Polyethylene tarping controls verticillium wilt in pistachios

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Large-scale plantings of pistachio nut trees in the San Joaquin Valley began in about 1970, although a small commercial acreage existed 30 years earlier in the Sacramento Valley. Once begun, new development rapidly increased in the past decade from a few hundred to about 32,000 acres in production.

Although the climate in the San Joaquin Valley favors tree growth more than in the Sacramento Valley, verticillium wilt, caused by the fungus *Verticillium dahliae*, was soon found to limit the success of many San Joaquin Valley plantings. Groves planted on virgin or pasture soils initially did very well, because such soils had nonexistent or low infestations of the fungus. But groves on soils with histories of susceptible row crops, such as cotton, lost as many as 30 percent of the trees in the first year.

Some trees are killed the first time they are infected, but others recover and may be free of symptoms for one or more years. Results of tests show, however, that such trees are very likely to be reinfected in another year. Observations made in two groves in 1981, for instance, showed that 39 and 33 percent of trees infected in 1980 had symptoms again in 1981, while 4 and 6 percent of trees in the same groves, healthy in 1980, were infected in 1981.

Attempts have been made to halt progress of the disease within affected groves by removing dead trees and fumigating individual tree sites with methyl bromide-chloropicrin mixtures. Likewise, attempts have been made to protect healthy trees from infection with injections of a systemic fungicide, benomyl. Neither procedure was successful. However, an adaptation of the "solarization" procedure (discovered by J. Katan, Hebrew University, Jerusalem, Israel) has proved very effective in young affected pistachio groves.

Katan found that covering moist fallow soil with clear polyethylene tarps for several weeks during hot summer weather controlled verticillium wilt and other disease and weed pests in subsequently planted annual crops. Disease control was attributed to soil heating under tarps.

Tarping existing plantings of trees is a departure from the standard soil solarization procedure. We had four major reservations about success of the procedure: the possibility of significant root damage due to elevated temperatures; the effect of shade on soil temperature, especially on the north side of trees; the impact of tree infection before tarping on disease incidence after tarping; and the possibility of relatively deep-placed fungal inoculum escaping the influence of solarization, since assay results showed the inoculum occurred as deep as 4 feet. Nevertheless, we began a series of experiments in 1978 in a drip-irrigated grove of one- to six-year-old trees.

In the first test, inoculum density (ID) of *V. dahliae* was 4.6, 1.5, 0.3, and 0.2 microsclerotia (MS) per gram of soil at depths of 0 to 8, 8 to 16, 16 to 24, and 24 to 32 inches, respectively. The test was begun on about 1 July to take advantage of high summer temperatures. After preirrigation (using furrows) to wet soil to a depth of 4 feet, the entire soil surface was covered with overlapping, clear, 6-mil-thick polyethylene sheets (tarps), which were slit to go around trunks of trees. The tarps were held in place, where they overlapped, by bands of soil applied by hand.

Two weeks after tarping, inoculum at the 6-inch depth was essentially eradicated in unshaded tarped areas but was unchanged on the north sides of trees, where shading occurred daily. Six weeks after tarping, however, the fungus was reduced to nondetectable or trace amounts (less than 0.05 MS per gram soil) in unshaded and shaded areas. These amounts are comparable to amounts observed in virgin desert soils and result in little infection to pistachio trees. Tarping caused no damage to trees.

Other small tarping tests were made each month from December 1, 1979, through May

TABLE 1. Influence of clear polyethylene tarps and preirrigation on reduction of inoculum density of *Verticillium dahliae* after two months during summer, 1979

Pre-irrigation	Sampling depth	Inoculum density (number of microsclerotia/g soil)						
		Un-mulched control	Solid tarps		1.5-ft space between tarps in rows		4-ft space between tarps in rows	
			Tree rows	Middles	Tree rows	Middles	Tree rows	Middles
	ft							
Yes	1	4.6	0.07	ND†	0.3	ND	3.7	TR
Yes	2	0.9	TR*	ND	0.8	TR	0.9	TR
Yes	3	0.6	TR	ND	0.8	TR	0.5	TR
Yes	4	0.4	TR	ND	0.7	TR	1.1	TR
No	1	—	0.05	ND	0.1	ND	1.5	ND
No	2	—	TR	ND	0.2	TR	0.8	0.1
No	3	—	TR	TR	0.1	TR	0.5	0.1
No	4	—	TR	ND	0.1	TR	0.7	0.1

*Trace, less than 0.05 microsclerotia (MS)/g soil.
†Not detected.

1980. Tarps were removed after two months, and the amount of inoculum remaining was determined. We found that tarping in winter (December) to early spring (April) did not control *V. dahliae*. Inoculum density of the fungus was unchanged two months after tarps were applied between December and April. Tarping in May was moderately effective in unshaded but not in partly shaded areas. Tarping in June was not tested.

We conducted a large experiment in July 1979. The amount of *Verticillium* inoculum (ID) was 4.6, 0.9, 0.6, and 0.4 MS per gram at depths of 0 to 1, 1 to 2, 2 to 3, and 3 to 4 feet, respectively. In this test we investigated whether preirrigation, as suggested by Dr. Katan, was essential or whether moisture held by the undisturbed soil was adequate. We also determined whether coverage of the entire soil surface was necessary or whether some space between tarps could be tolerated. Spaces between tarps occurred in the tree row, eliminating the labor required to slit and pull them around trees. Tarps 4 mils thick were laid by hand and held in place by bands of soil as before. They were removed after two months.

Complete tarping in July killed the wilt fungus, as before, to a depth of at least 4 feet (table 1). This was true whether soils had only moisture from winter rains and from drippers near trees, or whether the entire soil profile was irrigated with sprinklers immediately before the test. Any space between tarps reduced their effectiveness, although the tarped portions of these treatments were as effective as the complete tarping treatment.

We observed about 75 percent control of wilt in 1980 following complete tarping in 1979; that is, 6.3 percent of the trees in untarped areas were infected compared with 1.5 to 1.7 percent infection in completely tarped areas. Treatments with spaces between tarps were less effective than the completely tarped treatment (table 2), which agrees with inoculum control data just described.

TABLE 2. Influence of clear polyethylene tarps applied in summer 1979 on control of verticillium wilt of pistachio trees in 1980

Pre-irrigation	Amount of infection by *Verticillium dahliae*			
	Control	Space between tarps		
		None	1.5 feet	4 feet
	%	%	%	%
No	6.3	1.7	3.6	3.1
Yes	—	1.5	3.1	3.7

TABLE 3. Influence of moisture and temperature upon survival of *Verticillium dahliae* microsclerotia in moist field soil under laboratory conditions

Exposure period	Survival of microsclerotia*			
	86°F	95°F	104°F	112°F
	%	%	%	%
4 hr	100	100	14	3
24 hr	100	100	7	TR†
32 hr	100	100	3	TR
1 wk	100	100	ND‡	ND
4 wk	100	100	ND	ND
8 wk	100	100	ND	ND
11 wk	100	TR	ND	ND
16 wk	100	ND	ND	ND

*Percent of initial inoculum density (14 MS/g soil).
†Trace, less than 0.5 percent of initial inoculum density.
‡Not detected.

Efficiency of the tarping treatment is increased where previously and currently infected trees are removed before tarps are applied. This is because, as mentioned earlier, 30 to 40 percent of trees that survive initial infection will be reinfected in the following year. Thus, 1.3 and 4.6 percent infection was observed in the year after tarping in a test comparing, respectively, tree removal and no tree removal before tarping.

The total amount of infection observed in the year following tarping also is affected by trees that develop symptoms of verticillium wilt during the tarping period. In this experiment, about one-half of infections observed in the following year were accounted for by such trees, since only 0.6 percent of trees were infected for the first time and the total infection was 1.3 percent. It is not known whether the wilt fungus survived in these trees or whether they were reinfected by soil-borne inoculum of the fungus in 1981. Some survival in pistachio trees may occur, since the fungus is known to survive in olive trees in some years. It seems prudent to remove infected trees as they are discovered.

Tarping of pistachio trees appears to have potential for a long-lasting effect, since there is no evidence of inoculum increase three years after our first treatments and two years after second treatments were made. Inadequate control of susceptible weeds, which can induce increases in the fungus inoculum, could alter this outlook. But, with regard to reinfestation, the amount of infested soil used to anchor tarps in our tests does not appear detrimental when it is returned to the soil surface after tarps are removed.

We performed other experiments to obtain information for interpreting tarping test results. The influence of temperature on survival of *V. dahliae* microsclerotia in naturally infested soil was determined in the laboratory. Also, soil temperature was monitored in bare and tarped soil from December 1979 to September 1980.

Soil heating induced by tarps appears to account for death of the survival structures (microsclerotia) of the wilt fungus to a depth of a least 1 foot, since temperature at that depth exceeded 104°F, which is lethal within 32 hours (table 3). Soil at a 2-foot depth or more, however, was not heated sufficiently to account for death of microsclerotia.

Although the precise cause or causes for success of tarping of young pistachio groves are not known, the method appears to have practical value. It is expensive, however, ($400 to $1,000 per acre).

Thus far, 4,000 to 8,000 acres of trees have been treated commercially. Some tarping has been done with equipment designed for soil fumigation. Tarps are made continuous with glued joints, using an ultraviolet-resistant glue, which costs about twice as much as standard glue used in fumigation but has a useful life of about two months. Blackwell Land Company is also using equipment it has developed, which lays tarps and deposits a band of soil where they overlap to hold them in place. After tarping, a modified hay baler designed by Berenda Mesa Farms collects the sheets in rolls for disposal.

We are now conducting tests to determine whether tarping is of value in older groves where soil receives little direct sunlight. Other experiments are under way to determine whether individual tree sites and small affected areas can be successfully treated.

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