Published September, 1980

Long-term Progress Made by Cotton Breeders in Developing Fusarium Wilt Resistant Germplasm[1]

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ABSTRACT

Breeding for resistance in cotton, *Gossypium hirsutum* L., to fusarium wilt, *Fusarium oxysporum* Schlect. f. *vasinfectum* (Atk.) Synd. & Hans., began shortly after the causal agent was described in 1892 and continues. Many cultivars and advanced breeding stocks having resistance are deficient in agronomic and fiber characteristics or properties present in less resistant stocks. Breeding stocks and cultivars submitted annually by 11 cooperators from 1969 to 1978 were evaluated for wilt resistance by growing them on a soil highly infested with both the wilt organism and root-knot nematodes, *Meloidogyne incognita acrita* (Chitwood & Oteifa). The relative mean wilting percentages of all entries evaluated during the last 3 years of this test were significantly less than wilting percentages of those evaluated at the beginning of the test period. These results indicate that progress has been made in hreeding for fusarium wilt resistance. The rate of progress in combining acceptable agronomic properties and fusarium wilt resistance into commercial cultivars also increased in the last 3 years of the test.

Additional index words: **Host-plant resistance, *Gossypium hirsutum* L., *Fusarium oxysporum* Schlect. f. *vasinfectum* (Atk.) Synd. & Hans., Root-knot nematodes, *Meloidogyne incognita acrita* (Chitwood & Oteifa).**

ATKINSON (2), in 1892, first described the causal agent and symptoms of fusarium wilt, *Fusarium oxysporum* Schlect. f. *vasinfectum* (Atk.) Snyd. & Hans., of Upland cotton, *Gossypium hirsutum* L. His report implied, however, that this disease had probably existed in areas of the southeastern United States for several years before its identification. Orton (9) found that varieties of cotton differed markedly in their resistance to fusarium wilt. These differences in resistance, in both the Sea Island, *G. barbadense* L., and Upland types, were utilized promptly and intensified by early workers such as W. A. Orton, E. L. Rivers, and E. F. Smith (10). Additional wilt resistant cultivars were developed later, but many of these were lower yielding on uninfested soils than the best agronomically acceptable but less resistant cultivars. Most of these wilt resistant cultivars were also deficient for many other needed agronomic properties (13). Improved cultivars with higher wilt resistance and better agronomic properties were eventually developed. 'Coker 100 Wilt,' released in 1942, was probably the first cultivar combining wilt resistance with acceptable agronomic properties (11).

In general, improvements in yield potential and both plant and fiber quality of highly wilt resistant cultivars developed from 1941 to 1978 have not equalled those achieved in more susceptible ones, because it is difficult to select concurrently for both wilt resistance and desirable agronomic properties. However, several highly wilt-resistant cottons with good quality have been developed since 1967 (5).

Several workers have developed artificial inoculation techniques to evaluate fusarium wilt-resistant plants under controlled conditions (1, 3, 4, 7, 8, 12). These techniques have proved useful in developing increased wilt resistance. Plant response following use of one of these techniques was highly correlated with those obtained in field trials with the same cultivars (6). For various reasons, however, including the difficulty of using these procedures to screen large segregating populations and the lack of facilities for such screening, most resistant materials have been selected based on results obtained following evaluations in fields infested with the wilt fungus.

Uniformly infested fields are rare and usually these fields are not conveniently available to many cotton breeders. However, a test site, uniformly infested with the wilt and root-knot nematodes was discovered at Tallassee, Alabama, in 1948. Since then the populations of both the wilt fungus and root-knot nematodes at this site have been augmented through the use of a rotational system. Each year since 1952, breeding materials and commercial cultivars have been evaluated for resistance to the fusarium wilt-nematode disease complex in a regional fusarium wilt test conducted at this site.

The objective of the study reported in this paper was to determine the degree of progress made by American cotton breeders for increased fusarium wilt resistance during the 10-year period 1969 to 1978.

MATERIALS AND METHODS

Entries studied were those submitted by 11 cooperators, from throughout the U. S., for evaluation in the regional fusarium wilt test from 1969 through 1978. Cooperators were five state breeders who submitted their advanced breeding materials (group 1), five private (commercial) breeders who submitted their advanced materials (group 2), and one state breeder who submitted commercial cultivars grown in the southeastern and southern U. S. plus one or two advanced lines (group 3). The number of entries entered by both state and private breeders who submitted their own advanced lines varied over years but averaged about 10. About 25 entries were evaluated for the one state breeder who submitted mainly commercial cultivars. Entries tested for the 10 cooperators in groups 1 and 2 could be included in one of the following categories: (a) identical to an entry previously tested for the given cooperator, (b) advanced selections from a previously tested entry, or (c) new selections from crosses involving a resistant entry evaluated in an earlier test.

All entries along with a susceptible check ('Rowden'), which was entered every 10th row, were arranged in a systematic design with a gradient check. Four to six replications of these materials were evaluated for fusarium wilt resistance annually. The soil in this field, located at Tallassee, Ala., is a Wickham sandy loam, a member of the fine-loamy, mixed thermic family of Typic Hapludults. This soil was infested uniformly with high levels of both the wilt organism and root-knot nematodes.

The high levels of infestation with these two organisms have been maintained and perhaps augmented by a cotton-hairy vetch

[1] Contribution from Crop Sci. Res. Unit. AR, SEA, USDA, in cooperation with the Dep. of Agronomy and Soils, Alabama Agric. Exp. Stn., Auburn Univ., Auburn, AL 36830. Received 21 Dec. 1979.

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(*Vicia villosa* Roth) rotation that was initiated in 1965 and maintained throughout the test period. Rotation included the following practices: (a) in the fall, cotton stalks were chopped and disked into the soil, then the field was planted with hairy vetch; (b) during the next spring, about 8 weeks before normal planting time for cotton, the field was plowed to a depth of about 15.2 to 20.3 cm; (c) cotton entries to be evaluated were planted on one-half of the field and a 3:1 mixture of cottons moderately to highly susceptible to fusarium wilt was planted on the other half; (d) this process was repeated the next year, except cotton entries were planted on the opposite side of the field. This rotational system has increased the uniformity of infestation in the test area.

From 1969 through 1971, entries were inspected every 10 to 14 days throughout the growing season, at which time plants with wilt symptoms of any type were removed and recorded. Plants infected with both the wilt fungus and nematodes were not differentiated from those just infected with the former. The

Table 1. Relative mean wilting of cotton.

	Relative mean wilting				
Year	Lines from state breeders (group 1)	Lines from private breeders (group 2)	Cultivars and advanced stocks (group 3)	Unweighted mean	Rowden
	%				
1969	46.5	23.8	27.6	32.6	130.6
1970	47.4	42.5	49.2	46.4	129.9
1971	48.6	46.7	45.6	47.0	123.6
1972	29.2	28.4	29.6	29.1	89.7
1973	44.1	45.0	34.7	41.3	94.7
1974	38.5	39.9	40.1	39.5	74.8
1975	38.2	39.0	59.8	45.7	82.7
1976	18.0	15.7	19.9	17.9	83.7
1977	19.4	14.4	22.8	18.9	117.6
1978	10.2	10.7	13.8	11.6	72.6

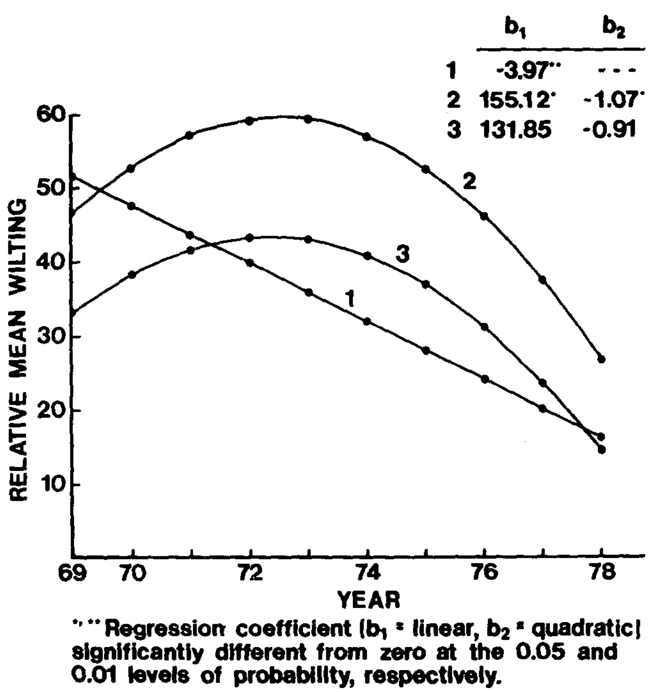

Fig. 1. Regression of relative mean wilting percentages on years. Lines 1, 2, and 3 represent the change in relative mean wilting (RMW) over years. Lines 1 and 2 = RMW of entries submitted by five state and five private breeders, respectively. Line 3 = RMW of commercial cultivars and one or two highly advanced lines evaluated for one state cooperator.

remaining symptomless plants were counted at the end of the growing season. From 1972 through 1978, initial live-plant counts were made early in the growing season, after losses from seedling diseases had occurred, and again near the end of the season. One to three inspections were made during the interim and wilted plants were removed and recorded. Total wilting was determined from the differences between initial and final live-plant counts.

Because environment influences wilt expression and incidence, the mean wilting percentages for cooperators' entries were adjusted for the effects of both field location and year relative to that of the common susceptible check. Adjustments were made as follows: $Y = AB/C$, where Y = mean wilting percentage of a given cooperator's entries adjusted for both location and year effects; A = mean wilting percentage of a given cooperator's entries within year; B = mean wilting percentage of all Rowden rows within test over years; and C = mean wilting percentage of the nearest Rowden rows within years. These Y values were then designated as relative mean wilting (RMW).

Following these adjustments, percentages were divided into the three groups mentioned above and group means calculated. These means were then transformed (arcsine transformation) and regressed on years.

RESULTS AND DISCUSSION

When the RMW of entries submitted by the three groups was transformed and regressed on years (Fig. 1), wilting of lines from date breeders was reduced in a linear fashion ($P = 0.01$). The change in RMW of entries from private breeders and the commercial cultivars followed a curvilinear regression ($P = 0.03$ and 0.15, respectively).

During the 1st year of study, the unweighted RMW percentage for all entries prior to transformation was 32.6 (Table 1), although RMW of individual cooperator's entries varied from 50 to 20%. Even greater variation occurred during the following years for individual breeders. This result probably occurred because greater selection pressure was applied for characteristics other than wilt resistance (yield, fiber properties, maturity, etc.) at that time.

Our data indicate that only limited progress for fusarium wilt resistance occurred in group 1 and none occurred in groups 2 and 3 during the first 7 years of this study. During the last 3 years of the study, resistance of entries evaluated was markedly improved. For example, the unweighted RMW of all entries was 45.7% in 1975 and only 11.6% in 1978. In 1975, commercial cultivars were much more susceptible than entries from both state and private breeders. However, in 1978 the resistance of commercial cultivars was not different from that of lines included in the other two groups.

The drastic reduction in RMW of all entries evaluated during the last 3 years indicate that fusarium wilt-resistant materials with desirable agronomic and fiber properties have been developed. Thus, (a) the "unfavorable association" between resistance and the other needed properties must have overcome and (b) breeders can combine these needed properties and wilt resistance determined under different test conditions into the same genetic background. Most the fusarium wilt-resistance cultivars currently in use in the southern and southeastern United States were evaluated for resistance at Tallassee during their development. Thus, the field procedures described here and the data generated from these evaluations undoubtedly have contributed to the development of fusarium wilt-resistant cottons of commercial value. Continued use of this test and test procedure will allow breeders to continue applying selection pressure for fusarium wilt resistance. As a result, they should be able to continue to incorporate high levels of fusarium wilt resistance into their best new cultivars.

REFERENCES

1. Armstrong, G. M., and J. K. Armstrong. 1960. American, Egyptian and Indian cotton-wilt *Fusaria*: Their pathogencity and relationship to other wilt *Fusaria*. USDA Tech. Bull. 1219.
2. Atkinson, G. F. 1892. Some diseases of cotton, III. Frenching. Ala. Agric. Exp. Stn. Bull. 41:19-65.
3. Bugbee, W. M., and J. T. Presley. 1967. A rapid inoculation technique to evaluate the resistance of cotton to *Verticillium albo-atrum*. Phytopathology 57:1264.
4. Fahmy, T. 1934. The selection of wilt immune strains of long staple cotton (Sakha 4 Gidid). Egypt. Ministry Agric. Techn. Sci. Serv. Bull. 130.
5. Kappelman, A. J., Jr. 1971. Fusarium wilt resistance in commercial cotton varieties. Plant Dis. Rep. 55:896-897.
6. ———. 1975. Correlation of *Fusarium* wilt of cotton in the field and greenhouse. Crop Sci. 15:270-272.
7. Lagiére, R., and M. Cognée. 1960. Selection pour resistance a la fusariose (*Fusarium oxysporum* f. *vasinfectum*). (In French) Coton Fibres Trop. 15:188-191.
8. Miller, D. A., and W. E. Cooper. 1967. Greenhouse technique for studying Fusarium wilt in cotton. Crop Sci. 7:75-76.
9. Orton, W. A. 1900. The wilt disease of cotton and its control. USDA Div. Physiol. Pathol. Bull. 27.
10. Presley, J. T., and L. S. Bird. 1968. Diseases and their control. p. 347-366. *In* F. C. Elliot, M. Hoover, and W. K. Porter, Jr., (ed.). Advances in production and utilization of quality cotton: Principles and practices. Iowa State Univ. Press, Ames, Iowa.
11. Smith, A. L. 1953. Fusarium and nematodes on cotton. *In* Plant Diseases, USDA Yearbook of Agric., U.S. Gov. Printing Office, Washington, D. C.
12. Wickens, G. M. 1964. Methods for detection and selection of heritable resistance to fusarium wilt of cotton. Emp. Cotton Grow. Rev. 41:172-193.
13. Young, V. H., J. O. Ware, and G. Janssen. 1929. Cotton wilt studies, II. Preliminary studies on wilt resistance and the effect of certain soil factors on the development of cotton wilt. Ark. Agric. Exp. Stn. Bull. 234.