Rotation ineffective as Verticillium control

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Verticillium wilt, caused by *Verticillium albo-atrum*, is a major pathogen of cotton and several other California crops. The pathogen is a soil-borne fungus, attacking its host through the root system. It survives long host-free periods in naturally infested soil as microsclerotia, which are formed in infested host tissue. Incorporation of this host tissue into the soil and its subsequent decomposition are responsible for the inoculum levels of this fungus in the soil.

No satisfactory control measures are available for controlling Verticillium wilt on cotton. Chemical control has been economically unfeasible, and tolerant cotton varieties such as Acala 4-42 have had only short-term usefulness. Only time will determine whether the current variety, Acala SJ-4, will have lasting value.

Over the years, various workers have investigated crop rotations as a control measure for this pathogen with conflicting results. Several workers have reported that crop rotations did not control Verticillium wilt. The fungus persisted in the soil, and crops planted after 10 years of nonsusceptible cropping could still become severely infected in problem fields. In contrast, other workers have reported reductions in wilt infections or increased cotton yields, or both, following short-term (2 to 3 years) rotations with nonhost crops.

We have recently developed a quantitative assay for Verticillium that has made it possible to directly monitor the pathogen in the soil. Thus, results are not masked by other possible agronomic effects of the rotations. The assay consists of wet sieving a 15-gram soil sample and plating the 38- to 125-micron residue on a semi-selective agar medium. Viable *Verticillium* propagules can be detected by their characteristic colony appearance after 8 to 14 days.

Field sampling

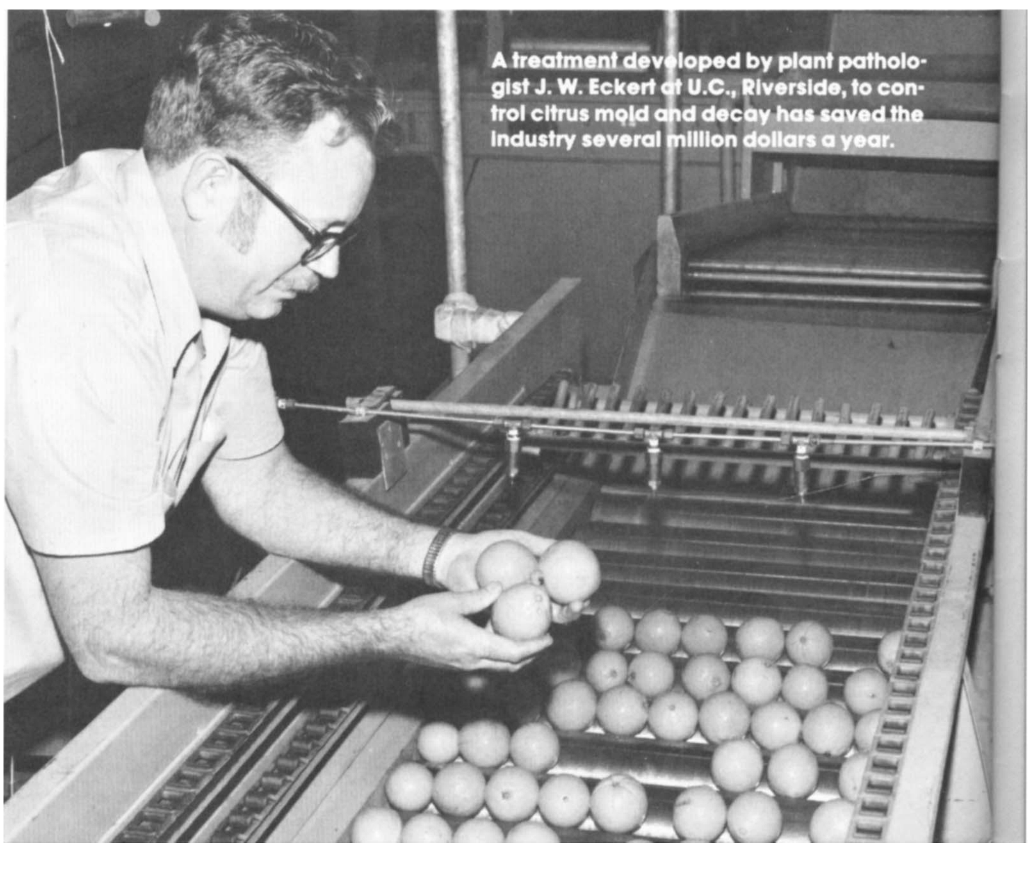
The investigation was conducted in commercially cropped fields of the San Joaquin Valley. Eight fields were selected because of differences in crop history and inoculum levels of the Verticillium wilt fungus. For the next 3½ to 4 years, these fields were sampled monthly and assayed for *Verticillium*. Within a field, the assay results were quite consistent over time, and any changes in inoculum densities from month to month generally were gradual. The graph shows maximum annual inoculum densities determined in July-September in these fields.

High inoculum densities (20 to 60 microsclerotia per gram of soil) build up and persist in fields repeatedly cropped to a susceptible crop (cotton). Inoculum levels can also build up rapidly to high levels in 1 or 2 years in fields (88, 42, and 86) where the pathogen is initially present in low levels. This buildup does not become evident until the year after a susceptible crop is planted, whether the subsequent crop is cotton or a nonsusceptible one (fields 88, 42, and 86). The reason is that the infested host tissue must first be incorporated into the soil and decompose before inoculum buildup is detectable.

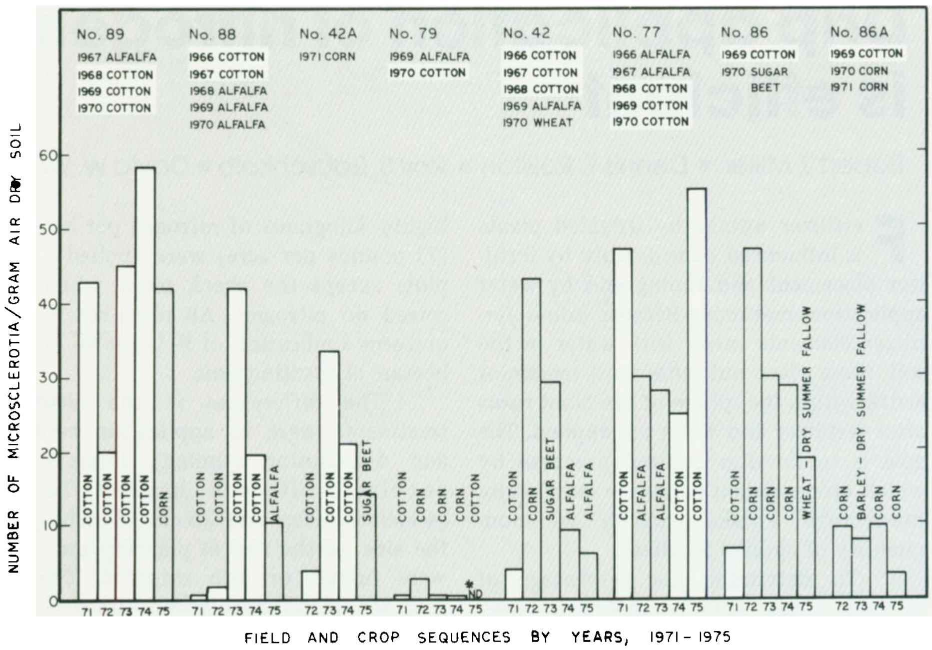
This time lag in inoculum release must be taken into consideration in any effort to manipulate pathogen populations in the soil. Our data further suggest that *Verticillium* can survive in soils for long periods. Extrapolation of attrition rates in fields 77, 86, and 86A indicates that from 10 to over 20 years are required for the pathogen population to drop to near zero.

The rapid buildup combined with the slow decline rate of *Verticillium* in soil limits the value of crop rotation for controlling this soil-borne pathogen. Within 1 to 2 years the fungus can increase to 30 to 40 microsclerotia per gram of soil in fields with initially relatively low (1 to 5 microsclerotia per gram of soil) population levels (fields 42A, 86, and 88). These values are over ten times the amount (about 4 microsclerotia per gram of soil) needed to cause 100 percent infection in a cotton crop. Although attrition occurs during nonsuscept culture, the observed rate is far too slow to make short-term crop rotation useful. In field 86A, *Verticillium* microsclerotia levels had not dropped sufficiently after 6 years of nonhost cropping to make it safe again for cotton.

Crop rotations, however, can be useful under certain circumstances. If rotation begins when the inoculum is close to the minimum level needed for 100 percent infection in a susceptible crop, the attrition rate could be sufficient to drop the inoculum to a level where disease incidence in a subsequent susceptible crop would be reduced significantly. This situation is evident in field 79. However, such a situation would probably be the exception in the San Joaquin Valley, because inoculum buildup is so rapid. This may explain some of the conflicting reports on results of crop rotation



A treatment developed by plant pathologist J. W. Eckert at U.C., Riverside, to control citrus mold and decay has saved the industry several million dollars a year.



Maximum annual inoculum densities of the Verticillium wilt fungus determined in July-September in eight fields.

in controlling *Verticillium*, for, depending on the inoculum level of an experimental field when a rotation regime was initiated, the attrition rate may or may not be sufficient to reduce disease incidence. The occasional large decreases in inoculum level observed in most fields (see graph) may also be a factor in the conflicting reports, because the unpredictable and short-term nature of such decreases would necessarily lead to inconsistent results.

It is not surprising that wilt incidence is often higher, or yield is lower, or both, in continuous host plots than in rotation plots. Inoculum buildup progresses steadily in continuous host culture but is disrupted during the nonhost cycle in rotation plots. Therefore, a direct comparison of rotation plots at the end of the rotation sequence would be misleading. Our ability to measure the pathogen directly has enabled us to avoid this complication. In most reports in which lower disease incidence has been observed in rotation plots than in continuous cotton plots, the incidence of disease has rarely decreased in any given plot over the years of the study. This, along with the findings of our study, suggests that rotations stretch out the time involved in inoculum buildup but are unable to prevent it.

Conclusion

We conclude that rotations have little effect on *Verticillium* survival in soils, and that they are ineffective in the long run as control measures for this pathogen. Rotations have a number of agronomic benefits, and thus we would not want to discourage their use. However, rotations of cotton with such crops as corn, alfalfa, or grain should not be undertaken to combat Verticillium wilt.

In California, where crop rotations have been reported in relation to Verticillium wilt in cotton, yield increases in the rotation plots have averaged 10 percent (our own calculations of reported data). Our results suggest that these yield increases are probably the result of beneficial effects of crop rotation and are unrelated to *Verticillium*. Crop rotation can influence soil structure and porosity, the soil moisture regime, soil fertility, and other variables, each of which could affect yields.

Although significant attrition of microsclerotia does occur in field soils, such attrition occurs independently of the crop grown. Because inoculum reductions in continuous susceptible culture were equal to any in immune-crop culture, such reductions cannot be attributed to the presence of sugar beets, alfalfa, or corn. Apparently, factors independent of the crop grown govern reductions in inoculum density. It will be important to identify these factors both for understanding the biology of this pathogen in the soil and for developing control measures.

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Research brief

Maintaining quality of fruits and vegetables

A major portion of the estimated $200 million annual losses of fruits and vegetables during shipment and marketing can be attributed to diseases caused by less than a dozen fungi and bacteria. Significant progress has been made in controlling these diseases.

Fifteen years ago two University plant pathologists, after testing hundreds of compounds, discovered that an ammonia-related chemical, 2-aminobutane, effectively controlled rotting of oranges, lemons, grapefruit, and tangerines, and was nontoxic to humans. Today over 50 packing houses (about 40 percent of the total in California) use this compound to control decay during storage and marketing. Mold loss, which cost the citrus industry several million dollars a year, is now almost nonexistent.

The treatment is highly effective for control of penicillium decay in oranges during the degreening operation and during short-term storage before packing; previous treatment materials had become ineffective because resistant strains of penicillium had developed. Two-aminobutane has also become a profitable patent of the University of California, making funds available for research by graduate students at all campuses. (PPA 2763)