Strains of the

VERTICILLIUM WILT FUNGUS

in California Cotton

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COTTON YIELDS have progressively decreased in many fields in Tulare and Kings counties in the San Joaquin Valley since 1960. Losses have been attributed to new races of *Verticillium albo-atrum*, potassium deficiency, and a change in tolerance to Verticillium wilt in the Acala 4-42 variety (grown exclusively in the San Joaquin Valley since 1954 because of its wilt-resistance).

Plants affected with Verticillium wilt exhibit slight to extensive vascular discoloration in stems, epinasty (downward angle of the petiole) followed by sudden defoliation, and sometimes general chlorosis. Earlier studies indicated that the strain of *V. albo-atrum* causing major damage to California cotton is a severe defoliating type which is not characteristic of isolates obtained earlier from cotton in the San Joaquin Valley, or from other plant species grown elsewhere in California prior to 1960.

Potassium

Some soils where the disease occurs are marginal for potassium, but potassium deficiency was not thought to be a primary cause. Suggestions that tolerance of the Acala 4-42 variety had changed were not supported by results of periodic tests against isolates of *V. albo-atrum*. The presence of a more virulent strain of *V. albo-atrum* was considered the most likely cause of severe Verticillium wilt (sudden wilt).

When a typical isolate of *V. albo-atrum*, designated SS-4, taken from cotton in Fresno County in 1957, was compared in greenhouse experiments with isolate T-1 (characteristic of a large group obtained from defoliated cotton in the central San Joaquin Valley) marked differences in symptoms were apparent. Three cotton varieties, representing the two species *Gossypium hirsutum* and *G. barbadense*, were selected for inoculation with conidial suspensions, dormant mycelia, and microsclerotia of the SS-4 and T-1 strains: Acala 4-42 and Delta Pine 15 represented tolerant and highly susceptible varieties of *G. hirsutum*, respectively, and the variety Tanguis 2885 (*G. barbadense*) represented the resistant cotton type.

Symptoms differ

All three varieties developed symptoms earlier when inoculated with T-1 than when inoculated with SS-4. Early symptoms caused by T-1 were downward curling and epinasty in the terminal leaf followed by epinasty of most leaves 1 to 2 days later. Affected leaves of all three varieties exhibited general chlorosis 1 to 3 days later, and defoliation followed. Defoliation was complete in many instances in 14 to 15 days after inoculation with conidia. When Delta Pine 15 plants were inoculated with SS-4, the lower leaves exhibited interveinal chlorosis followed by necrosis, and within 15 to 20 days after inoculation, these plants died. There was little or no epinasty, and dead leaves remained on the plants. Acala 4-42 exhibited tolerance to SS-4, with only a few lower leaves showing chlorosis and necrosis, although some stunting occurred. Tanguis cotton appeared unaffected externally by SS-4, but discoloration was occasionally present in the lower stem when cut. Differential symptoms occurred with both strains when conidial or microsclerotial inoculum was used, but symptoms appeared slower in plants in soil infested with microsclerotia. Whereas T-1 caused defoliation and death in all three cotton varieties, their responses to SS-4 inoculation were typical of susceptible, tolerant, and highly resistant reactions, respectively.

Virulence differs

When cotton was seperately inoculated with both strains at the same inoculum level (microsclerotial and conidial inocula), T-1 was clearly much more virulent. Inoculum potential studies were initiated to determine the magnitude of the increased virulence of T-1 over SS-4. Again conidial and microsclerotial inocula were used.

Acala 4-42, Delta Pine 15, and Tanguis 2885 were seperately inoculated with conidia of SS-4 and of T-1 at 0, 10^3, 10^4, 10^5, and 10^6 viable conidia per ml of suspension. Acala 4-42 withstood an inoculum level of SS-4 ten times higher than did Delta Pine 15. Tanguis proved to be highly resistant to SS-4 at all inoculum levels.

The T-1 strain caused symptoms in Delta Pine 15 at an inoculum level 0.1

DIFFERENTIAL REACTION OF SEVERAL COTTON VARIETIES TO SS-4 AND T-1 STRAINS OF VERTICILLIUM ALBO-ATRUM

Cotton variety	Disease reaction* Verticillium strain	
	SS-4	T-1
Delta Pine	++++	+++++
Acala 250	++++	+++++
Stardel	++++	+++++
Acala 1517V	+++	+++++
Acala 49-4	+++	+++++
Acala 4-42	++	+++++
New Mexico 8229	++	+++++
M59-14	+	+++++
Tanguis 2885	—	+++++

* Disease reaction based on a scale of — to +++++: — = no visible external symptoms but vascular discoloration occurring in some cases; ++++ = lethal reaction without defoliation; and +++++ = lethal reaction with defoliation. The above disease reactions are based on varietal response to inoculum adjusted to 5 × 10^5 viable conidia per ml of suspension.

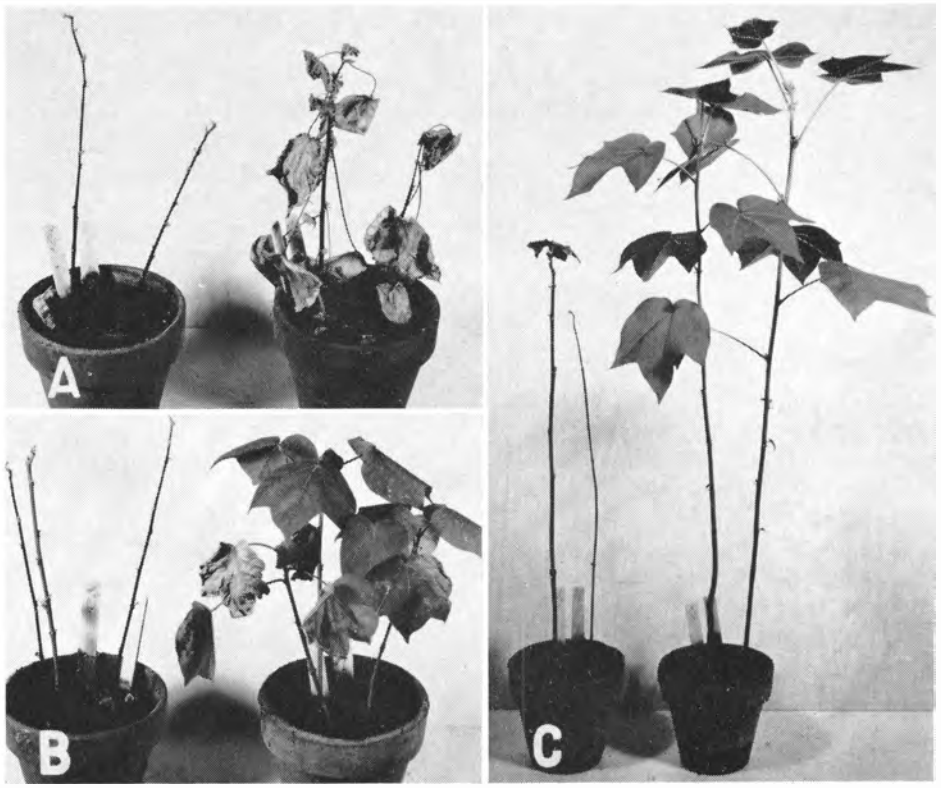
that of the SS-4 strain, and inoculation with as few as 10^3 conidia per ml resulted in defoliation. Acala 4-42 did not show symptoms until 10 times more (10^4) conidia of T-1 were used. Defoliation of Tanguis occurred at all inoculum levels producing symptoms; however, at 10^4 conidia per ml, most of the infected Tanguis plants retained their leaves—in contrast to Delta Pine 15 and Acala 4-42, where complete defoliation occurred if leaf symptoms appeared. Results of experiments using soil infested with microsclerotia at different inoculum levels were similar. Thus, virulence of T-1 was estimated to be 10 times greater than SS-4 on Delta Pine 15 and at least 100 times greater on Acala 4-42 and Tanguis. The fact that T-1 was lethal to Tanguis at high inoculum potentials suggests that its virulence advantage over SS-4 is much greater than 100 times on this variety.

Varietal resistance

A high degree of resistance to strains of *V. albo-atrum* similar to SS-4 has been found in *G. barbadense* and particularly in various lines of the Tanguis variety. Several varieties of *G. hirsutum* are tolerant. Results obtained indicated that T-1 was capable of causing lethal reactions in tolerant lines of *G. hirsutum* as well as in resistant lines of *G. barbadense*.

All 35 varieties and *G. hirsutum-G. barbadense* hybrids tested proved to be very susceptible to T-1, with lethal reactions and defoliation occurring in all instances. Defoliation was less pronounced in *G. barbadense* varieties but the reaction was still lethal. It was apparent that no variety or hybrid tested had a high level of tolerance to T-1 under greenhouse conditions. Tanguis, however, did not express severe symptoms in fields in which Acala 4-42 was severely affected. This suggests that either the high levels of inoculum used in the greenhouse were not present in field soils or that plants are more resistant under field conditions, or both. It is possible, therefore, that *G. barbadense* may impart a degree of economic tolerance to *G. hirsutum* varieties that may decrease the severity of wilt caused by T-1 at the inoculum levels now present in field soils. The indications are, however, that if the inoculum potential increases substantially (about 10 times) in field soils, even varieties of *G. barbadense* may be severely affected.

Although a differential response was found to these two strains in cotton, further evidence of strain differences was sought in inoculation tests with species other than those of *Gossypium*. The following plant species were inoculated with conidial suspensions of SS-4 and T-1 adjusted to 10^6 conidia per ml: snapdragon, celery, safflower, pepper, watermelon, okra, tomato, salsify, and cowpea.



Differential response of three cotton varieties six weeks after inoculation with conidia of SS-4 and T-1 strains of *Verticillium albo-atrum*. **Delta Pine 15 inoculated with SS-4 (right) and T-1 (left), Acala 4-42 inoculated with SS-4 (right) and T-1 (left), and Tanguis 2885 inoculated with SS-4 (right) and T-1 (left). Note the increasing tolerance in Acala 4-42 and Tanguis varieties to SS-4 but the severe defoliating reaction caused by T-1 on all three varieties.**

Cowpea, muskmelon, and watermelon were not affected by either strain. Pepper exhibited only vascular discoloration, and salsify showed symptoms only in old leaves with both strains. Okra and celery were severely affected by both strains. Tomato was very susceptible to SS-4 but only slightly susceptible to T-1. Safflower and snapdragon were mildly affected by SS-4 but severely affeeted by T-1. Both strains were recovered from all species except cowpea, muskmelon and watermelon. Plant species that can be used to differentiate SS-4 and T-1, therefore, are cotton, safflower, snapdragon, and tomato.

Field infection

Tests were conducted to determine whether symptoms caused by T-1 in the greenhouse could be duplicated in the field. A small plot at Davis was fumigated and infested with microsclerotia of T-1 to a depth of 15 to 20 cm. Noninfested areas served as controls. Symptoms typical of the T-1 strain occurred and increased throughout the summer. Many plants were defoliated. No infected plants were found in the noninfested areas. This response to *Verticillium* infection is frequently seen in many areas of the San Joaquin Valley.

It is apparent from the results that T-1 (and similar isolates) is a major factor in the severe wilt disease in the San Joaquin Valley. The T-1 isolate causes different symptoms, is much more virulent, and attacks varieties and species of cotton that were previously considered tolerant or resistant to Verticillium wilt. The latter observation indicates that breeding for resistance may be difficult. Control may require measures to lower the inoculum level of *V. albo-atrum* in field soils and to maintain them at low levels through chemical treatment of soil, rotation of crops, and other cultural practices—in addition to planting varieties with high levels of tolerance.

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