Published March, 1981

Breeding for Early Maturity and Verticillium Wilt Tolerance in Upland Cotton[1]

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ABSTRACT

Inheritance of earliness of crop maturity and Verticillium wilt (*Verticillium dahliae* Kleb.) tolerance and the relationship between the two characters, was investigated using seven strains of cotton (*Gossypium hirsutum* L.). Maturity rank was consistent over the two locations used, Las Cruces, N.M., USA, and Matamoros, Coahuila, Mexico.

Only general combining ability effects (GCA) were significant for either character. The strains Nectariless and Stahmann had the largest GCA effects for crop earliness, indicating that these cottons are potentially useful sources of germplasm in earliness breeding programs. Yugoslavian and 'Deltapine 16' exhibited the largest GCA effects for Verticillium wilt tolerance.

Yugoslavian and Stahmann showed the largest GCA effects for lint yield, suggesting that these strains could have value in developing wilt tolerant cultivars with good fiber yields. The strong association between wilt tolerance and lint yield at Las Cruces suggested that selecting for wilt tolerance among progenies stemming from these cottons on wilt-infested soil might also increase lint yield.

Simultaneous selection for earliness of crop maturity and wilt tolerance, using Stahmann as a donor of earliness, could be accomplished using the pedigree method of breeding.

Additional index words: Short season cotton, Bloom rate, Date of first bloom, *Gossypium hirsutum* L., *Verticillium dahliae* Kleb.

EARLY maturing cultivars of Upland cotton (*Gossypium hirsutum* L.) are important in the Texas High Plains where the season is short. They are also useful where weather adversities at the end of the season impair fiber quality. Such an area is the Yaqui Valley of Sonora, Mexico, where harvest is frequently delayed by rain. There boll rots often take a toll of fiber yield (Martinez, 1971; Hernandez, 1972). Early maturing cultivars also are important in the "short season" trials that are aimed at reducing water and insecticide costs now in progress across the Cotton Belt.

Verticillium wilt (*Verticillium dahliae* Kleb.) is one of the most serious diseases of Upland cotton in La Comarca Lagunera in the states of Coahuila and Durango, Mexico and in the western United States. Cultural practices do not provide complete control (Leyendecker, 1950; Perches et al., 1971; Minton et al., 1972; Butterfield et al., 1976). Presley's (1950) statement is still largely valid:

"Since Verticillium wilt cannot be controlled by cultural practices or by the use of fertilizer or soil amendments, the most practical method of control is the development of a disease resistant variety."

Unfortunately, no known sources of heritable immunity have been found in Upland cotton (Cotton, 1965; Bell, 1973; Bassett, 1974). Therefore, the development of highly tolerant cultivars is the best alternative.

The investigation reported here was made to determine the inheritance of both earliness and tolerance to Verticillium wilt and their relationship. Earliness and Verticillium wilt tolerance combined in the same variety would be doubly profitable. Cotton breeders have suspected that earlier maturing cotton cultivars are generally more susceptible to Verticillium wilt. However, to the authors' knowledge there is not a specific study of the relationship between these two traits.

Richmond and Radwan (1962), working on seven methods for measuring earliness, found that all measurements were positively correlated. Any of seven methods, including number of days from planting to appearance of the first bloom, could be used with confidence to estimate earliness in cotton on a single-plant basis. Ray and Richmond (1966) considered that the node of the first fruiting branch (NFB) was a reliable basis for estimating genetic earliness.

In a cross between tolerant and susceptible strains of Acala cotton, Barrow (1970) concluded that the differences in tolerance to Verticillium wilt was conditioned by a single dominant gene. Similar results were reported in interspecific crosses and in crosses between races of *G. hirsutum* L. by Wilhelm et al. (1969, 1974). In contrast, Stith (1969), concluded that the genetic mechanism involved in resistance to Verticillium wilt was quantitative rather than qualitative.

Barnes and Staten (1961) found that general combining ability (GCA) for Verticillium wilt tolerance was significant, while specific combining ability (SCA) was not. Verhalen et al. (1971b) agreed that additive genetic variance was the most important source of variation, but they also reported that dominant gene action was toward greater susceptibility, which is in agreement with Roberts and Staten's (1972) findings.

MATERIALS AND METHODS

Plant Materials. The parental materials used in this study were seven Upland cottons, four of which ('Deltapine 16,' 'Delcott 277,' 'Lankart 57,' and 'Coker 310') were commercial cultivars. The three experimental lines were as follows: Yugoslavian, an Acala 1517V sib × Texas CA491; Stahmann, a selection from (Acala 1517D × Oklahoma CR-4) × Stahmann 876; and Nectariless, selected from (Acala sel. 9519 × Meyer 1514) × Acala 1517-70. The parents were chosen primarily for their diversity in earliness and thus do not represent a random sample

[1] Journal article 732, Agric. Exp. Stn., New Mexico State Univ., Las Cruces, NM 88003. Received 20 Sept. 1979

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Table 1. Mean squares and combining ability effects for first bloom and bloom density in two environments (GCA effects ranked from earliest to latest first bloom).

Source	df	First bloom MS	Bloom density MS
Environments (E)	1	11,936.96**	15,224.00**
Replications within E [Error (a)]	4	29.54	36.69
Varieties	20	13.98**	17.92**
GCA	6	33.21**	37.57**
SCA	14	5.74	9.50
E × GCA	6	2.94	2.06
E × SCA	14	4.61	8.43
Error (b)	80	5.95	6.93
GCA Effects			
Stahmann		−1.25	−1.32
Nectariless		−1.21	−1.49
Yugoslavian		−0.46	−0.22
Lankart 57		−0.14	0.11
Coker 310		0.61	0.48
Deltapine 16		1.21	1.58
Delcot 277		1.25	0.88
† SE ($\hat{g}i$)		0.41	0.44
†† SE ($\hat{g}i - \hat{g}j$)		0.63	0.68

** Differences significant at the 0.01 level of probability.
†, †† Standard errors of GCA effects and for the differences between GCA effects, respectively.

from any particular population. Therefore, inferences derived from this study are meant to be applicable to these parents and the crosses between them.

Experimental Procedure. The seven parents were crossed in a diallel pattern (excluding reciprocals), at Iguala, Mexico in the winter of 1975-1976. On 12 May 1976 the experimental material was planted in randomized complete blocks with three replications at New Mexico State Univ. Plant Science Research Center, Las Cruces, and at the Center for Agricultural Research of the Northeast (CIANE) in Matamoros, Coahuila, Mexico.

A plot was a single row 5 m long planted on 92 cm centers at Matamoros and 102 cm centers at Las Cruces. Hills were spaced approximately 20 cm apart and thinned to one plant/hill. To equalize border effects, single rows of the cultivar 'Stoneville 213' were planted between experimental plots. Cultural practices were standard for the regions involved.

Five competitive plants were randomly chosen and tagged within each plot at both locations. Individual plant records were kept on earliness and Verticillium susceptibility. Earliness was measured at both locations as the number of days from planting to first bloom, and from planting through the first seven blooms (bloom density). These methods for measuring earliness were then compared between locations. In the Matamoros experiment, earliness was also estimated as percent of total lint yield picked at the first of six harvests. Verticillium wilt susceptibility was measured as the number of nodes per plant and as the number of days from planting to the end of growth. To evaluate this trait, plant height was measured weekly until the plant failed to increase in height by 1 cm, when growth was considered ended. This trait was measured only in the Las Cruces experiment, where the Verticillium wilt organism was well-distributed throughout the experimental plots.

A combined analysis of variance was conducted on the plot means for earliness over the two locations. The other traits could not be analyzed in the same way because of confounding with Verticillium wilt effects at Las Cruces. Therefore, analyses of variance were performed separately for each location for the remaining traits. For these traits we recognized that the variance component for genotypes could be confounded with genotype by locations and genotypes by years interaction because the remaining data came from a single year at a single location.

Both one-and two-environment data were analyzed according to Griffing's (1956) Method 4, Model 1 to obtain estimates of

Table 2. GCA effects for Verticillium wilt tolerance (nodes/plant) and lint yield. (Ranked from highest to lowest for yield).

Parent	GCA effect: Nodes/plant	GCA effect: Lint yield
	no.	g/plot
Stahmann	0.33	23.27
Yugoslavian	0.73	17.30
Delcot 277	−0.60	4.23
Nectariless	0.40	2.34
Deltapine 16	0.73	−2.25
Coker 310	−0.06	−17.66
Lankart 57	−1.53	−27.24
† SE ($\hat{g}i$)	0.29	7.79
†† SE ($\hat{g}i \times \hat{g}j$)	0.45	11.90

†, †† Standard error for GCA effects and for the differences between GCA effects, respectively.

GCA and SCA effects and variances. Lentner et al. (1975,1977) APL computer programs were used in the analysis of the data.

RESULTS AND DISCUSSION

Earliness. The two-environment diallel analysis for earliness revealed highly significant differences among entries for GCA for days to first bloom and bloom density (Table 1). No SCA estimates were significant. These results suggest that earliness in the current material relates to additive effects and/or additive by additive epistasis. This conclusion agrees closely with earliness studies by Miller and Marani (1963), White and Richmond (1963), White and Kohel (1964), and Murray and Verhalen (1969). Other investigators argue for dominance (Verhalen et al., 1971a; Baker and Verhalen 1973, 1975).

Al-Rawi and Kohel (1969) as well as Miller and Marani (1963) reported significant epistatic effects. Significant differences ($P < 0.01$) were found between environments (locations) for the two methods of measuring earliness, because the lines were earlier at Matamoros. However, the nonsignificant interactions show that crosses between these seven parents can be evaluated at a single location. The lack of significance for first bloom and first seven blooms (Table 1) in the Las Cruces experiment was unexpected because of the results of the combined analyses, but the trend at Las Cruces was similar to Matamoros.

GCA effects for first bloom and bloom density are azlso shown in Table 1. Ranking of the GCA effects was similar but not identical for the two parameters. Phenotypic correlation between these methods was significant at the 0.05 level of probability (r_p = 0.219; df = 124) but of low predictive value. Either method could be used to predict earliness, but for selection purposes, "first bloom" has lower variability and is more easily measured. The Stahmann and Nectariless families had the largest GCA effects for first bloom and bloom density, suggesting that both parents may be included in a breeding program for the development of an early cotton cultivar.

Verticillium Wilt Tolerance and Lint Yield. At Las Cruces differences in resistance to Verticillium wilt could be measured by the relative number of nodes produced per plant. Analysis of the Las Cruces data showed highly significant differences among genotypes for GCA. No significant differences were detected for SCA, which is in agreement with the findings of Barnes and Staten (1961) and Verhalen et al. (1971b). Days to plant death showed no significant differences.

The significant GCA suggests that the gene action for Verticillium wilt tolerance was additive and/or additve by additive epistasis.

Yugoslavian and Deltapine 16 parents exhibited the largest GCA effects for tolerance (Table 2. This result indicated that both parents may be included in a breeding program designed for the development of a tolerant cultivar. However, crosses derived from the Stahmann and Yugoslavian parents produced more lint than Deltapine 16.

Diallel analysis for lint yield showed highly significant differences among genotypes for GCA (Table 2). There were no significant SCA effects. Since the experimental plots were severely infested with Verticillium wilt in the Las Cruces experiment, differences among genotypes for lint yield were primarily due to differences in tolerance to Verticillium wilt. This conclusion is supported by the Matamoros experiment (wilt free) where no significant differences among entries were detected. Results indicated that selecting for wilt tolerance in crosses between these parents on wilt-infested soils should give an improvement in lint yield.

The Stahmann parent showed the largest GCA effect for earliness (Table 1) and has the largest GCA effect (Table 2) for lint yield on wilt-infested soil. No significance was detected for SCA effects in either trait. This result suggested that its progeny can be selected for earliness and wilt tolerance simultaneously. Roberts and State (1972) showed that selection for Verticillium wilt tolerance shuld be made on the basis of progeny rows rather than single plants. Therefore, we suggest that the pedigree method be used in the selection for earliness and wilt tolerance.

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