

## Verticillium Wilt of Pistachio: The Influence of Potassium Nutrition on Susceptibility to Infection by *Verticillium dahliae*

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### ABSTRACT

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The incidence of Verticillium wilt of pistachio, grown in soils with low inoculum densities of *Verticillium dahliae* (0.02–0.2 microsclerotia per gram of soil) increased dramatically during 1981–1983. Increased incidence of disease was associated with unthrifty trees having low levels of leaf K (0.5–0.8%) during midsummer. During 1982, 39.6% of K-deficient trees surveyed were infected. Infection was rare (0.37%) among thrifty trees having 1% or more leaf K. Infection percentages were 18.8, 13.8, and 9.7 in 1983 for, respectively, 1.0, 1.5, and 3.0 kg of K per tree treatments. Tree survival, compared with the 1.0 kg of K per tree treatments, was improved 8% and 13% in, respectively, the 1.5 and 3.0 kg of K per tree treatments

during 1983. Results were similar in 1984 except the 1.5 and 3.0 kg of K per tree treatments were equally effective. Annual increases of infection observed during 1981–1983 were reversed in 1984 following treatments of 1,620 ha with 1.5 kg of K per tree in 1983. No infection of thrifty trees was observed in 1984. Incidence of disease in 1984 was 35% less than that during 1983. Phosphorus deficiency, discovered in 1984, also may influence susceptibility to infection, however, P deficiency was corrected following the peak infection period. Reduced susceptibility to infection appears to be a klendusic response of actively growing trees in low inoculum density soils.

*Additional key words:* phosphorus deficiency, potassium deficiency.

Essentially all pistachio trees grown in the San Joaquin Valley of California have a common rootstock-scion combination; scions are *Pistacia vera* L. 'Kerman' and the rootstock is *P. atlantica* Desf. produced from seed from various sources. Both are susceptible to *Verticillium dahliae* Kleb.(1,3,5). A positive relationship between inoculum density (ID) of *V. dahliae* in soil and the number of young trees with Verticillium wilt was observed. Losses were relatively small in new plantings over a 2-yr period (0.9–5.5%) where ID ranged from 0.02–0.2 microsclerotia (MS) per gram of soil (5), but 85% of trees were killed within 6 yr where ID approached 5 MS/g (3). In 1984, we observed 69% infection of 1-yr-old trees growing in soil having an ID of about 20 MS/g (L. J. Ashworth, Jr., unpublished).

Contrary to observations made on younger plantings, in 1982 we observed up to 18% infection of previously uninfected 8- to 12-yr-old trees growing in a soil where the ID was less than 0.05 MS/g. The maximum percentage of infection observed 1 yr earlier was

about 6%. We report here the relationship between K deficiency (4) and the increased percentages of infection by *V. dahliae* observed during 1981–1983 and on the influence of K nutrition upon the susceptibility of trees to infection by *V. dahliae*. A brief report was made earlier (2).

### MATERIALS AND METHODS

Trees of 28 plantings totalling 1,620 ha were examined for prevalence of K deficiency during midsummer, 1982. Plantings had 119 rows of 174 trees each, except for five plantings which were smaller. In each case, all trees of every fifth row were examined.

A 12% KCl solution was used for soil treatments in amounts of 1.0, 1.5, and 3.0 kg of K per tree during March–April 1983. Infection counts were made on all trees of six two-row replicate blocks of 174 trees per row during 1–15 July in 1983 and 1984. Infected trees had characteristic wilted foliage and vascular necrosis symptoms (5). The number of trees harvested in treatments, as a measure of tree survival, was determined in 1983 and 1984, as described for infection counts. Inoculum density determinations were made as described earlier (7).

In addition to the multiple-treatment, replicated test described above, all trees in the experiment were treated through the drip irrigation system with 1.5 kg of K per tree during the summer of

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1983 (4). Following treatment in 1983, the percentages of infection observed during 1984 were compared with percentages observed during 1981, 1982, and 1983. *Verticillium* wilt counts were made each year during 1-15 July, as described above for counts made of K-deficient trees.

## RESULTS

**Prevalence of potassium deficiency.** Prevalence of K-deficient trees in 28 plantings varied from less than 1% to 32% during 1982 (Fig. 1). Infection of thrifty trees ranged from none to 1.8% (average = 0.4%) of total trees while up to 70% of the K-deficient trees were infected. The average percentage of diseased K-deficient trees was 39.6% in 1982.

**Relationship between potassium deficiency and prevalence of *Verticillium* wilt in low inoculum density soils.** Inoculum densities of *V. dahliae* in all plantings were less than 0.05 MS/g of soil. Low inoculum density resulted from the earlier applications of polyethylene mulches to native desert soils planted with several crops of cotton before planting pistachio trees (3,5). In others, however, low inoculum densities of *V. dahliae*, which is endemic to desert soils (5), persisted after the pistachio trees were planted.

The lowest percentages of diseased trees, whether thrifty or K deficient, were observed in plantings with the lowest numbers of K-deficient trees (2). Data for 10 of the 28 plantings studied (Table 1) illustrate this point. P-deficient trees were easy to classify, but thriftiness of trees was relative. Therefore, error due to subjectivity in classifying such trees may account for the increased percentages of infection of thrifty trees that were observed as the proportion of K-deficient trees increased (Table 1).

**Influence of potassium on *Verticillium* wilt and tree survival.** During 1983, disease was reduced in both the 1.5 and 3.0 kg of K per tree treatments compared to the 1.0 kg of K per tree treatment; no difference was detected between the 1.5 and 3.0 kg of K per tree treatments (Table 2). The percentages of disease observed during 1984 were reduced compared with 1983, but the differences

TABLE 1. Prevalence of K-deficient pistachio trees and the percentage of diseased thrifty and potassium-deficient trees in ten pistachio plantings

Planting no.	K-deficient trees (% of population)	Verticillium wilt <sup>a</sup>		
		Thrifty trees (%)	K-deficient trees (%)	Total infection (%)
1.	1	none	13	0.1
2.	1	0.03	16	0.2
3.	1	none	24	0.2
4.	7	0.17	26	2.0
5.	9	0.41	34	3.5
6.	10	0.15	31	3.3
7.	14	1.75	52	9.0
8.	18	0.17	73	13.4
9.	28	1.04	59	17.5
10.	31	1.75	52	17.9

<sup>a</sup> Inoculum density in all cases was less than 0.06 microsclerotia per gram of soil.

TABLE 2. The influence of potassium treatments applied to pistachio trees in 1983 upon the subsequent incidence of *Verticillium* wilt and the number trees with harvestable nuts in 1983 and 1984

Potassium treatment (kg/tree)	1983			1984		
	Wilt (%)	Harvested (no./row)	Lost <sup>a</sup> (no./row)	Wilt (%)	Harvested (no./row)	Lost <sup>a</sup> (no./row)
1.0	18.8	119	33	12.7	97	22
1.5	13.8	129	23	8.3	112	17
3.0	9.7	136	15	7.5	124	12
LSD, <i>P</i> = 0.05	4.2	10		3.3	13	

<sup>a</sup> Infected trees that died or became unproductive.

between the 1.5 and 3.0 kg of K per tree treatments and the 1.0 kg of K per tree treatment persisted (Table 2). In both 1983 and 1984, the numbers of trees that survived to be harvested were enhanced by K treatments. On 25 April 1983, rows had  $152 \pm 5$  trees. Thus, during the 1983 growing season, an average of 33 trees per row died or deteriorated to an unharvestable condition in the 1.0 kg of K per tree treatment while an average of 16 trees were lost in the 3.0 kg of K per tree treatment (Table 2). Similarly, during the 1983 and 1984 growing seasons, an average of 55 trees in the 1.0 kg of K per tree treatment were lost while only 40 trees and 28 trees per row, respectively, were lost in the 1.5 and 3.0 kg of K per tree treatments (Table 2).

The percentages of diseased trees observed during 1981, 1982, and 1983 were compared with the percentages observed in 1984, 1 yr following treatment of 28 plantings with 1.5 kg of K per tree. The percentages of trees with *Verticillium* wilt increased yearly during 1981-1983 in all plantings (Fig. 2) except in those with few K-deficient trees (Fig. 1). Overall infection during 1984 was reduced approximately 35% compared with 1983, although reductions varied from planting to planting (Fig. 2). No infected thrifty trees were observed in 1984.

## DISCUSSION

Thrifty, nonbearing pistachio trees, although susceptible to *V. dahliae*, had low or high percentages of diseased trees depending upon the ID of the fungus in the soil (3,5). During 1982, however, we determined that apparent susceptibility to infection at low levels of inoculum was altered by K deficiency; 97 to more than 99% of all new infections were associated with K-deficient trees. Thus, total

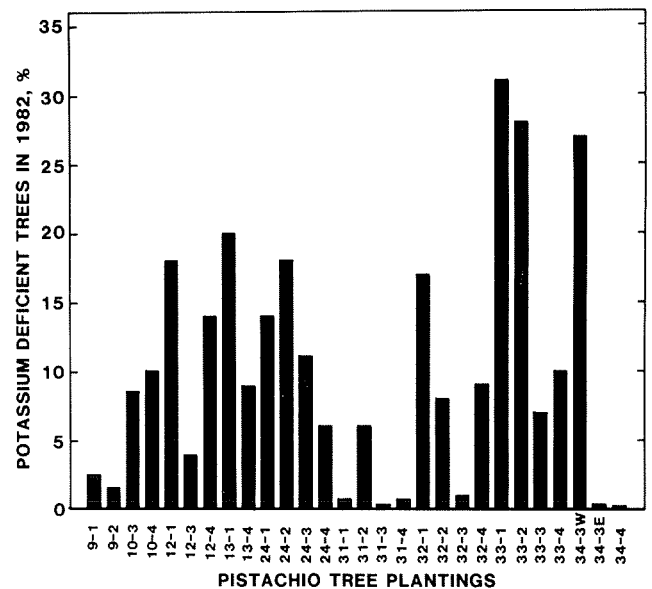


Fig. 1. Prevalence of potassium-deficient trees during 1982 in 28 pistachio plantings.

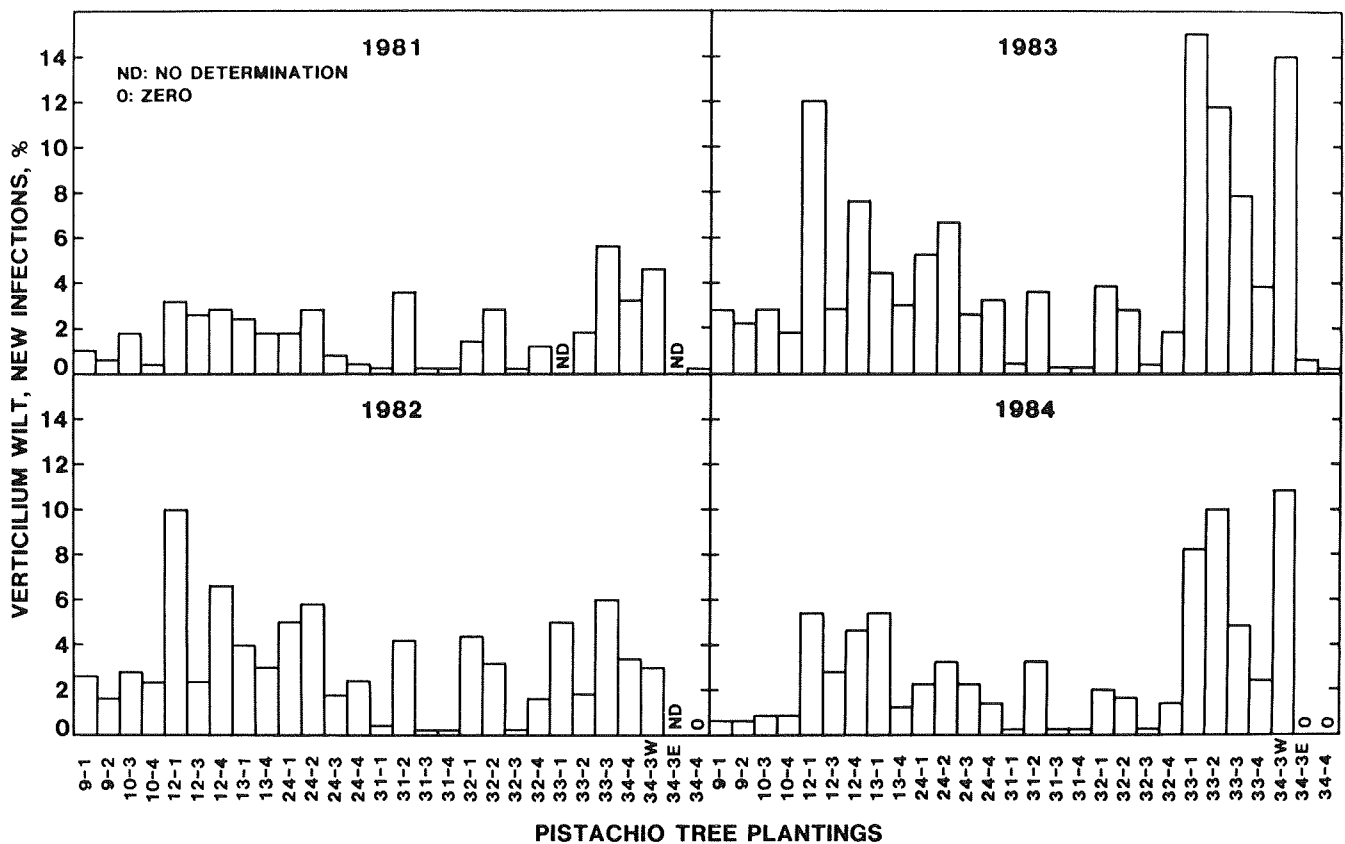


Fig. 2. The incidence of *Verticillium* wilt in previously uninfected pistachio trees of 28 plantings during 1981, 1982, 1983, and 1984. Potassium was applied at 1.5 kg of K per tree in 1983.

diseased trees in plantings depended upon the percentage of K-deficient trees present (Table 1). Recharging exchangeable K in deficient soils (4) resulted in reduced percentages of diseased trees and in lower tree losses during the year of treatment and the year following treatment (Table 2), although a growth response was not observed until the year following treatment (4).

Increased percentages of *Verticillium* wilt observed during 1981–1983 (Fig. 2) paralleled reduced vegetative growth by trees observed during the same years (4). Also, growth resumption during 1984, in plantings treated with K in 1983 (4), also was paralleled by reduced percentages of *Verticillium* wilt (Table 2, Fig. 2). Thus, K deficiency, as it affected growth of trees, caused increased susceptibility to infection by *V. dahliae* in low ID soils. While only shoot growth measurements were made (4), we assume that root growth of K-deficient trees also was reduced.

Reduced root growth may explain why K-deficient trees were much more susceptible to infection than thrifty trees in low ID soils. That is, slowly extending susceptible root tips might be exposed to immobile microsclerotia for longer periods of time than rapidly extending root tips. This would be analogous to increasing the ID of soil.

While trees treated with K in 1983 made substantial growth and had increased nut yields in 1984, vegetative shoot growth ceased by mid-July and P deficiency became obvious (4). We believe P deficiency, which was part of a syndrome observed in 1982 (4), may account for significant percentages of infection observed in 1984, following K treatments made in 1983 (Table 2, Fig. 2). Phosphorus deficiency, thus, may affect susceptibility to infection in the same way as K deficiency. Evidence, however, is lacking since correction of P deficiency on 3 October 1984 followed the peak disease period, (4). If true, deficiency of other essential elements could have the same effect on disease by affecting the rate of rootlet growth.

The *Verticillium* wilt syndrome of nutritionally deficient pistachio trees in low ID soils may be paralleled in the olive

industry of the San Joaquin Valley of California. That is, paradoxical observations between ID and infection in mature plantings have been recognized for 10–12 yr. Repeated assays of soil for *V. dahliae* showed that the average ID of 50 plantings remained about 0.4 MS/g, while annual *Verticillium* wilt rates varied from less than 1% to about 30% under similar ID levels (L. J. Ashworth, Jr., unpublished).

We know of no other reports on the alteration of susceptibility to infection by plant nutrition at inoculum densities of a pathogen that would be inconsequential to thrifty plants. This is not to say, however, that disease escape mechanisms recently reviewed by Huber (6) would not apply if differential inoculum densities were taken into account.

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