

Relationship of Inoculum Density and Soil Types to Severity of Fusarium Wilt of Sweet Potato

Shirley N. Smith and W. C. Snyder

Assistant Research Plant Pathologist and Professor, respectively, Department of Plant Pathology, University of California, Berkeley 94720.

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ABSTRACT

Fusarium oxysporum f. sp. *batatas* was incorporated as chlamydozoospores into wilt-conducive and wilt-suppressive cultivated and noncultivated soils from California. Fusarium wilt on sweet potato planted in these soils was more severe in the wilt-conducive than in the wilt-suppressive soil, with the same number of chlamydozoospores in each soil. Noncultivated suppressive soil was intermediate between the two cultivated soils in disease development on sweet potato. A few plants in the conducive soil

became diseased within 4 weeks, when as few as 50 chlamydozoospores/g were present, but one-third of the plants in the suppressive soil remained disease-free when as many as 5,000 chlamydozoospores/g were present. Furthermore, the pathogen propagule counts doubled in both the conducive and the noncultivated suppressive soils at the 500/g level, but remained the same in the cultivated suppressive soil after two sets of cuttings were grown. Phytopathology 61:1049-1051.

The differential spread of *Fusarium* wilt through soils of different types has long been observed (13, 16). Chemical (12, 13, 17) and physical (13, 17) characteristics have been correlated with suppression in soils to Panama wilt spread in Central American banana plantations. Stotzky et al. (10) associated the presence of montmorillonoid-type clay minerals with soils productive for Gros Michel bananas (wilt-suppressive) for 20 or more years.

In California, *Fusarium* wilt diseases do not occur in fields in the Salinas Valley, in spite of long and intensive cultivation in these soils of a wide variety of crops, many of which are wilt-susceptible. However, soils in an adjoining watershed in the Castroville area are wilt-conducive, and when susceptible crops are grown, wilt outbreaks frequently occur on such crops as peas and crucifers. Soils from these two watersheds were used in the experiments described in this paper. The sweet potato was the test plant used, even though it is not cropped in either the Salinas Valley or the Castroville area.

MATERIALS AND METHODS.—Cultivated field soils of somewhat similar texture from each of these areas, one with a recent history of serious wilt occurrence on radishes and the other having had no wilt history, were used in a greenhouse study to assess the relative disease severity in sweet potato that occurred with various inoculum levels of *Fusarium oxysporum* Schlecht. f. sp. *batatas* (Wr.) Snyder & Hans. In addition, a noncultivated soil from the area of the wilt-suppressive soil was tested.

The soils used in these experiments were (i) Elkhorn sand, the wilt-conducive soil ("C"); (ii) Chualar sandy loam, the wilt-suppressive soil ("S"); and (iii) Chualar sandy loam noncultivated ("N-S"), the parent soil type of the suppressive soil.

Random sampling of soil in sweet potato fields in the San Joaquin Valley surrounding plants wilting in a field infested with *F. oxysporum* f. sp. *batatas* gave densities of 50 propagules/g or less of the fungus, yet there was evidence that these low levels were adequate for disease development in the field. Since the organism exists in soil as chlamydozoospores (2, 8), this

was the form of the fungus used in the experiments. Chlamydozoospores were established in the three soils by adding conidia in heavy concentrations in water, allowing the soils to dry, rewetting them, and letting them dry out again over a period of 4-6 weeks. Samples were then microscopically examined for the presence of chlamydozoospores of the pathogen. Sweet potato cuttings were planted in the potted soils (three cuttings/5-inch pot) and placed in a greenhouse at 32 C. Water was applied by subirrigation. Five pots containing three cuttings each were planted in each experiment for each inoculum level and soil type.

Evaluation methods.—Since rather low inocula were used in these experiments, indexing seemed the most feasible way for comparisons. Three methods were devised, and experiments using one or another method were found to compare with each other. Index A is the percentage of plants showing wilt symptoms at 4 weeks, and represents incidence of disease. Index B is based on comparisons of symptom development of test plants with that of cuttings given a massive inoculation. It is a measure of severity based on rapidity of attack or a "time-severity" index. In the field, individual sweet potato plants show wilt symptoms throughout the season, and some plants die early and some late. Plants that receive a small amount of inoculum may survive for the entire season, but if the cuttings are dipped into a concentrated conidial suspension of *F. oxysporum* f. sp. *batatas* and planted in sand at 32 C in the greenhouse, severe symptoms (complete vascular browning and yellowing of leaves, followed by collapse and death within a few days) occur in all plants during the 2nd week after inoculation. High temperatures are necessary for the pathogen to move rapidly in plants (5, 8). Test plants in the greenhouse, which developed severe symptoms, were pulled before death in order to avoid sporodochial formation on dead tissue and further seeding of the soil with conidia (2, 4). All plants that developed severe symptoms during the 2nd week after placing the cuttings in the pots were pulled and scored 100; this disease development was equivalent to that of receipt of a massive conidial inoculation. Plants pulled during the 3rd week

scored 83, and those in the 4th week, 67. At the end of the 4th week, the remaining plants were harvested and rated from 0 to 66 according to the amount of leaf yellowing and the extent of vascular browning. The average rating of all plants in a series was the index for the group.

Index C was employed in another experiment, and is based on visible intensity of vascular necrosis. Thus, all the plant stems were sliced off 1 inch above the soil level 12 days after planting, and the per cent of discolored vascular ring was estimated. Figure 1 diagrams the appearance of some typical stem cross-sections of plants that were evaluated at this stage. The average percentage of vascular discoloration in each series of plants was the index.

After the sweet potato cuttings were harvested and indexed, the potted soil still containing the pathogen was replanted with another set of sweet potato cuttings. At the end of this second 4-week period, soil with 500 propagules/g incorporated was plated to determine the population change after two successive plantings.

RESULTS.—The data obtained in the three experiments using the three indexing systems compared reasonably well (Table 1). Although in these pot experiments little disease occurred within 4 weeks when only 50 propagules/g were present, some disease did occur consistently in the conducive soil. This suggests that, should this population be present in a field of conducive soil, serious losses in a sweet potato crop could occur before the end of the season. These results also indicate that at high populations, disease could be serious in the suppressive soil under appropriate climatic conditions, but buildup of such populations is unlikely.

Immediate replanting generally increased disease in all the soils (Table 2), particularly at the 500/g levels. Still no disease occurred in the cultivated "S" soil at the 50/g level. The noncultivated parent "N-S" soil behaved intermediately between the cultivated "S" and

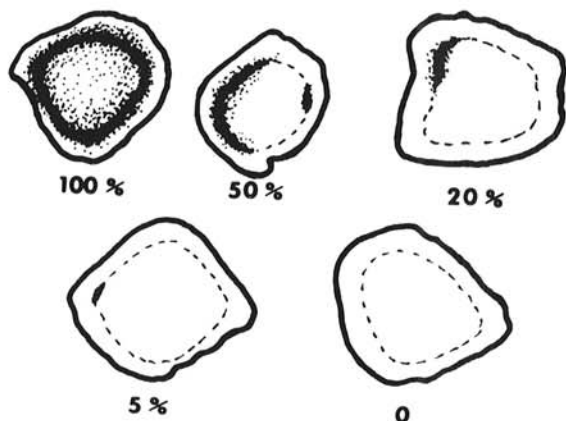


Fig. 1. The percentage of discoloration in the vascular ring in cross sections of sweet potato stems inoculated with *Fusarium oxysporum* f. sp. *batatas* sliced 1 inch above the soil level. This diagram illustrates typical discoloration of the vascular ring obtained in greenhouse experiments.

TABLE 1. Disease severity of sweet potato cuttings in relation to inoculum density of *Fusarium oxysporum* f. sp. *batatas* and soil type^a

Index	Chlamydo- spores/g soil	Soil type ^b		
		"S"	"N-S"	"C"
		%	%	%
A. Per cent of diseased plants	0	0	0	0
	50	0	0	12
	500	21	29	33
	5,000	67	75	96
B. Time-severity index	0	0	0	0
	50	0	0	7
	500	2	3	9
	5,000	10	40	60
C. Avg per cent of vascular ring discolored	0	0	0	0
	50	0	0	2
	500	26	30	36
	5,000	33	37	57

^a Indices A and B were determined within 4 weeks of transplanting cuttings, and index C after 12 days.

^b "S" = Suppressive soil; "N-S" = noncultivated suppressive soil; "C" = conducive soil.

TABLE 2. *Fusarium* wilt (*Fusarium oxysporum* f. sp. *batatas*) severity on sweet potato cuttings in replanted soil in pots

Index	Chlamydo- spores/g soil	Soil type ^a		
		"S"	"N-S"	"C"
		%	%	%
A. Per cent of diseased plants	0	0	0	0
	50	0	7	20
	500	47	67	73
	5,000	80	87	93
B. Time-severity index	0	0	0	0
	50	0	2	7
	500	13	17	25
	5,000	31	35	68

^a "S" = Suppressive soil; "N-S" = noncultivated suppressive soil; "C" = conducive soil.

"C" soils. Apparently, cultivation of this soil improves its wilt-suppressive effect.

The plate count results of composited soil from each pot at the 500 chlamydo-spore/g level were as follows: "S" averaged 513/g (435-713); "N-S", 952 (850-1,210); and "C", 976 (950-1,010). These counts show that the propagule increase in the "N-S" soil is similar to that of the "C" soil.

DISCUSSION.—The comparison of differences in degree of sweet potato wilt in different soils with the same inoculum level, point again to the variability of *Fusarium* wilt potentials in different soil types (13, 16, 18). It also demonstrates that a soil known to be favorable to one *Fusarium* wilt in the field, namely, radish wilt, may be favorable also to another *Fusarium* wilt, even though the soil must be placed in a warmer environment to demonstrate it.

Numbers of 500 and 5,000 chlamydo-spores of *F. oxysporum* f. sp. *batatas* of soil are considerably higher than one encounters in San Joaquin Valley field soils where the disease prevails. Even 50/g occur only in isolated pockets (which probably contain rem-

mants of old diseased tissue). The field distribution of this forma specialis thus fits that described by Trujillo & Snyder (15) for *F. oxysporum* f. sp. *cubense* in infested soils of banana plantations.

According to McClure (5), the onset of sweet potato wilt infection usually develops in the freshly cut transplants, unless roots become damaged at a later date to expose freshly opened xylem elements. Nielson (8) showed that inoculation and infection can occur through roots broken during the harvest. Cuttings procured from sweet potato storage roots infected during harvest afterward wilted with varying degrees of severity, the sprouts transplanted latest being the most severely diseased.

Since plants in the field have a longer period for symptom expression than those in pot tests, plants that incurred light infections at the transplant stage in the low inoculum levels of field soil could eventually succumb. Other *Fusarium* wilt diseases which occur at relatively low field soil populations are banana wilt (Panama disease) (9, 14), radish wilt (E. E. Trujillo, unpublished data), and tomato wilt (Shirley N. Smith, unpublished data).

On the other hand, *F. oxysporum* f. sp. *vasinfectum* has been found distributed throughout cotton fields in the San Joaquin Valley at high population levels (7) relative to the amount of disease. Wensley & McKeen (18) detected *F. oxysporum* f. sp. *melonis* at populations of 1,000/g of field soil at the site of wilted muskmelon plants, but these levels dropped considerably in the 9-month interval between crops. *Fusarium roseum* f. sp. *cerealis* 'Culmorum' (1) and *F. solani* f. sp. *phaseoli* (6) also occur in high numbers in seriously infested fields. These fungi may well fit Gäumann's (3) model of thousands of units/g needed for infection in the case of wilt-inducing fungi, or, in the case of the cortical invaders, for enough individual lesions to form for a serious disease.

Comparisons of the "S" and "N-S" soil show that cultivation increases the tendency of a soil to suppress *Fusarium* wilt. This increased suppression may be explained on the basis of an increased biological buffering due to increase in numbers and types of competitive microorganisms. Should this be the case, the very temporary benefits following flood following (13) of banana soils infested with *F. oxysporum* f. sp. *cubense* might be explained, in that flooding temporarily removes many of the pathogen propagules. However, flooding also removes the competitive organisms and allows the wilt pathogen to re-establish even more readily.

The increase in propagule numbers in the "C" and "N-S" soils reflect the severe infection of plants in these soils. Occasionally, saprophytic *F. oxysporum* clones have been observed to build up tremendously in greenhouse soils, but usually, pathogenic formae speciales incorporated into such soils die off under the varying moisture conditions. Stover (11, 12, 13) reported that *F. oxysporum* f. sp. *cubense* survived best

in soils with low (15-30% saturation) rather than high (100% saturation) moisture content. The increase in numbers of *F. oxysporum* f. sp. *batatas* in these soils probably came principally from diseased plant material left after harvest and from conidia formed on diseased stems at soil level. We cannot be sure whether there was an increase in the pathogen in plant rhizospheres.

Although increasing inoculum density may partially overcome the wilt suppressive character of a soil, this would not occur in nature.

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