New Method . . .

Control Root Rot in Replant Sites

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Root rots of plants are caused by many and diverse fungi that live in the soil. These pathogenic fungi invade and destroy host root systems under varying conditions of soil moisture and temperature. The most common cause of death of a very large number of woody plants during the summer months in many areas of Arizona is a root rot caused by the soil-dwelling fungus, *Phymatotrichum omnivorum.* This fungus is indigenous in soils of much of the southwestern United States and parasitizes more than 2000 species of dicotyledonous plants.

Although the disease is known to occur at elevations as high as 5000 feet in Arizona, it is much more common and serious at elevations below 3500 feet where higher summer temperatures favor disease development. Symptoms of the disease consist of rapid wilting and death of infected plants, primarily during the hot months, June through September. The foliage dries rapidly and usually remains attached to the plant. Spore mats (cottony-white to tan in color, spreading, irregular in outline) of the fungus are often produced on the surface of soil around diseased plants following rain or irrigation during the summer months. Positive identification of the organism, however, usually requires microscopic examination of infected roots.

When the disease is detected before root damage is extensive a technique developed by Dr. R. B. Streets of the Department of Plant Pathology has been successfully used for a number of years in preventing or delaying plant death. This treatment consists of incorporation of manure, soil sulfur, and ammonium sulfate into the soil at the base of the infected plant. The method is described in detail in Folder 157, "Control of Texas Root Rot in Trees and Shrubs," which may be obtained from the Cooperative Extension Service, University of Arizona. Success of the method is attributed to creation of a soil environment favorable for plant growth but unfavorable for activity of the fungus pathogen.

When a plant dies, however, the fungus produces in the soil and on the dead roots specialized structures known as strands or filaments. These fungus structures enable the pathogen to survive for long periods of time in the soil and function as infective propagules. A method of soil treamtent that would eliminate these infective structures would facilitiate the planting of susceptible plants into the infested area. A successful chemical must be not only safe to use and highly active against the fungus, it must be able to penetrate the soil from surface application. During the past 2 years we have evaluated a large number of chemicals and fumigants to determine if they could be used to control Root Rot. The purpose of this paper is to report the results of these studies and to recommend the use of a specific soil fumigant for control of Root Rot in replant sites.

Soil Studies — Laboratory studies consisted of incorporating chemicals at various concentrations into two very different soil types, Superstition sand from Yuma and Gila silt loam from Marana. The fungus was then introduced into the treated soils which were moistened and incubated. Soil samples were watered after different periods of time to determine the effect of the chemical on the fungus. Movement of the chemicals in soil was determined by adding the materials in water to the sur-

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***Trade names used in this publication are for identification, only, and do not imply endorsement of products named, or criticism of similar products not mentioned.*

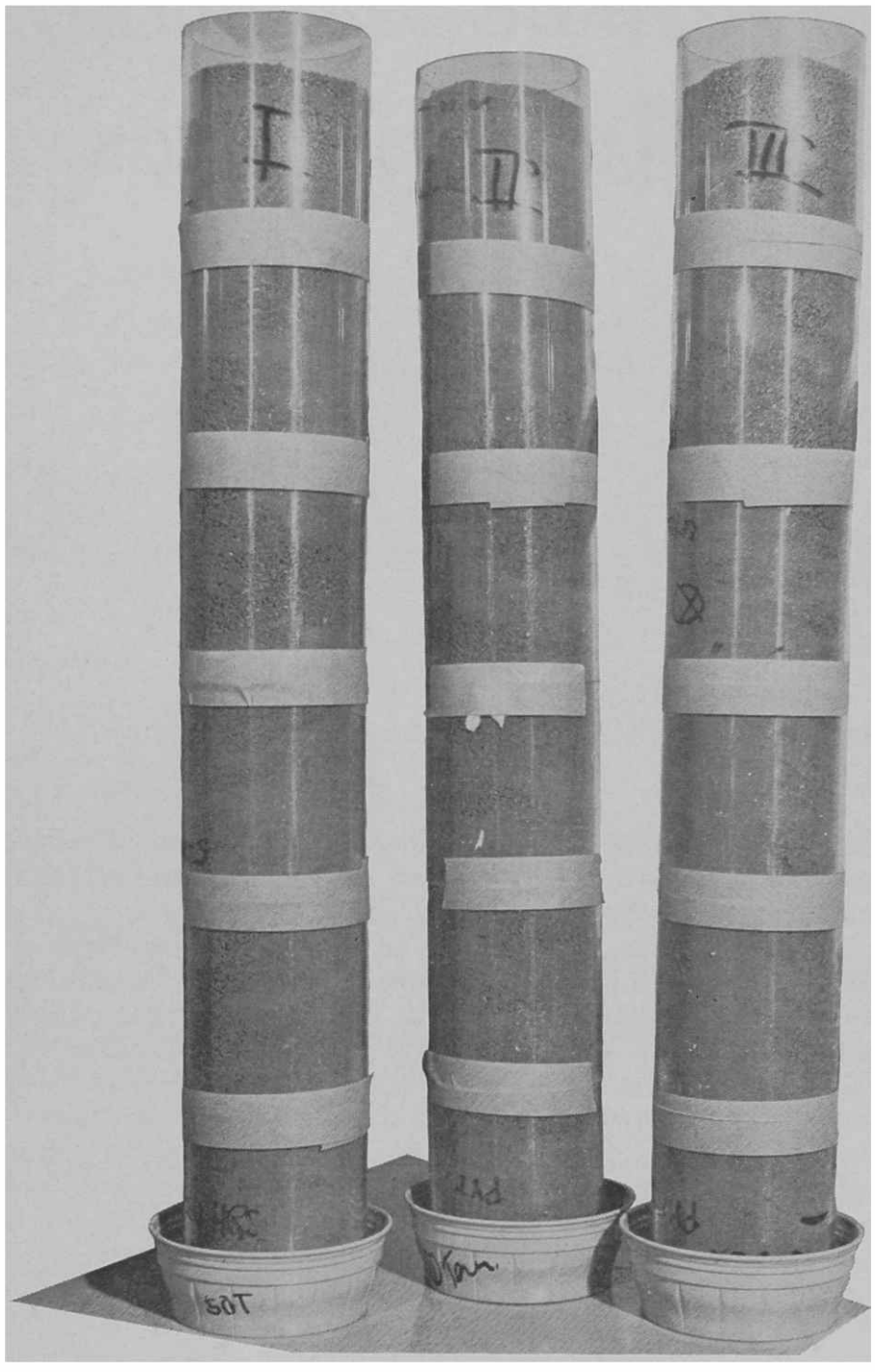

Figure 1. Examples of soil columns designed to determine movement of fumigants and other fungicides in soil.

face of soil held in columns 2 feet in length and 3 inches in diameter and determining movement in relation to the water front movement. Chemical location and distribution was determined by effect on the fungus which had been placed at different depths in the soil columns. Three such soil columns are shown in the photograph (Figure 1).

More than 60 chemicals were evaluated. Sodium methyldithiocarbamate, (sold under the trade names, Vapam**-Stauffer Chemical Co. and VPM**-DuPont) a water soluble chemical that decomposes in moist soil to release a volatile fraction highly toxic to the Root Rot fungus, was shown to be the most active chemical with fumigant activity. A number of other chemicals were shown to be highly active against the fungus but were eliminated from further study because of lack of movement through soil. The comparative activity of Vapam** and 2 other fumigants shown to be active in preliminary studies, Vorlex (dichloropropene-dichloropropane mixture plus methylisothiocyanate) and Telone** (1,3-dichloropropene and related hydrocarbons), was studied. Vapam, when applied as a soil drench at a concentration of 250 ppm in enough water to wet the soil column, killed the fungus at 20 inch depths in the soil columns where as Vorlex and Telone were inactive at this level. All three fumigants killed the fungus at the three soil levels (4, 12, and 20 inches) when applied at 500 ppm concentration (Table 1). In other studies, Vapam concentrations of 50 ppm or higher (based on soil weight) applied as a soil drench killed the fungus at 4, 12, and 20 inch depths in soil columns of Superstition sand and Gila silt loam. At 25 ppm the fungus was killed at depths of 20 inches in the sand but not in silt loam indicating deeper movement of the chemical in the sand (Table 2).

Table 1. Comparative activity of the soil fumigants Vapam, Vorlex, and Telone against *Phymatotrichum* when applied as a soil drench.

Chemical	*Chemical concentration*[1] *(ppm)*	*Depth of Fungus*[2] in soil column *(Gila silt loam)*	*Fungus viability*[3]
Vapam	**500**	**4 inches**	–
		12	–
		20	–
	250	**4**	–
		12	–
		20	–
Vorlex	**500**	**4**	–
		12	–
		20	–
	250	**4**	–
		12	–
		20	+
Telone	**500**	**4**	–
		12	–
		20	–
	250	**4**	–
		12	–
		20	+
Check		**4**	+
		12	+
		20	+

[1] *A 500 or 250 ppm active solution of each chemical applied to soil surface with sufficient water to wet soil column.*
[2] *Fungus placed at depth of 4, 12, and 20 inches in column of soil.*
[3] *Fungus viability determined by recovering the fungus 48 hours after treatment and plating on agar. A minus sign indicates no fungal growth (not viable), a plus sign indicates no effect on fungus.*

Experiments were also designed to determine the minimum concentration of sodium methyldithiocarbamate (Vapam or VPM) necessary to kill the fungus in soil without considering the penetration characteristics of the fumigant in soil. In these experiments the chemical was added directly to soil infested with *Phymatotrichum omnivorum* in pint-sized plastic containers. The containers were sealed after treatment and attempted recovery of

Table 2. Activity of Vapam against *Phymatotrichum* when applied as a soil drench to two soil types.

Application Rate Chemical concentration[1] *(ppm)*	*Depth of fungus*[2] *in soil column*	*Fungus viability*[3]	
		Soil Type	
		Gila silt loam	*Superstition sand*
100	4 inches	–	–
	12	–	–
	20	–	–
50	4	–	–
	12	–	–
	20	–	–
25	4	–	–
	12	–	–
	20	+	–
0 (Check)	4	+	+
	12	+	+
	20	+	+

[1] *Parts per million of active ingredient based on weight of air-dry soil in column. Fumigant added with sufficient water to wet soil column to a depth of 20 inches.*
[2] *Fungus placed 4, 12 and 20 inches from surface of column.*
[3] *Fungus viability determined by recovering the fungus 48 hours after treatment and plating on agar. A minus sign indicates no fungal growth (not viable), a plus sign indicates no effect on fungus.*

fungus was made after 48 hours of exposure to the fumigant. Concentrations of 10-20 ppm Vapam were sufficient to kill the Root Rot fungus. Telone was inactive at low concentrations (Table 3).

Table 3. Comparative effects of the soil fumigants Telone and Vapam against *Phymatrotrichum.*

Chemical	*Chemical concentration*[1] *(ppm active-air-dry soil weight basis)*	*Fungus viability*[2] *(percent)*
Vapam	5	33
	10	4
	20	0
Telone	5	100
	10	100
	20	100
Check		100

[1] *Fumigants were added to pint volumes of moist, infested Gila silt loam.*
[2] *After 48 hour exposures the fungus was removed and cultured on agar. Data based on total of 60 recovered fungus plantings at each concentration.*

Replicated field plots treated with Vapam were established during August, 1969 at the University of Arizona's Marana Farm to determine if *Phymatotrichum omnivorum* could be eliminated from the roots of diseased plants. Vapam, at the rate of 1 qt./100 sq. ft. of surface area, was added to the soil at the base of cotton plants killed by Root Rot. Water was added at the rate of two acre inches to diked-plots to move the chemical into the soil. One week after application roots were removed from the treated and check plots and fungus viability determined by removing fungal strands, placing them on agar in the laboratory, and observing fungus growth, if any, after 72 hrs. All strands were killed by the Vapam treatments, indicating that the chemical had penetrated into the soil with the water. Strands removed from roots from the check plots were alive.

CHARACTERISTICS OF VAPAM AND *VPM* — Sodium methyldithiocarbamate is a water soluble compound that in moist soil releases a gaseous chemical that is active against weed seed, fungi and nematodes. The chemical is presently recommended for controlling a number of other soil-borne fungus organisms, including *Rhizoctonia* sp., *Pythium* sp., *Fusarium* sp., and *Armillaria mellea.* The recommended rate for controlling *Phymatotrichum omnivorum* in replant sites is 1½ (sandy soil) to 2 qts. (heavy soil)/100 sq. ft. Sufficient water should be added to wet the soil to a depth of 4 to 6 feet. A minimum well-basin diameter of 3 to 4 feet should be treated. The chemical should never be applied closer than 3 feet to the drip line of living plants, shrubs, or trees because it is phytotoxic. Plots established in the Tucson area indicate that the material is safe to use if this recommendation is followed. It should be emphasized that this recommendation is for replant sites only. The fumigant should NOT be used around living plants.

Directions for use of Vapam or VPM for treatment of sites to be replanted may be summarized as follows:

1. Apply to soil which has been thoroughly cultivated and kept moist for at least 5 days prior to application.
2. Apply Vapam or VPM when soil temperature is between 60°F and 90°F. Mix required amount in 2 to 3 gallons of water and apply evenly over basin.
3. Apply with sufficient water to wet soil to a depth of 4 to 6 ft. (Approximately 6 inches of water in heavy soil and 3 inches in sandy soils).
4. Cover the treated area with a tarp for 5 to 7 days after treatment.

PRECAUTIONS:

1. Do not apply Vapam or VPM within 3 feet of the drip line of living plants, shrubs or trees.
2. Do not apply in confined spaces without adequate ventilation.
3. Do not apply to dry soil.
4. Keep off of desirable lawns and plants.
5. Material should not be allowed to contact skin or eyes. Contaminated clothing should be removed and laundered. Follow label recommendations.

FINAL STEP — After fumigant treatment, which is designed to eliminate or greatly reduce the amount of *Phymatotrichum* in the soil, a further treatment to prevent or reduce the chances of reinvasion by the fungus into the treated site, is recommended. This method consists of incorporating manure (up to one-fifth of soil volume), soil sulfur (one-quarter pound per cubic foot of tree hole), and ammonium sulfate (one ounce per cubic foot) into the replant site. The technique is described in Folder 158, "Preparing Tree Holes for Root Rot Control." These treatments including the fumigation, should be made 30 to 60 days before planting time.

The methods described above are presently considered to be the best available for control of Root Rot.