

Verticillium wilt disease of tomato: Influence of inoculum
density and root extension upon disease severity

L. J. Ashworth, Jr., O. C. Huisman, D. M. Harper, and L. K. Stromberg
University of California, Berkeley 94720, and University of California,
Cooperative Extension, Fresno, California.

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ABSTRACT

Rate of infection of tomato by Verticillium dahliae increased with
increases of inoculum density in four field experiments where micro-
sclerotia (MS) in naturally infected tomato plants was the inoculum.
But essentially all plants were infected by the end of the growing
season regardless of inoculum density (range = 0.1 - 80 MS/g soil).
Only slight external symptoms occurred at inoculum densities of nine or
fewer MS/g in a friable clay loam soil in which root growth was un-
restricted and plant growth otherwise was favored. Nevertheless, plants
in these blocks with nine or fewer MS/g soil yielded 8-30 percent less
fruit than plants grown in blocks infested with 0.1-2 MS/g soil. Maximum
loss under these conditions was about 40 percent, depending upon the
experiment. In a sandy loam soil with a dense layer 15-60 cm below the
surface, the combination of wilt disease, restricted root growth, and
poor water penetration was devastating to tomato. Maximum yield under

1 these conditions was about 12 tons/acre compared with about 37 tons/acre
2 under the more favorable growing conditions.

3 Additional key words: Verticillium dahliae, V. albo-atrum, soil
4 borne pathogens, fungal disease, epidemiology.

5
6 The importance of Verticillium wilt disease of tomato, Lycopersicon
7 esculentum Mill. has been viewed as nil by some workers and as extremely
8 important by others, as discussed by Jones and Crill (6). Results of
9 their definitive tests, in which noninoculated and inoculated differen-
10 tially tolerant cultivars were transplanted in the field, confirmed the
11 yield reducing potential of Verticillium dahliae Kleb., the cause of this
12 wilt disease. Yield reductions were 67% for Bonney Best, 38% for Walter,
13 and two and 6% for, respectively, Tropic and Florida MH-1. Recognition
14 in 1971 of a strain of V. dahliae that induced severe disease of
15 cultivars having the Ve gene for resistance (8) caused renewed interest
16 in the disease in California (5). The new strain is called tomato
17 strain-2 (5) and affects cultivars with the Ve gene as earlier
18 prevalent populations affected older cultivars such as New Improved
19 Pearson and Early Pak-7 (K. A. Kimble, personal communication). Jones
20 and Crill (6), while showing the yield reducing potential of V. dahliae
21 to inoculated tomato plants, used but one inoculum density of a conidial-
22 mycelial suspension in their tests.

23 We determined rate of infection and disease severity for cotton as
24 well as tomato in differentially infested blocks in the field, using
25 microsclerotia (MS) in naturally infected tomato plants as inoculum.
26 Results for cotton tests are in another preceding paper (2). We also
27 studied root density in relation to infection and disease severity.

1 Tests were made to determine whether plants with restricted root systems
2 were more severely affected by wilt disease than plants with unrestricted
3 root systems. We became interested in mapping root systems following a
4 report by Grimes, et al. (4), which showed that root maps through depths
5 of 150 cm accurately described water extraction by cotton and corn. For
6 instance, plants whose roots were restricted to near surface soil, by a
7 compact subsurface layer, used little water in deeper layers and required
8 more frequent irrigation than plants with unrestricted root systems.

9 MATERIALS AND METHODS

10 Tests were made at two locations in each 1974 and 1975 but inoculum,
11 except for small amounts of native inoculum, was the same at both
12 locations (2). Soils were markedly different. Grimes, et al. (4)
13 described the Hanford sandy loam soil at Kearney Horticultural Field
14 Station (KHFS) as high strength because it had a compacted layer at
15 depths varying from 15-60 cm below the surface. Soil strength is a
16 measure of bulk density and increases as moisture tension increases (9).
17 It limits root extension when it offers an impedance greater than about
18 18 bars (4). Strength of the dense layer at KHFS ranges up to 30 bars.
19 In contrast, West Side Field Station (WSFS) soil was homogeneously low
20 strength to a considerable depth and offered little impedance to root
21 growth (4). We followed the procedure for determining root length
22 described by Newman (7) as modified by Grimes, et al. (4). Briefly, root
23 segments are washed from duplicate 50 g soil samples dispersed with 1%
24 sodium hexametaphosphate. They are decanted into a 15 cm Buckner-type
25 funnel, the filter paper is removed and sandwiched between plexiglass
26 sheets, one etched with 10 mm squares. Root segments crossing one or
27 more lines in 20 random squares are counted. These data form the basis

1 for calculating cm of roots/cm³ of soil.

2 The tomato cultivar Early Pak-7 was used in all tests. Early Pak-7
3 is intolerant of V. dahliae populations then prevalent in California
4 soils, as it also is to the recently discovered pathogenic type named
5 Tomato strain-2 by Hall and Kimble (5). Plots were planted in early
6 April and mature fruit were hand harvested once in late August to late
7 September. Sunburned fruit were accounted for separate from others in
8 both 1974 and 1975.

9 Other more general experimental procedures are described in the
10 preceding paper (2).

11 RESULTS AND DISCUSSION

12 INFLUENCE OF SOILS ON ROOT DEVELOPMENT.- Tomato plants in the high
13 strength soil at KHFS had more roots than did plants in the low-strength
14 soil at WSFS in the surface 30 cm. Root lengths were similar at the 30-
15 60 cm depth at both locations. But, at greater depths, root length was
16 always greater in the low strength soil, Fig. 1. Perhaps of greater
17 importance, root lengths were similar through 90 cm in the low-strength
18 soil whereas root lengths diminished at each 30 cm increment of depth
19 in the high-strength soil, Fig. 1.

20 INOCULUM DENSITY AND INFECTION.- Amounts of infection generally
21 were low, regardless of inoculum density, through mid July. Data for
22 the 1975 WSFS test (Fig. 2) are typical of all four tests. We found
23 that tomato, like cotton (2), had little infection (based upon isolation
24 results) during the first three months of the growing season. There-
25 after, rates of infection varied with inoculum density, with differences
26 between inoculum densities being greatest 1-1.5 months before harvest.
27 By harvest, however, essentially all plants were infected, regardless

1 of inoculum density, Fig. 2. In this regard, the tomato cultivar used
2 in these tests (Early Pak-7) behaved like the cotton cultivars Acala SJ-4
3 and Acala SJ-5 (2). That is, essentially all plants became infected at
4 very low inoculum densities. But it was unlike cultivar Acala SJ-2
5 which required an inoculum density of four or more MS/g soil before
6 essentially all plants became infected (1). Differences in rates of
7 infection observed appeared to be principally influenced by inoculum
8 density, not soils. But inoculum density also had a variable quantita-
9 tive effect due to fungistasis of MS in soil (1).

10 INOCULUM DENSITY AND DISEASE SEVERITY.- SYMPTOMATOLOGY.- In both
11 years, plants in the KHFS high strength soil grew well and were dark
12 green in color until early August when first fruit ripened. Rapid
13 deterioration of vines followed, and most plants were dying by early
14 September. Symptoms were similar at all inoculum densities.

15 Plants grown in the low-strength clay loam soil of WSFS were larger
16 and thriftier in appearance than those grown in the high-strength soil
17 of KHFS in both 1974 and 1975. Except for occasional yellowed leaflets,
18 plants grown at inoculum densities of nine or fewer MS/g soil were free
19 from external symptoms although essentially all plants were infected, as
20 discussed earlier. At the highest inoculum densities (24 MS/g in 1974
21 and 17 MS/g in 1975), however, plants were yellow-green by 1 August,
22 Fig. 3. In addition to yellowing, there was much killing of basal
23 leaves.

24 Sunburn of fruit was especially common at KHFS, where there was
25 essentially total collapse of vines. However, sunburn was not pref-
26 erentially present at higher inoculum densities.

27 YIELD.- Fruit yields at WSFS were greater in 1974 than in 1975 but

1 yield reductions due to wilt disease also were greater in 1974 than in
2 1975. In 1974, yield losses for 2.6, 4.7, and 23.9 MS/g soil were,
3 respectively, 27%, 32%, and 40%, compared to the lowest inoculum density
4 (1.9 MS/g soil), Fig. 4-A. On the other hand, in 1975, yields at 0.1
5 and 2.0 MS/g soil were similar, with 8% and 25% reductions in yield,
6 respectively, for 9.1 and 17.1 MS/g soil, Fig. 4-B.

7 These observations both support and contradict the view of Chupp
8 and Sherf (3) who said that infected plants could be externally symptom-
9 less. But, symptomless plants can, depending upon the growing season,
10 suffer significant losses, Fig. 4-A. Time of infection, as with other
11 systemic diseases, probably is important in this regard. And, the rate
12 of development of infection was faster in 1974 than in 1975. In 1974,
13 maximum infection about 20 July was 32% compared with 11% about the same
14 time in 1975. Similarly, 70% or more of plants, regardless of inoculum
15 density were infected by mid August in 1974. In 1975, however, only the
16 greatest inoculum density had more than 70% infected plants by mid
17 August, Fig. 2.

18 Data for KHFS (Fig. 4-C, -D) are more difficult to interpret than
19 those for WSFS. Yields were poor, regardless of inoculum density at
20 KHFS, and never exceeded 12 tons/acre. The poor performance of plants
21 at KHFS was probably due to the cumulative effects of poor root distribu-
22 tion (Fig. 1), poor water penetration because of the subsurface dense
23 layer, and wilt disease. Whether these parameters might be synergistic
24 is not known since a disease-free treatment was absent. However, tomato
25 appears to be quite tolerant of wilt disease (Fig. 3, 4-A, -B) providing
26 other factors such as root development (Fig. 1) are favorable for plant
27 growth.

FIGURE LEGENDS

Fig. 1. Differential root development of tomato in a homogeneous friable clay loam soil (open bars) and in a sandy loam soil with a root restricting dense layer 15-60 cm below the surface.

Fig. 2. Rate of infection of tomato by Verticillium dahliae at four inoculum densities in a clay loam soil at West Side Field Station, 1975.

Fig. 3. Near absence of symptoms of Verticillium wilt disease at an inoculum density of about nine microsclerotia/g soil (A) compared with severe chlorosis in adjacent block infested with about 24 MS/g soil (B) in a friable clay loam soil at West Side Field Station, 1974.

Fig. 4. Yield of tomatoes under different inoculum densities of Verticillium dahliae at West Side Field Station (upper) in 1974, Fig. 4-A, and in 1975, Fig. 4-B, and at Kearney Horticultural Field Station (lower) in 1974, Fig. 4-C, and in 1975, Fig. 4-D.

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