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SOIL FUMIGANTS FOR CONTROL OF PHYTOPHTHORA ROOT ROT

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Research on soil fungicides at the University of California, Riverside, has covered a number of aspects over the past 20 years, including studies of soil fumigants for attempting to eradicate the avocado root rot fungus *(Phytophthora cinnamomi)* studies of chemical barriers, and studies of fungicides that can be applied to living trees. This paper concerns work on soil fumigants for eliminating or severely reducing the root rot fungus population.

All of the chemicals that show promise in eliminating or greatly reducing the root rot fungus in soil are of the fumigant type, which are highly injurious to avocado trees at the rates necessary to be effective against the fungus. Thus, these chemicals have been tried in areas where the trees were removed and the area treated, with the object of later replanting to avocados.

Chemicals that have shown good results in these tests over the past 20 years are: Vapam (sodium methyldithiocarbamate), Mylone (dimethyltetrahydro thiadiazinethione), D-D (mixture of dichloropropanes and dichloropropenes), Telone (dichloropropene), and methyl bromide.

If applied at sufficiently high dosages all of these chemicals will penetrate soil well and kill *P. cinnamomi.* As examples of this, the following table from some of our tests with these materials in large containers is of interest.

		Kill of P. cinnamomi at					
		1"	6"	12"	18"	24"	
Treatment	Gal/acre						
D-D	37.5	—	—	—	—	—	
	75	+	+	—	—	—	
	150 (6" injection)	+	+	+	+	+	(8% soil moisture)
	150 (8" injection)	—	+	+	+	—	(18% soil moisture)
	150 (12" injection)	—	+	+	+	+	(4% soil moisture)
	150 (12" injection)	—	—	+	+	—	(19% soil moisture)
Vapam	50 ppm	+		+		+	
	100 ppm	+		+		+	

Following these early tests that showed that these materials were good fungicides against the avocado root rot fungus, nearly 1,000 tree sites were treated in field plots in San Diego, Orange, Los Angeles, Ventura and Santa Barbara counties to test these materials under field conditions. The objectives of these tests were: to determine if the fumigants would penetrate soil and kill *P. cinnamomi* under field conditions as well as they had in the glasshouse tests, to determine if avocado trees could be successfully

replanted in fumigated areas, and, in a few cases where only one or two diseased trees were present, to determine if the avocado root rot fungus could be eradicated.

As examples of penetration of the chemicals, the following tables show occurrence of the avocado root rot fungus in several plots before treatment and at intervals after treatment.

			Occurrence of Avocado Root Rot Fungus at Various Depths:						
Plot	Fumigant		0-6"	6-12"	12-18"	18-24"	24-30"	30-36"	36-42"	42-48"
1	Telone	A	+	+	0	+	0	+	+	0
	150 gal/acre	B	0	0	0	0	0	0	0	0
	6" injection	C	0	0	0	0	0	0	0	0
		D	0	0	0	0	0	0	0	0
		E	0	0	0	0	0	0	0	0
2	Telone	A	+	0	0	0	+	0	0	0
	150 gal/acre	B	0	0	0	0	0	0	0	0
	12" injection	C	0	0	0	0	0	0	0	0
		D	0	0	0	0	0	0	0	0
		E	0	0	0	0	0	0	0	0
3	D-D	A	+	+	0	0	0	0	0	0
	150 gal/acre	B	0	0	+	+	+	+	0	0
	6" injection	C	0	0	0	0	0	0	0	0
4	D-D	A	+	+	0	0	0	0	0	0
	150 gal/acre	B	0	0	0	0	0	0	0	0
	12" injection	C	0	0	0	0	0	0	0	0
5	Vapam									
	1 qt/100 sq ft	A	+	+	+	+				
	4 gal water/	B	0	0	0	0				
	sq. ft	C	0	0	0	0				
		D	0	0	0	0				
		E	0	0	0	0				
6	Vapam									
	1 qt/100 sq ft	A	+	+	+	+	0	0		
	4 gal water/	B	0	0	0	0	0	0		
	sq. ft	C	0	0	0	0	0	0		
		D	0	0	0	0	0	0		
7	Vapam									
	1 qt/100 sq ft	A	+	+	+	+	0	0		
	4 gal water/	B	0	0	0	0	0	0		
	sq ft	C	+	+	0	0	0	0		

A = recovery of root rot fungus before treatment
B = recovery of root rot fungus 1 month after treatment
C = recovery of root rot fungus 3 months after treatment
D = recovery of root rot fungus 6 months after treatment
E = recovery of root rot fungus 1 year after treatment

These results and similar ones from many treated areas indicated that these fumigants

could be effective under field conditions in drastically reducing the root rot fungus, and possibly eliminating it from small areas. Most of the areas treated were small — ranging from 10 x 10 ft. squares to 20 x 20 ft. squares, with some larger areas involved (20 x 150 ft.). In some plots, as noted above with plot 7 with Vapam, the treatment was not successful. Usually Vapam is more effective when applied in a split application — applying one-half of the chemical followed by one-half of the volume of water, then applying the remainder of the chemical, followed by the rest of the water. Methyl bromide was more effective on relatively light, well-drained soils than on soil with considerable clay. Recent research on this fumigant has shown that it is more effective in dry than in wet soils.

Following fumigation of these plots most of them were replanted to young avocado trees or seedlings, and observations were made on growth of the new trees and the occurrence of the root rot fungus. The following table indicates some of these results on elimination of the fungus:

Fumigant		*No. of Infested Tree Sites Treated*	*Per cent of tree sites from which avocado root rot fungus eliminated*
Vapam	27.5 gal/acre	18	22
	40	19	42
	55	6	67
	82-165*	55	91
Telone	75 gal/acre	2	0
	150	6	100
	300	4	100
D-D	150 gal/acre	4	100
	230	1	100
	300	5	100

* (Use of 1 qt. of Vapam per 100 sq. ft. is a dosage of 110/gallon-acre)

Many of these plots were planted to avocado trees, and observations made as to growth and cultures made to record recurrence of the avocado root rot fungus. As an example, of 58 trees replanted in areas fumigated with D-D (or Dowfume N, an earlier commercial product of the Dow Chemical Company), one year later 42 were in good condition, 13 showed indications of root rot, and 3 were definitely affected with root rot. The situation was similar in plots treated with other fumigants — in the first year or two the majority of the trees made excellent growth, but as the time after planting increased the percentage of sites re-invaded by the root rot fungus increased greatly. This was anticipated, as in the case of most of the plots there were other diseased trees nearby on the same grove.

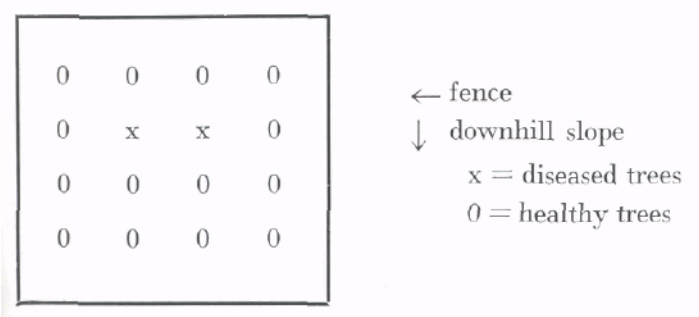
In several cases, with localized infections, it was possible to treat the entire infected area (as determined by making culture tests for the presence of *P. cinnamomi)* and to eliminate the fungus, on the basis of samples taken several years after treatment. The tests in the glasshouse and in the small plots had indicated that this could be possible,

under ideal conditions for treating all of the infested soil. These successful eradications were on small areas with 1 or 2 diseased trees. In the case of one isolated tree site fumigated with Vapam, the fungus was eliminated, based on samples at intervals up to 2 years, with samples taken to a depth of 6 feet.

Recently we have had opportunity to treat additional limited infections and try to eliminate the fungus. Also, a grower in Fallbrook, Mr. Allen Chaikin, has done an exceptionally thorough fumigation treatment to apparently eliminate the avocado root rot fungus from his diseased area.

In one of our plots, one young avocado tree in Fallbrook was found to be infected with *P. cinnarnomi.* with no other trees in the grove showing infection. The area was sampled to 24", on three sectors radiating out from the tree, then fumigated with 2 Ib. methyl bromide per 100 sq. ft. of soil surface and covered with a 6 ml polyethylene tarpaulin for 30 days. Samples taken at intervals up to 15 months after treatment indicate no further occurrence of *P. cinnamomi.*

On Mr. Chaikin's grove, samples we took in September 1968 showed that only two trees were diseased, and we recovered the fungus at the following depths from 5 locations under these two trees: 12-18", and 24-30". Mr. Chaikin then set up his very thorough treatment regime which involved: 1) turning off the water from 16 trees in the area (shown in the accompanying diagram); 2) enclosing the diseased trees and 14 other surrounding trees, as indicated in the accompanying diagram with a 4 ft. "chick tight poultry fence"; 3) treating the surface soil over the entire 16-tree area with Vapam solution, beginning with the outside of the plot and working inward; 4) fumigating the entire 16-tree area with Telone at a dosage of approximately 600 gallons per acre, injecting 18" deep at 12" intervals, then covering with 4 ml polyethylene tarpaulin for 10-15 days (this was done in 20 ft. wide strips across the plot); 5) cutting off the trees at the ground level and burning the tops on the site. When working in the diseased area, Mr. Chaikin and helpers put on boots which were left inside the area on leaving the fenced plot.



Since this fumigation treatment we have taken three series of samples in the area: in December 1968, March 1969, and July 1970. The cultures have shown no recurrence of the avocado root rot fungus in this time, so it looks very much as though the treatment has eliminated it in this area. This area has been replanted to avocado trees (Hass on Duke 6 cutting which we provided), and to date (October 1970) the trees are growing

well and show no sign of root rot.

We have also recently made cultures from another plot in Santa Barbara county, involving 2 diseased trees and 4 adjacent healthy trees. This plot was fumigated by the grower with methyl bromide, and also with Vapam around the edges of the diseased area which were on a slope down into a small creek. Samples taken 6 months after treatment show no avocado root fungus in that treated area.

In addition, another eradication plot was established earlier this summer in Fallbrook, in an area where only one tree was diseased in one area of the grove. On this plot the area was first treated with Vapam (at the rate of 2 quarts per 100 sq. ft., followed by 2 gallons of water per sq. ft.), then fumigated by injecting Telone at a 12" depth at 12" intervals, at the rate of 440 gallons per acre, then the area was covered with a 6 ml polyethylene tarpaulin for 2 weeks. Samples taken two months after treatment show no occurrence of the fungus.

Thus, several fumigants are available for attempting to eliminate small-sized infections from the avocado grove, as outlined in our Circular 511 (Zentmyer, G. A., A. 0. Paulus & R. A. Burns, Avocado Root Rot, 1967. Univ. of Calif. Circular 511; 16 pp.) This type of treatment is worth trying, particularly where only a few trees are involved. For the best possibility of success the area should be treated as early as possible. In some cases diseased trees will show up in the first year or two after planting; this is an ideal time for eradication trials. All possible precautions should be taken to avoid spreading the infection before the area is heavily fumigated — such as fencing the area, keeping traffic completely from the area, and diverting drainage water from the area if it is above healthy trees.

Suggested amounts of fumigants to provide a heavy dosage are as follows:

Vapam or VPM: Use 2 quarts per 100 sq. ft. of soil surface; this should be applied in a split application, with 1 quart followed with 1-2 gallons of water per sq. ft. of soil surface, then the other quart, followed by 1-2 gallons of water per sq. ft. The amount of water to be applied will depend on depth of the soil; with shallow soils (24-30"). 2 gallons of water per sq. ft. should be sufficient.

D-D or Telone: Inject at the rate of 300 gallons per acre, at a depth of 12 inches, with injections 12" apart and rows of injections staggered. Cover with a plastic tarpaulin for 2-3 days.

Methyl bromide: Use 2 Ibs. per 100 sq. ft. of soil surface to be treated. Inject under a heavy (4-6 "mm) polyethylene tarpaulin and leave tarpaulin on for at least one week.

Mylone: Use 4 Ibs. of 50% formulation per 100 sq. ft. of soil surface. Spread evenly over soil surface, and follow with from 2 to 4 gallons of water per sq. ft., depending on depth of soil.

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