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THIRTY-SIX YEARS OF REGIONAL HIGH QUALITY VARIETY TESTS

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Abstract

The Regional High Quality Variety Tests (RHQ) were initiated in 1964 with objectives of broadening the cotton genetic base, promoting open exchange of germplasm and producing varieties with better fiber quality. The specific objective in this report is to evaluate breeding progress for producing cottons with better combinations of yield and fiber quality. The RHQ was conducted on an average of 9.2 states/year for the years 1964 to 1999. The nine states covered the Mid South from the Carolinas to East Texas. The variation for yield, yield components, and fiber traits was partitioned into variations due to states (E), genetic entries (G), and their GXE interaction. About 80% of the total variance for yield, and colorimeter Rd and +b was associated with E. For the yield components, lint percentage, and boll and seed weight, 53% was associated with E, 29% with G, and 18% with GXE. The estimates of fiber length, upper half mean, 2.5% and 50% span length and uniformity averaged 52% for E, 22% for G, and 25% for GXE. Strength estimates were the most heritable with 44% of its total variance being associated with G. Micronaire and its component, maturity, averaged 63% for E and 16% for G.

The test average yield increased at a rate of 2.9 lb/acre/year (Prob. = 0.13) for the 36-year period. Lint percentage increased and boll and seed weight decreased (Prob. < 0.001). The results for fiber length varied with slight increases in 50% span length and uniformity, and decreases in upper half mean and 2.5% span length. In general, little progress for fiber length was observed. Breeders did make progress in improving stelometer and HVI strength (Prob. = 0.001). Expressed as a percent of the mean, the increase was 0.6 and 0.3% per year. In these tests, no trend for micronaire was detected.

Six traits showed significant (Prob. <0.05) changes in their association with yield, lint percentage became more positively correlated with yield and boll weight and seed weight became more negatively associated with yield. Increasing fiber length and HVI strength became more negatively associated with yield. The trait whose association with yield changed the most was micronaire. For the first 18 years, there was no association of yield on micronaire, b = 0.0. For the last 18 years, the average regression of yield on micronaire was 147 lb/acre. If a high yielding cotton with micronaire of 5.2 was reduced to 4.2, one expects yield to be decreased 147 lb/acre.

Analysis of these 36-years of breeding for fiber quality show that small increases in yield and fiber strength have occurred. It also shows that increasing yield still has a higher priority in breeding than increasing fiber quality and that increases in yield have been mainly due to increases in lint percentage and micronaire.

Introduction

The Regional High Quality Variety Tests (RHQ) was begun in 1964 with seven (7) states participating with 16 entries. Currently, the nine states participating are North Carolina, South Carolina, Georgia, Alabama, Mississippi, Arkansas, Missouri, Louisiana, and Texas, with 24 entries. The purpose of the RHQ were to broaden the genetic base of cotton and develop better combinations of yield and fiber quality. Most of the varieties currently grown in the MidSouth can be traced back to entries that were first evaluated in the RHQ studies. Previously, information from this data set have been used on related subjects, (Meredith, 2001 and 2002).

Yield and yield components were determined by the cooperators from yield tests consisting of four to six replications. Yield components were determined from two of the replications and fiber samples were determined from lint obtained from these two replications by ARS and a commercial company, StarLab Laboratories, Knoxville, TN.

The objective of this study was to: (1) estimate the components of variance for states (E), variety-entries (G), and their GXE interaction and determine if there has been detectable changes in variance components of yield, yield components, and fiber properties; (2) estimate breeding progress for the 36 years as indicated by the regression of trait average from each years' test on year of test; and (3) determine if the association of yield and major fiber traits had been modified by 36 years of breeding. This last sub-objective is the most essential factor in developing improved combinations of yield and fiber quality.

Partitioning Trait Variability

Determining the proportion and size of total variability is information used by breeders to plan breeding experiments and to allocate resources. The variance components for states (E), and varieties-strains (G), and their interaction (GXE) are estimated for each year and then pooled over the 36 years. No trend in changing variance components over the 36 years was detected. The same is not true of co-variances as will be discussed. The E component was not partitioned into locations, years, and their interactions as the entries changed each year with little overlap between years. All of the environmental factors (E) are not due to uncontrollable factors. Over a wide range of state environments, such factors as soil type and management factors are fixable. Within a given state, much of GXE is manageable. The percentage of total variability due to E, G, and GXE is given in Table 1.

Eighty percent of the total variance for yield is due to E and only 7% for G, and 13% for GXE. A commonly used breeding technique to reduce E is to sub-divide a large area into smaller areas. The philosophy is that for each sub-area there is an optimum variety, but this variety is not optimum for all environments. Genetic factors that influence GXE are plant maturity and pest resistance. Colorimeter data, Rd and +b are also greatly influenced by E as 81 and 74% of their total variance is associated with E. It is well known in the MidSouth, that weather, principally rainfall, greatly affects fiber color and grade determination.

The three yield components are highly heritable with 26, 27, and 35% of the total variance components for lint percentage, boll weight, and seed weight, respectively being due to G. Lint percentage is determined routinely as it is necessary to compute lint yield. High priorities have been placed on increasing lint percentage for decades, but it has recently received renewed attention as a method to increase lint yields. High genetic contributions for upper half mean and 2.5% span length are evident in Table 1, but their components, 50% span length have a large GXE; 30 and 32% respectively. With increased emphasis from the textile industry, both domestic and foreign, on decreasing short fiber content and increasing uniformity, the cause of this large GXE needs future investigation.

The most heritable traits are those associated with fiber strength. The combined G and GXE components accounted for 68.8, 65.7, and 60.6% of the total variance components for stelometer bundle strength (T_1), HVI strength, and miniature yarn spinning strength, respectively. In contrast, micronaire has a high E (61%) influence. The limited data on fiber maturity and perimeter suggests that maturity is the component of micronaire that is most influenced by E. Its' E influence is 66% of the total variability.

Breeding Progress Yield, Yield Components and Fiber Properties

The linear regression coefficient (b) of trait mean year on year of test is given in Table 2 for 14 traits. Yield tended to increase at a rate of 2.9 lb/acre/year (Prob. = 0.13). The most significant changes were in the yield components, lint percentage, boll and seed weight. Lint percentage increased apparently at the expense of seed weight which also resulted in smaller bolls. The longer fibers, as measured by upper half mean and 2.5% span length tended to become slightly shorter, while slight improvements in 50% span length and uniformity index were detected. Fiber strength as measured by both the stelometer and HVI, indicate breeders have improved strength over the span of the studies. Miniature ring yarn strength tenacity improved slightly over time, but its magnitude was not significant. Colorimeter Rd and +b varied greatly among years and showed no clear trend of change.

Changes in Genetic Association of Yield with Yield Components and Fiber Quality

The major factor limiting breeding progress for better combinations of yield and fiber quality is the negative genetic association of yield and fiber quality. Regression of average RHQ test yields across environments with yield components and fiber properties (b_y) was computed for each test year. Assuming b_y for all years are from the same population and correcting for each year's intercept difference, the average common regression coefficient of yield on 11 traits is given in Table 3. Within the assumptions noted, all traits show a highly significant (probability <0.0001) relationship with yield. For example, the regression of yield and lint percentage is b = 23.75 lb/acre (table 3). For one unit increase in lint percentage, yield is expected to increase by about 23.75 lb/acre. Recently, breeders have rediscovered this relationship by producing proposed varieties with 4 units increase in lint percentage. As expected, these varieties have increased yields, but in general, the increases have been at the expense of seed weight and the possible problems that go along with smaller seed. Micronaire increases of one unit (4.0 vs 5.0) are expected to result in yield increases of about 90 lb lint/acre. Fifty percent span length is positively associated with yield. An increase of 50% span length from 0.55 to 0.60 would be expected to be accompanied by an increase in lint yield of 70 lb/acre. In contrast, all other length and strength determinations are negatively correlated with yield with R^2's exceeding 70% for all traits. An increase in upper half mean by 1/32 of an inch, or .03125 inches would be expected to result in a yield decrease of 8 lb of lint/acre. An increase in HVI strength from 28 to 30 grams/tex would be expected to be accompanied by a lint decrease of 29 lb/acre.

The assumption of common b_ys across years can be tested by several means. A practical question is "has there been any linear change in b_y's over the 36-year period". For each trait in Table 3, the regression of (b_y) on year of test is given in Table 4. Significant trends, probability of <0.05, were detected for six of the 11 traits. The positive change over time for yield with lint percentage and micronaire implies that breeders through selection have simultaneously concentrated the genes that confer greater yield, lint %, and micronaire. The cost of determination of lint % and micronaire is very small, making selection for these two traits very attractive. Micronaire, which measures mostly fiber maturity, is a component of lint percentage. Also associated with higher lint percentage is smaller seed. These results agree with the National trend which shows a steady increase in micronaire in the last 10 years (Figure 1). Also review of current public variety tests results show new varieties and proposed varieties tend to have higher lint percents, and micronaire, and smaller seed than current popular varieties. One method of demonstrating the change in micronaire is to compare the common association of yield and micronaire into six, six-year periods. This is shown in Figure 2. For the first 18 years, the average relationship between yield and micronaire is zero; the relationship for the last 18 years was 147 lb lint/acre. Thus decreasing micronaire from 5.0 to 4.0 would result in a yield decrease of 147 lb/acre. The results in Table 4 show that the b_y s for fiber length and HVI strength have become more negative during the past 36 years, making improvement in yield and these traits even more difficult.

These results indicate that the emphasis on increasing yield has greater priority with breeders than increasing fiber quality.

Summary

Cotton breeders have large genetic variances to select for improved yield and fiber quality. In the past 36 years, there has been a small increase in yield (2.9 lb lint/acre/year), no net change in fiber length, small increase in HVI fiber strength in the last 20 years, and increases in micronaire. Breeding for improved combinations of yield and fiber quality has not resulted in reducing the negative genetic association of yield and fiber quality. The results of 36 years of testing implies that breeders continue to place the greater priority on yield than on fiber quality improvement.

While fiber properties are easier to genetically improve than yield, breeders place greater priority on yield because there is little economic incentive for improving fiber quality. The increase in yield's value is greater than that lost due to fiber quality discounts. It is theoretically possible to increase both yield and fiber quality, but the expected progress for both is expected to be slow. Progress can be made in improving fiber quality if there are economic incentives put into place that encourage better fiber quality.

References

Meredith, W. R., Jr. 2002. Factors that contribute to lack of genetic progress. In D. Richter (ed.) Proc. Beltwide Cotton Conf. Jan. 8-12, Atlanta, GA.

Meredith, W. R., Jr. 2001. Changes in yield and quality due to genetic and climatic factors. Appendix 1. 14th Annual Engineered Fiber Selection Systems Conf. June 11-13, Greenville, SC.

USDA-Agr. Marketing Service. 2002. Ten year micronaire trend in USA cotton. Memphis, TN.

Table 1. Average proportion (%) of total variance components that are associated with states (E), variety-strains (G), and their interaction (GXE) for yield, yield components, and fiber traits.

Characteristic or Trait	Percent				
	No. of Years (y)	State (E)	Genetics (G)	Interaction (GXE)	Combined G & GXE
Yield	36	79.6	6.9	13.4	20.3
Yield Components					
Lint %	36	57.2	26.0	16.8	42.8
Boll weight	36	54.6	26.6	18.8	45.4
Seed weight	36	46.8	35.5	17.8	53.3
Fiber Properties					
Upper Half Mean	31	50.1	30.6	19.2	49.8
2.5% Span Length	36	50.8	29.3	19.9	49.2
50% Span Length	36	52.8	16.8	30.3	47.1
Uniformity	23	55.5	12.2	32.3	44.5
Strength (T_1)	31	31.3	46.9	21.9	68.8
Strength, HVI	20	34.3	43.5	22.2	65.7
Yarn Tenacity	36	38.3	42.7	19.0	60.6
Micronaire	36	61.0	21.2	17.9	39.1
Maturity	13	65.6	11.5	22.9	34.4
Perimeter	13	39.7	25.7	34.6	60.3
Colorimeter, Rd	35	81.2	5.5	13.2	18.7
Colorimeter, +b	35	73.7	9.5	16.9	26.4

Total equals 100% ± 0.1 depending on rounding off.
All estimates are statistically significant at the <0.01 probability levels.

Table 2. Average yield, yield components, and fiber traits for the National High Quality Cotton tests' years 1964 to 1999 and linear regression coefficient (b) of trait mean per year on years.

Characteristic (Y)	Trait mean per year on				
	Mean	b	b % of mean	R^2	Prob.
Yield, lb/acre	917	2.933	0.31	6.5	0.135
Lint %	38.5	0.069	0.18	45.7	<.001
Boll weight, g/boll	5.66	-1.040	-0.71	76.6	<.001
Seed weight, mg/seed	11.1	-0.067	-0.60	82.0	<.001
Upper Half Mean	1.16	-0.001	-0.09	26.2	0.003
2.5% Span Length, in.	1.15	-0.000	-0.00	0.2	0.795
50% Span length, in.	0.55	0.001	0.18	42.9	<.001
Uniformity	83.8	0.052	0.06	22.3	0.023
Stelometer strength (T_1)	207	0.653	0.32	60.4	<.001
HVI Strength	28.2	0.325	1.15	48.3	<.001
Yarn tenacity	135	0.148	0.00	2.8	0.332
Micronaire	4.53	0.002	1.14	0.9	0.572
Colorimeter, Rd	8.31	-0.081	-0.98	1.7	0.119
Colorimeter, +b	72.1	-0.013	-0.02	6.4	0.142

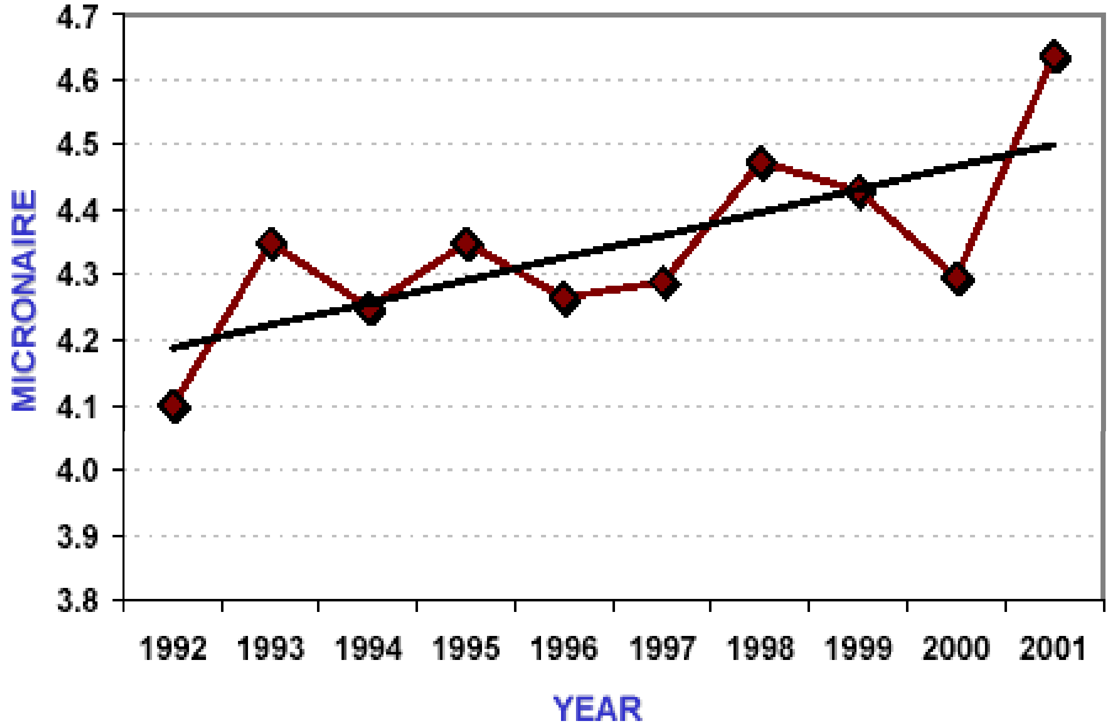
Table 3. Common regression coefficient[f] of yield, lint acre^{-1}, on traits for the 20 to 36 period's research.

Traits (X)	Common slope (by) B	R^2	Prob.
Yield Components			
Lint %	23.75	78.4	<0.0001
Boll weight	-8.25	74.4	<0.0001
Seed weight	-35.59	77.5	<0.0001
Fiber Properties			
Upper Half Mean	-254	69.7	<0.0001
2.5% Span Length	-272	74.6	<0.0001
50% Span Length	1395	75.7	<0.0001
Uniformity	-12.87	68.9	<0.0001
Strength (T_1)	-2.77	75.2	<0.0001
Strength, HVI	-14.6	70.9	<0.0001
Yarn Tenacity	-3.68	78.0	<0.0001
Micronaire	89.9	76.1	<0.0001

[-1] Regression coefficient computed assuming all years regression are from the same population and correcting for each year's intercept differences.

Table 4. Slope of changes in yield's association with yield components and fiber traits.

Traits	Regression of b_y change over time	R^2	Prob.
Yield Components			
Lint %	0.613	20.7	0.01
Boll weight	-1.671	11.1	0.047
Seed weight	-0.625	5.4	0.175
Fiber Properties			
Upper Half Mean	-31.80	26.5	0.003
2.5% Span Length	-30.51	16.4	0.014
50% Span Length	-13.42	0.7	0.641
Uniformity	0.811	10.3	0.136
Strength (T_1)	0.030	7.8	0.128
Strength, HVI	-0.850	22.6	0.035
Yarn Tenacity	0.055	8.6	0.082
Micronaire	6.274	32.6	0.001



Source: USDA-AMS Cotton (2002).

Figure 1. Ten year micronaire trend for US upland cotton.

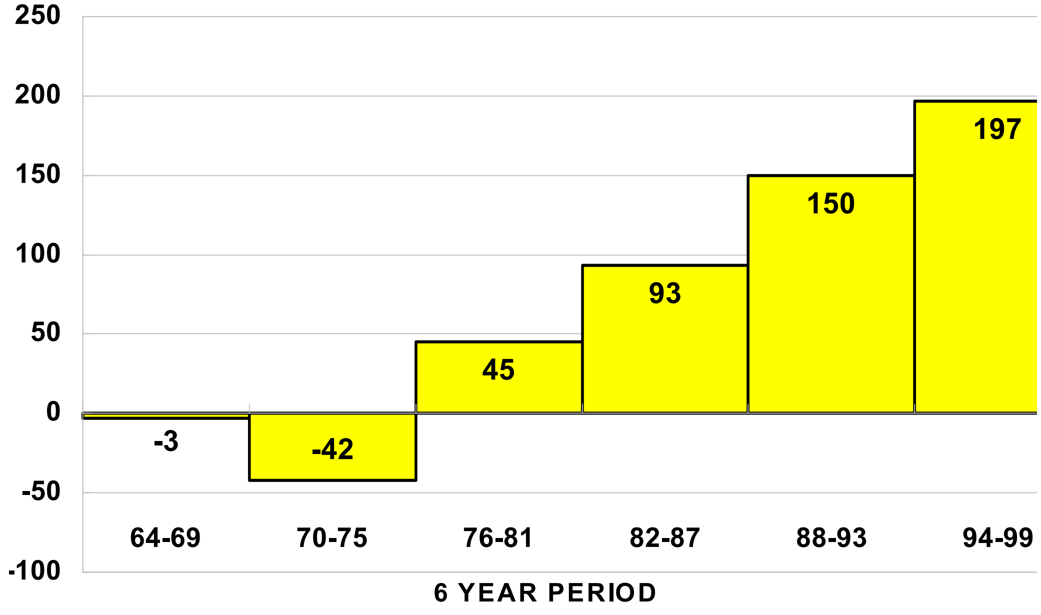


Figure 2. Change in lint lb/acre association for 1 units' change in micronaire in 6-year periods.