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Genotype by Environment Interaction Study of Cotton in Oklahoma[1]

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ABSTRACT

Eleven cotton (*Gossypium hirsutum* L.) varieties were grown at three locations in Oklahoma over a three-year period. Lint yield, fiber length, fiber coarseness, and two measures of fiber strength were studied using the analysis described by Comstock and Moll.

Significant varieties by years mean squares were obtained for fiber length and one measure of fiber strength. However, those mean squares were so small relative to their respective varietal mean squares that the evaluation of length and strength over years was considered unnecessary. A very large and significant varieties by locations mean square for yield suggested that the state should be subdivided in some manner for varietal testing and breeding purposes. A division into dryland and irrigated production may be adequate. The second-order interaction mean squares for yield and fiber coarseness were large and significant. Therefore, a sizable proportion of the interactions exhibited by those two traits could not be attributed to locations or to years. Inferences made from comparisons of variance components were the same as those obtained from an examination of mean squares.

***Additional index words:* *Gossypium hirsutum* L., Lint yield, Fiber length, Fiber coarseness, Fiber strength.**

COTTON, *Gossypium hirsutum* L., is grown in Oklahoma under a wide range of moisture conditions from the semi-arid regions of the southwest to the relatively high rainfall areas of the east. In certain parts of the state, large acreages often receive supplemental irrigation. Climatic, soil, insect, disease, and cultural conditions also differ from one section of the state to another and frequently from year to year at any one location.

Cotton variety tests have been conducted at several locations in Oklahoma for many years to facilitate comparisons of relative varietal performance in the state. However, these tests are expensive to run, especially when fiber quality evaluations are made. Obviously, the number and locations of the tests should be adequate to sample the environments where cotton is grown; yet no more tests should be conducted than are necessary because of the expense. Compromises between these two considerations are frequently necessary.

The experiments reported herein were conducted to obtain an indication of the genotype by environment interactions in cotton that are important in Oklahoma and to consider their implications in regard to future varietal testing and evaluation within the state.

LITERATURE REVIEW

Miller, Robinson, and Pope (3) analyzed the performance of 16 cotton varieties over 3 years at 11 locations from North Carolina to Texas (not including Oklahoma). They found a significant variety by year component for fiber length and a significant variety by location component for lint yield (when all locations were considered, but not after the three Texas locations were omitted). Significant variety by year by location components were observed for both characters. The second-order component for yield was large in comparison to the varietal component. The authors concluded that "while it is essential to test varieties over a number of different environments, it apparently makes little difference as to how these environments are distributed over locations and years."

Abou-El-Fittouh, Rawlings, and Miller (1) studied four cotton varieties over 101 environments which represented 3 years data at some 39 locations across the Cotton Belt (including Oklahoma). Interaction components for fiber length and strength in these tests were fairly small compared to their respective varietal components. Second-order interaction components were larger than the first-order ones, except for yield where the variety by location component was of considerable magnitude. Second-order components for yield and fiber fineness were large compared to the varietal component. Lint yield over the 3 years was also investigated using 9, 15, 12, 12, and 4 varieties from the Regional Cotton Variety Tests in the Eastern, Delta, Central, Plains, and Western regions, respectively. In these analyses the genetic component was generally the largest in magnitude followed in order by the second-order component, the genotype by location component, and the genotype by year component.

Fifteen cotton varieties were studied by Miller, Williams, and Robinson (4) at nine locations in North Carolina over a 3-year period. They found significant variety by year components for fiber length and fineness, a variety by location component for fiber fineness, and variety by year by location components for lint yield, fiber length, and fiber strength. All components except the second-order interaction for yield were small in comparison to the varietal components. They inferred that "there would be little if any advantage to be gained from attempting to divide the state into subareas for breeding and testing purposes", but that "breeding for specific environments might be feasible . . . to the extent that the important environmental factors are under some degree of control or predictable."

Verhalen and Murray (6) in a test for genotype by environment interaction which involved 10 cotton varieties, 2 years, and one location in Oklahoma found a significant variety by year interaction mean square for fiber coarseness, but not for fiber length or strength. Since only one location was included in the tests, this apparent variety by year effect was actually a confounded estimate which included the second-order interaction component as well as the variety by year component (2).

MATERIALS AND METHODS

Eleven varieties ('Auburn 56,' 'Stoneville 62,' 'Parrott,' 'Rex,' 'Paymaster 101,' 'Western Stormproof,' 'Austin,' 'Northern Star

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No. 5,' 'Gregg,' 'Lankart 57,' and 'Stoneville 7') were grown in a randomized complete block design with six replications over 3 years, 1962 to 1964, at three locations per year. Each location was specifically chosen to represent one of the major environments under which cotton is grown in Oklahoma in relation to moisture. Mangum was selected because it typifies cotton production in the western part of the state, i.e., droughts are frequent and usually prolonged. Perkins was chosen to represent eastern Oklahoma where droughts are not as common and less severe than in the western parts of the state. Chickasha was selected to represent those sections of the state which receive supplemental irrigation and within which moisture should rarely be a limiting factor. Since it was desired that the inferences obtained be applicable in the future to the state as a whole, locations and years were treated as random variables in the analysis of the data.

Plots were four rows 15.2 m long rows spaced 1.0 m apart. Plant spacing within rows corresponded to that used in commercial production. The center two rows of each plot were harvested to obtain estimates of lint yield in kilograms per hectare. Samples from each plot were saw-ginned, and the fiber was taken to the laboratory for measurement of its length, coarseness, and strength. Fiber length was measured on the digital fibrograph as 2.5% span length in inches, fiber coarseness on the micronaire in micronaire units, and fiber strength on the 1/8-inch and 0-inch gauge stelometer in grams per tex.

The methods outlined by Comstock and Moll (2) were used to analyze most of the data. Patterson's (5) method of adjustment for calculating comparable yields in variety tests was used for the data presented in Fig. 1. The interpretations of Comstock and Moll (2), Miller et al. (3), and Miller et al. (4) were used as guidelines in the interpretation of these results.

RESULTS AND DISCUSSION

Mean yield and fiber properties for each variety over years and over locations are listed in Table 1 to allow the reader to form an idea of the varieties' relative performance for these traits over the test period. As shown later in Table 2, significant differences among varieties were observed for all traits except yield. Fairly clear-cut differences in fiber length were apparent between the open-boll and stormproof varieties. With the exception of Stoneville 62, the open-boll types had a fiber which averaged over an inch in length while none of the stormproof varieties did so. Mean fiber coarsenesses were all within the currently acceptable micronaire range (3.5 to 4.9) while Gregg consistently had the strongest fiber among the varieties tested.

Table 2 includes the mean squares relevant to the study of genotype-environment interactions from the analyses of variance for each trait over years and locations. The lack of significance for yield was rather unexpected since analyses of that trait within each location within each year had previously revealed significant differences among varieties often at the 0.01 probability level. However, in those separate analyses the mean squares for varieties were actually inflated estimates which contained interaction components in addition to the component for genetic differences among varieties (2). Other things being equal, significant differences are more likely to be found for inflated than for noninflated estimates. Considering the magnitude of the interaction terms found for yield in these tests, the results obtained probably should not have been too surprising.

The varieties by years interaction mean squares were significant for fiber length and the 1/8-inch gauge measurement of fiber strength but not for yield, fiber coarseness, or 0-inch gauge stelometer. This would suggest that testing over years is of some value for determining relative performance among varieties for

Table 1. Mean performance of varieties over years and over locations.

Varieties*	Lint yield, kg/ha	2.5% span length, inches	Micronaire, units	Stelometer, g/tex 1/8-inch gauge	0-inch gauge
1. Stoneville 7	729	1.064	4.6	20.2	38.6
2. Northern Star No. 5	716	0.982	4.4	18.6	35.6
3. Stoneville 62	697	0.977	4.4	18.4	36.9
4. Rex	694	1.046	4.3	19.7	37.4
5. Auburn 56	688	1.052	4.3	20.8	37.7
6. Lankart 57	673	0.999	4.6	18.8	33.7
7. Western Stormproof	672	0.971	4.2	18.1	37.2
8. Austin	644	1.036	4.3	19.2	38.4
9. Paymaster 101	635	0.946	4.4	20.6	39.6
10. Parrott	633	0.941	4.7	19.0	36.4
11. Gregg	605	0.964	4.1	21.8	40.8

* Varietal numbers correspond to those used in Fig. 1.

Table 2. Mean squares relevant to the study of genotype by environment interaction.

Sources	df	Lint yield, kg/ha	2.5% span length, inches	Micronaire, units	Stelometer, g/tex 1/8-inch gauge	0-inch gauge
Varieties (V)	10	60,127	.11781**	2.7097**	62.42**	200.98**
V by years(Y)	20	14,308	.00808*	0.5465	5.53*	9.24
V by locations (L)	20	44,058*	.00552	0.2517	3.44	9.75
V by Y by L	40	19,964**	.00431	0.4265**	2.75	7.83
Error	450	10,969	.00470	0.1778	3.06	7.53

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

fiber length and 1/8-inch gauge stelometer in Oklahoma. However, considering the small size of their mean squares relative to their respective varietal mean squares and considering how expensive those fiber analyses are to make, adequate data for these traits could probably be obtained from a minimum of test environments over years. Evaluation over years would probably not be necessary.

The only significant varieties by locations mean square was obtained for lint yield. The economic importance of this character and the very large and significant interaction suggested that yield results from a single location are inadequate to make varietal recommendations for the state as a whole and that the state should be subdivided in some manner for testing of varieties and probably of advanced-generation breeding lines as well. Such a subdivision for fiber traits is clearly unnecessary as their varieties by locations mean squares were nonsignificant and relatively small. How this subdivision for yield determinations should be made must next be ascertained. Examining the relative performances of varieties by locations would seem to be a logical place to begin. This information is presented in Fig. 1. Locations in the figure are listed in an order proceeding from left to right representing an increasing availability of moisture. The data in the figure were adjusted using Patterson's (5) technique to largely eliminate those differences due to locations. Differences between varieties within a location after adjustment are precisely the same as before adjustment. The average performances of locations over varieties and years were so different (336, 591, and 1,087 kg/ha for Mangum, Perkins, and Chickasha, respectively) that the interactions would largely have been obscured had unadjusted data been shown in the figure. Differences in relative varietal performance between the two dryland locations were present, but these were relatively minor compared to the striking, often drastic, differences between either dryland location and the irrigated test at Chickasha. On the basis of these data, at least one dryland test is required in Oklahoma to make reasonably accurate predictions of varietal performance for dryland production and

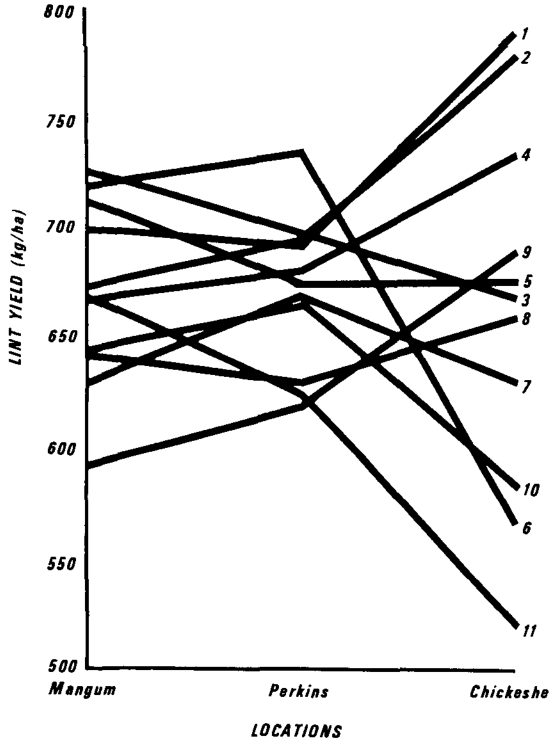

Fig. 1. Relative performance for yield among varieties at each location.

at least one irrigated test for irrigated production. These conclusions might possibly apply to the Texas Plains region as well since cotton is produced there under conditions similar to those of the Chickasha and Mangum tests reported herein. Additional experimentation is being conducted at the present time to determine if more than one of each is needed in Oklahoma and, if so, to determine where they should be located.

Considering varietal performance from location to location in Fig. 1, it is noteworthy that varieties responding positively relative to the others as the availability of moisture became greater were generally indeterminate in fruiting (Stoneville 7, Northern Star No. 5, and Rex) while those responding negatively were more determinate (Lankart 57, Parrott, and Gregg). However, Paymaster 101, a fairly determinate variety, did not fit this general pattern. Similar responses of this variety have been observed in dryland versus irrigated variety tests at Chillicothe, Texas (G. A. Niles, personal communication, 1969). Although this apparent exception may prove to be important, the general trend of these results suggests selection for fruiting type may be a means for increasing adaptation to a particular predictable moisture situation.

The varieties by years by locations mean squares were significant for yield and fiber coarseness but not for fiber length or strength. This indicates that a significant portion of the interactions exhibited by yield and coarseness were not attributable to years or to locations and that tests in different environments are necessary to obtain reliable estimates of relative performance for those traits. It apparently makes little or no difference how the tests are distributed over locations and years for fiber coarseness. However, in

Table 3. Estimates of variance components and their standard errors.

Components* (and standard errors)	Lint yield, kg/ha	2.5% span length,† inches	Micronaire, units	Stelometer, g/tex 1/8-inch gauge	Stelometer, g/tex 0-inch gauge
σ^2_V (S.E.)	402 (573)	.201 (.097)	.0433 (.0228)	1.04 (.52)	3.52(1.67)
σ^2_{VY} (S.E.)	000‡(353)	.021 (.015)	.0067 (.0110)	0.15 (.10)	0.08(0.19)
σ^2_{VL} (S.E.)	1,339 (813)	.007 (.011)	.0000‡(.0069)	0.04 (.07)	0.11(0.20)
σ^2_{VYL} (S.E.)	1,499 (754)	.000‡(.017)	.0415 (.0160)	0.00‡(.11)	0.05(0.30)
σ^2_E	10,969	.470	.1778	3.06	7.53

* σ^2_V is the component of variance due to genetic differences among varieties, σ^2_{VY} the variety by year component, σ^2_{VL} the variety by location component, σ^2_{VYL} the variety by year by location component, and σ^2_E the error variance. † Observed values were multiplied by 10^2. ‡ Negative estimate for which the most reasonable value is zero.

the case of yield, the non-significant varieties by years and the significant varieties by locations mean squares indicate the necessity for more emphasis on multiple locations rather than on a series of years.

The variance component estimates and their standard errors in Table 3 were calculated from the mean squares in Table 2. Some estimates were negative which intimates some error of estimation. The standard errors are informative in this respect. Since variances theoretically cannot be negative, one must assume in the cases where such estimates are obtained that the quantity being estimated is either zero or a relatively small positive number. In this experiment negative estimates were assumed to be zero.

Error variances for each trait were larger than the components, individually or combined, of that trait. Interaction components were relatively small for the fiber length and strength measurements in comparison to the varietal components for those traits. Substantial second-order components were found for lint yield and fiber coarseness, as well as a large variety by location component for yield. Only in the case of yield were interaction components larger than the corresponding varietal components. The second-order component for fiber coarseness did approach the varietal component in magnitude. The conclusions about testing obtained from comparisons of components were the same as those derived from an examination of mean squares.

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