Verticillium Wilt of the Pistachio Nut Tree: Occurrence in California and Control by Soil Fumigation

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ABSTRACT

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Virgin soils of the San Joaquin Valley of California are infested lightly with *Verticillium albo-atrum* but are suitable without fumigation for production of pistachio trees. However, 1-3 years of cotton production preceding planting of pistachio trees can result in sufficient fungal inoculum buildup to cause significant losses of trees. Fumigation for control of *V. albo-atrum* with mixtures of chloropicrin-methyl bromide (2:1, w/w) reduced inoculum densities and numbers of trees killed after 2 years to levels comparable to those of virgin soils. In addition, root distribution patterns influenced by the drip-type irrigation system used may contribute to favorable results by forcing root development below the generally infested soil during part of each year.

Additional key words: Verticillium dahliae, inoculum density and disease, *V. albo-atrum* in virgin soils.

The pistachio nut tree, *Pistacia vera* L., is native to Asia and Asia Minor where its fruit long has been a delicacy, being known as nuts of Jacob in biblical records and as batam by the early Arabs (7). It was introduced into Mediterranean Europe during the early Christian era and thereafter into Tunisia, France, Australia, and the USA (9). Pistachio cultivar testing began in 1902 at the U.S. Department of Agriculture Plant Introduction Station at Chico, California, where three adapted desirable cultivars were developed by 1940. One of these, Kerman, contributed to establishment of a small stable industry in the Sacramento Valley in the vicinity of Chico, although to this day, most of the pistachio nuts consumed in the USA still are produced in Turkey and Iran (9). However, about 12,500 hectares (ha) of trees have been planted in the San Joaquin Valley during the past 10 years. These trees are grown under irrigation and appear to have great production potential, barring serious damage from pests and diseases.

Pistachio trees have no known lethal diseases in Turkey and Iran, where trees may attain trunk girths of 1.97 m (6 feet) and remain productive for as long as 700 years (9). However, orchards are threatened by Verticillium wilt [which is caused by *Verticillium albo-atrum* R. and B. (*V. dahliae* Kleb.)] in the San Joaquin Valley, although not in the Sacramento Valley of California. Other tree, vegetable, and field crops susceptible to *V. albo-atrum* have been grown for many years on much of the arable land in the San Joaquin Valley and serious disease-inducing quantities of microsclerotia (MS) of the fungus are detected in most soils (1, 2). A similar situation occurs in Greece (8).

We report here on the occurrence of *V. albo-atrum* and wilt disease of pistachio in the San Joaquin Valley, both in virgin lands and in lands farmed since 1968 but which have produced no more than three susceptible crops (cotton). We also report on control of the disease by soil fumigation.

MATERIALS AND METHODS

About 900 ha of land were involved in this investigation. Individual blocks ranged from 20 to 94 ha in size. Assays for *V. albo-atrum* were made on composite samples of 10 core samples taken 0-30 cm deep and 60 m apart. Ten such composite samples were taken for a 67-ha block and proportionately fewer or more samples were taken, respectively, from smaller or larger blocks. Soil samples were handled and assayed as reported earlier (2, 3).

Soil was fumigated with a chloropicrin-methyl bromide mixture (2:1, w/w) as described by Wilhelm et al. for strawberry plantings (11, 12). Assays for *V. albo-atrum* were made before and after fumigation in the fall. Trees were planted in the spring and infection counts were made during October and November when disease intensity was maximum. Infection counts were based upon a desiccated leaf symptom, Fig. 1-A, B. It always is associated with necrotic vascular tissues, from which the fungus is readily isolated. All trees of each block were examined for infection in 1974, as were most in 1975. In a few cases in 1975, infection counts were based upon examination of 5,000 trees per block.

A qualitative estimate was made of the moisture distribution pattern in soil resulting from drip-type irrigation systems (6) used in the pistachio groves. Beginning 0.2 m from the water emitter (which was located about 0.6 m from the tree in the tree row) we determined with a soil tube the depths between tree rows at which soil moisture levels of about field capacity occurred. This was done by making vertical probes, in 0.2

m increments, until moist soil was reached. This was repeated every 0.2 m through 3 m outward from the tree row. Tree rows were 5.5 m apart. Determinations were made for four trees and mean values are reported here.

RESULTS AND DISCUSSION

Some pistachio trees show symptoms of infection by *V. albo-atrum* during spring months, but leaf and vascular necrosis symptoms are most pronounced in October and November. Leaves of affected branches become yellow then desiccate quickly and assume a light tan color, but remain attached for an extended period of time (Fig. 1-A, B). Xylem necrosis is a pronounced internal symptom of the disease and extends well out into small upper branches by the time foliage symptoms appear. The fungus appears to spread rapidly through infected trees, killing most during the first year of infection although some trees survive beyond the first year.

Verticillium was detected only in trace amounts (3) (0.02-0.05 MS/g of air dry soil) in three virgin blocks of land and tree losses were 0.6-1.9% during two growing seasons (Table 1). One end of a fourth field of virgin soil was subjected for several years to periodic flooding due to runoff of irrigation water from an adjacent cotton field. Inoculum density of *V. albo-atrum* was quite high in this part of the field (1.84 MS/g soil), which caused the field average to be higher than in other virgin soils (Table 1). Most infected trees occurred at the flooded end of the field.

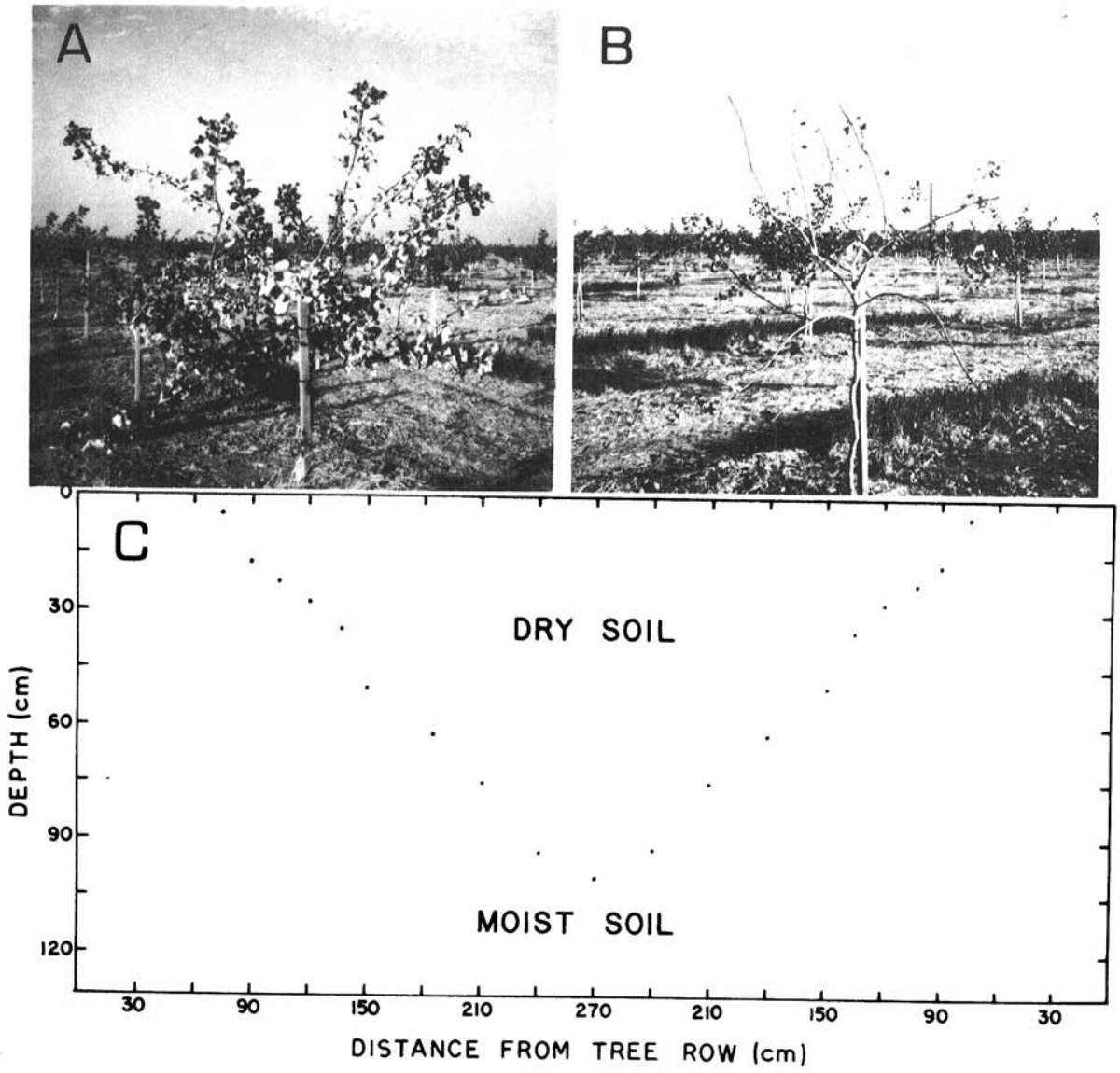

Fig. 1-(A to C). Two-year-old pistachio trees infected by *Verticillium albo-atrum* showing **A)** partial- and **B)** nearly complete defoliation. A typical soil moisture distribution pattern **C)** in orchard soil watered by drip-irrigation emitters (one per tree) located at the soil surface 0.6 m from trees in the tree row.

TABLE 1. Numbers of *Verticillium albo-atrum* propagules [microsclerotia (MS) per gram] in virgin and newly-cropped desert soils of the San Joaquin Valley of California, percentages of pistachio trees killed by different amounts of the fungus in soils, and control of wilt disease by soil fumigation

Years of cotton before pistachio	Verticillium in soil[a]			Trees killed (%)	
	Soil fumigation	Before fumigation	After fumigation	1974	1975
None	No	TR[b]	. . .	0.4	0.4
None	No	TR	. . .	0.4	1.5
None	No	TR	. . .	0.4	0.2
None[c]	No	0.37	. . .	. . .	1.6
1	No	0.10	. . .	2.4	0.8
1	No	0.20	. . .	4.3	1.2
3	No	1.03	. . .	9.5	0.8
3	No	1.20	. . .	8.9	1.5
3	No	2.03	. . .	12.5	1.5
3	Yes	7.60	TR	None	0.4
3	Yes	5.12	TR	0.8	1.2
3	Yes	6.54	TR	None	0.9

[a]Number of microsclerotia (MS) per gram of air-dry soil.
[b]Trace, 0.02 – 0.05 MS/g air-dry soil.
[c]One end of field subject to irrigation runoff from adjacent cotton field; inoculum density of periodically flooded portion of field was 1.84 MS/g soil.

Nonfumigated lands planted 1 year with cotton had higher inoculum densities of *V. albo-atrum* than virgin soils and cumulative tree losses were 3.2-5.5% (Table 1). Inoculum densities (1-2 MS/g soil) and tree losses (10.3-14%) increased further after three crops of cotton (Table 1). Fumigation reduced inoculum densities of the fungus in soils, cropped 3 years with cotton, from five or more MS/g soil to trace amounts. Two years after planting, tree losses were no greater than observed in virgin soil plantings (Table 1).

Infection percentages for pistachio trees in soil previously cropped but not fumigated were much lower in 1975 than in 1974 (Table 1). Attrition of the fungus does not appear to explain this observation. Although *V. albo-atrum* has little saprobic ability in soil (4), MS are quite persistent (1, 5). But root distribution, as influenced by cultural practices in 1975, may be important. The groves were interplanted with wheat that was sprinkler-irrigated. Following maturity of the wheat, the trees were individually irrigated with a drip-type water emitter (6) located about 0.6 m from each tree. Thus, the interplanted wheat used readily available moisture between tree rows and it was not replaced during summer and early fall months by the drip-irrigation system (6) (Fig. 1-C) which apparently encouraged root distribution below the zone of greatest *V. albo-atrum* infestation (10).

These observations indicate that virgin soils of the San Joaquin Valley are suitable for production of pistachio trees although some losses from infection by *V. albo-atrum* may be expected. Tree losses in fumigated, previously-cropped soils were comparable, during 2 years, with losses in virgin soils.

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