period of optimum temperatures in the southern zone but only the extremely early selections had such opportunity in the northern zone. Fiber properties were more influenced by first-order interactions than were production attributes.

Discussion

This study investigated the consequences from selection pressure applied solely on productivity of cotton. Admittedly, this method would not be used in applied cotton breeding because fiber quality, disease resistance, and other attributes are also important. The knowledge gained, however, could aid in establishing improved methods.

The gain in seeds per boll over the parental material is of special interest because seed production is the vital biological unit producing fiber. Seed size (or weight) is usually evaluated but seldom do investigators consider the number of seeds produced per boll. Further study of seed and its relationship to boll retention and to fiber development is needed. Other breeding material might not be as responsive to selection for seed number.

The magnitude of environmental sources of variance for production attributes suggests that much could be done to identify optimum production practices for adapted cultivars.

Fiber properties were influenced by the selection pressure in directions that have important implications. For three major fiber properties, there was a differential response of the groups and even the selections within groups across the zones. These results should intrigue breeders to investigate new procedures of selecting and testing. Cryptic variability was expressed in the northern zone. Equally important was the finding that some fiber properties show greater improvement for selections made in one zone when tested in other zones.

Various methods of breeding are employed by cotton investigators. Modification of any breeding method is likely to present a new set of problems. In a program that uses sib-lines to constitute a cultivar the cotton breeder must choose only the sibs that possess similar fiber properties. Neither can he include sibs that vary in quality significantly when grown across climatic zones of his trade district. A reduction in fiber quality while selecting for yield has been the common experience of cotton breeders. Results from this study indicate the possibility of genetic advances for productivity with improved fiber properties.

The results suggest that fiber length and strength might be manipulated in the desirable direction by screening progenies in an environment that differs from the conditions where the breeding material originates. The importance of these quality attributes warrants the exploration of new methods. More extensive studies are needed to verify the concept, but it appears that more frequent genetic gains in cotton quality may be accomplished by identifying and utilizing "optimum selection sites" for specific fiber properties. Furthermore, ecologically different sites may be utilized to exploit the cryptic variability in breeding material.

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