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Indirect Selection for Resistance to the Fusarium Wilt-Root-Knot Nematode Complex in Cotton[1]

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ABSTRACT

The reaction to fusarium wilt [*Fusarium oxysporum* Schlect. f. *vasinfectum* (Atk.) Synd. & Hans.] and root-knot nematode (*Meloidogyne* spp.) of nine families and cultivars of cotton (*Gossypium hirsutum* L.) that were developed using the multi-adversity resistance (MAR) selection program, was compared with that of susceptible 'Rowden' and resistant 'McNair 511.' These materials were field tested at Tallassee, Ala., in 1974, 1975, and 1976 growing seasons. Use of the MAR technique increased the resistance of strain composites for four new families by recombination of strains within families. The mean wilt resistance over 3 years of all nine of the final strains or composites of strains representing families developed by this indirect MAR selection technique was greater than that in Rowden, while resistance in seven of these strains was equal to that of McNair 511. Two older MAR cultivars, 'Tamcot SP 21' and 'Tamcot SP 37,' developed during the early phases of the MAR program, were less susceptible than Rowden but only Tamcot SP 21 was as resistant as McNair 511. Three new MAR cultivars, 'Tamcot SP 21S,' 'Tamcot SP 37H,' and 'Tamcot CAMD-E,' released from the composite cultivars tested during 1974, 1975, and 1976, and evaluated in 1978 had resistance equal to that of McNair 511 and were significantly less susceptible than Rowden. The high degree and rapid development of resistance in these composites achieved through indirect selection indicates that use of the MAR breeding technique can contribute significantly to the development of fusarium wilt resistance in cotton.

Additional index words: *Gossypium hirsutum*, Host plant resistance, Multi-adversity resistance.

WITHIN a plant species, genes for viability mnd adaptation tend to be linked and many such fitness genes are linked with some morphological traits (12,13). Consequently, identification of certain key fitness and seed traits should permit their use for indirect selection for diseased resistance.

Blank (7) and Smith (15) noted the apparent presence of genes in cotton that conditioned resistance to both Verticillium wilt [*Verticillium albo-atrum* (ms) Reinke & Berth.] and the fusarium wilt [*Fusarium oxysporum* Schlect. f. *vasinfectum* (Atk.) Snyd. & Hans.]-root-knot nematode (*Meloidogyne* spp.) complex. Additional evidence supporting these results were reported by Bird (1), Sappenfield (14), and Wiles (16).

Bird (1) and Brinkerhoff and Hunter (8) revealed a similar association between resistance to both wilts and bacterial blight [*Xanthomonas malvacearum* (E. F. Sm)Dows.]. Bird's (1) results indicated that the associations were stronger when more virulent races of *X. malvacearum* were used in selecting for resistance to bacterial blight. Desai and Bird (11) found a strong association between blight and wilt resistance, both being related to seed-coat resistance to mold growth. Campagnac (10) found a similar association indicating that, at the genetic level, the reaction to fusarium wilt and nematodes does not differ greatly from bacterial blight resistance.

Bird (2,3) used this information to develop the multi-adversity resistance (MAR) system for genetic improvement of cotton. The system selects simultaneously for improvement in resistance to diseases, insects, and stress (4,5,6). In this system, seed-coat resistance to mold, a reduced rate of germination at 13.3 C, and cotyledon immunity to a mixed inoculum of four virulent races of *X. malvacearum* were the key traits used to apply indirect selection for resistance to several diseases. Therefore, it was anticipated that the use of these selection criteria would increase resistance to the fusarium wilt-root-knot nematode complex (2, 3, 4, 5, 6, 10). Progress made in developing cottons resistant to the fusarium wilt-nematode complex with the indirect selection procedure is reported in this paper.

MATERIALS AND METHODS

Seven MAR family composites (CAMD-E, Lewis, CAMD-S, MAR, CAMD-H, OR-S, and OR-H) and their subsequent replacement composites or single strains, two Tamcot varieties ('Tamcot SP 21' and 'Tamcot SP 37,' developed during the early period of the MAR program), and two checks were evaluated for resistance to the fursarium wilt-root-knot nematode complex. Replacement composites were composed of reselections from within advanced generations or new selections from the original base populations that resulted from crosses of SP strains. The plants were grown on a Wickham sandy loam soil at Tallassee, Ala., for 3 years, 1974, 1975, and 1976. This soil was heavily infested with both the fusarium wilt fungus and the root-knot nematode.

Each year four replications of the materials, arranged in a randomized complete block design with a gradient check every 10th row, were evaluated at Tallassee. Plots were single rows 9.1 m long with rows spaced 1.1 m apart. Data obtained each year in each plot included the number of live plants after losses caused by seedling disease, the total number of wilted plants (these were removed after each count), and the number of healthy

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Table 1. Fusarium wilt in cotton cultivars and strain composites in the 1974, 1975, and 1976 uniform TAM-MAR tests plus two checks evaluated on a soil highly infested with the fusarium wilt fungus and root-knot nematodes, Tallassee, Ala.

Cultivar or composite	Susceptible plants* 1974	1975	1976	Mean†
	%			
McNair 511 (resist. check)	20 a	18 ab	9 a	16 a
CAMD-E	21 a	30 bc	15 a	22 a
Lewis	31 ab	24 abc	12 a	22 a
CAMD-S	32 ab	27 bc	12 a	24 ab
Tamcot SP 21	36 ab	19 ab	26 abc	27 ab
MAR	63 cd	9 a	18 ab	30 abc
CAMD-H	54 bcd	30 bc	7 a	30 abc
OR-S	49 abc	32 bc	25 ab	32 abc
Tamcot SP 37	50 bcd	40 c	31 abc	40 bc
OR-H	67 d	29 bc	41 bc	46 c
Rowden (susc. check)	63 cd	72 d	49 c	61 d

* Within a column means not followed by the same letter are significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test. † The cultivar-by-year interaction was not significant.

plants remaining at the end of the growing season. Although both nematodes and the wilt fungus contribute to disease symptoms, only plants with wilt symptoms were removed and recorded.

It is known that resistance to the wilt fungus can be broken when roots are injured by the root-knot nematode (9). For this reason the absence of wilt symptoms in the presence of the two pathogens reflects resistance to both organisms. Final damage due to the wilt-nematode complex was calculated from differences between initial and final counts of live plants. Percent wilted plants per plot and the mean wilting percentage for a given entry were then calculated. After the data were analyzed, means were compared using Duncan's Multiple Range Test.

After crosses have been made to produce a new family, selection with MAR procedure begins in F_1 for normal leaf and normal bract types and in F_2 for okra-leaf and frego-bract types. Each sequence of reselection based on the MAR system from F_3 through F_7 produces several strains per year for each family. The agronomic characteristics of individual strains are evaluated in small, local tests in Texas, and a composite of the strains is used to obtain sufficient seed to represent the family in large-scale tests at several locations. Performance of a composite cannot be used as a basis for eliminating strains; it indicates only the general potential of a family of strains. Each summer strains are eliminated based on general agronomic performance. During the winter the surviving old strains and the new strains are compared in a cold-soil laboratory test (20 C) for emergence and damping-off to determine which ones are to be carried forward to represent the family during the next season.

The 1976 composites were composed of strains that had survived the last cycle of reselection for the families. At this stage, all strains were at least F_4 and most were F_7, and it was apparent that usable genetic variability had been exhausted. In four families, CAMD-E, CAMD-S, OR-S, and OR-H, one or more of the final selections had been present in the 1974 composite. In two other families, Lewis and MAR, they were not present until 1975; in one family, CAMD-H, none of the final strains was present in 1974 or 1975.

In 1976, CAMD-E, CAMD-S, and CAMD-H were released as cultivars under the names 'Tamcot CAMD-E,' 'Tamcot SP 21S,' and 'Tamcot SP 37H,' respectively (4, 5, 6). The representative strains or composites of strains tested in 1976 were used to make up the breeders' seed for the respective cultivars. These cultivars were evaluated in 1978 to check their level of resistance relative to that measured during their development.

Table 2. Fusarium wilt in Tamcot cultivars and check cultivars evaluated in 1978.

Cultivar	Susceptible plants*
	%
Tamcot SP 21S†	2.6 a
McNair 511 (resist. check 1)	3.4 a
Tamcot SP 37H‡	6.0 a
McNair 511 (resist. check 2)	6.8 a
Tamcot CAMD-E§	8.0 a
Rowden (susc. check 1)	43.0 b
Rowden (susc. check 2)	52.4 b

* Means not followed by the same letter are significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.
† Tested as CAMD-S in the 1974 to 1976 tests, released as a cultivar in 1976. ‡ Tested as CAMD-H in the 1974 to 1976 tests, released as a cultivar in 1976. § Tested as CAMD-E in the 1974 to 1976 tests, released as a cultivar in 1976.

RESULTS AND DISCUSSION

Although the level of wilt symptoms varied over years, significant cultivar by year interactions did not occur. Therefore, the mean over years is the best measure of the wilt resistance of a given entry. According to these values, six new TAM-MAR composites and the MAR cultivar Tamcot SP 21 were as resistant as the resistant check (Table 1). Although the OR-H cultivar and the older MAR variety, Tamcot SP 37, were more susceptible than the resistant check over years, both were also significantly more resistant than the susceptible check; both, therefore, probably have sufficient resistance for satisfactory crop production. The high fusarium wilt-root-knot nematode resistance of these composites supports the theory of indirect selection for disease resistance, as expected with the MAR system.

In 1974, the year in which wilt symptoms were most prevalent, the MAR cultivar Tamcot SP 37 and the composites MAR, CAMD-H, OR-S, and OR-H were as susceptible to the wilt-nematode complex as Rowden (Table 1). In 1975, the MAR cultivars and all composites were more resistant than Rowden. Some of the differences had been caused by changing the strain composition of composites. As an example, in 1974 the composite OR-H (strains OR-30 and OR-37) wms as susceptible as Rowden while in 1975 OR-H (strain OR-37 only) was less susceptible than Rowden. In 1976, the composite OR-H (strains OR-37 and OR-74) was again as susceptible as Rowden, probably because the strain OR-74 was more susceptible than strain OR-37. Tamcot SP 37 was as susceptible as Rowden during both 1974 and 1976 but not during 1975. These differences did not occur due to any change in cultivar composition. All other newer composites were as resistant as McNair 511 and superior to Rowden. Of the seven new MAR families, all but OR-H retained or improved their levels of resistance as a result of indirect selection. Over years, all MAR cultivars were superior to Rowden and all but two were as resistant as McNair 511 (Table 1).

Evaluation of the three new Tamcot cultivars (4, 5, 6) in 1978 (Table 2) revealed that they had retained the levels of wilt-nematode resistance that had been observed in the earlier tests. This result indicates that progress was made probably in selecting genetically stable lines that were included in these composites. Among the first two cultivars released from the MAR program, only Tamcot

SP 21 was as resistant as the resistant check. However, the three new releases (Tamcot SP 21S, Tamcot SP 37H, and Tamcot CAMD-E) were all as resistant as the resistant check. This result indicates that the indirect selection procedure was effective for improvement of resistance to the wilt-root-knot nematode complex.

Although positive means of measuring field resistance to the fusarium wilt-root-knot nematode complex exist at Tallassee, Ala., and although such measurements are probably the best criterion of resistance, results from this test are limited due to the following: (a) only a relatively small number of entries may be evaluated each year; (b) the environment affects symptom expression, thus the true measure of resistance should be the mean over several years; and (c) a large amount of labor is needed to adequately evaluate materials within a relatively short period each year.

Results from this study indicate that a high degree of resistance to the fusarium wilt-nematode complex can be attained using the MAR indirect selection technique if genetic variability for resistance to this disease complex is present in the initial population. Selection of resistant strains using this technique may be achieved in a shorter time and possibly at a lower cost than by direct field selection. The MAR selection technique has increased greatly progress for resistance to this disease complex of cotton by its quick elimination of susceptible plants, thereby reducing the number of entries that need critical field evaluation in a wilt-nematode nursery. Even though direct selection for resistance is not practiced, maintenance of a good-field-evaluation nursery is essential for ascertaining the levels of resistance obtained as well as for validating future improvements in the MAR system.

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