Soil Fumigants and Fungicide Drenches for Control of Root Rot of Loblolly Pine Seedlings

S. J. ROWAN, Principal Research Plant Pathologist, Southeastern Forest Experiment Station, USDA Forest Service, Athens, GA 30602

ABSTRACT

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Soil fumigation with methyl bromide-33% chloropicrin was the superior treatment for controlling black root rot of loblolly pine (*Pinus taeda*) seedlings. The severity of root rot was reduced significantly when soil was fumigated with DD-mencs or drenched with benomyl but was not reduced when soil was drenched with thiabendazole. Both benomyl and thiabendazole soil drenches reduced ectomycorrhizal development, but neither soil fumigation treatment affected it.

Additional key words: *Fusarium oxysporum*

In 1966, the soil fumigant DD-mencs (Vorlex—methyl isothiocyanate mixed with chlorinated C_3 hydrocarbons) was recommended to control weeds and damping-off in southern pine nurseries (9). In 1977, two Georgia nurseries using this treatment reported heavy losses to black root rot. In preliminary tests, *Fusarium oxysporum* Schlecht. was the only pathogen consistently isolated from soil and diseased seedling roots. Soil populations of *Pythium* spp. were low (less than one propagule per gram), and no parasitic nematodes, *Phytophthora* spp., *Macrophomina phaseolina* (Tassi) Goid. (*Sclerotium bataticola* Taub.), or *Rhizoctonia* spp. were found in soil or seedling roots from either nursery.

Fungus isolations seemed to indicate that root rot was caused by *F. oxysporum*. However, because both nurseries had used 375 L/ha of DD-mencs as a preplant soil fumigant, it was possible that *F. oxysporum* alone caused the disease, that residues of DD-mencs were sufficiently high in the nursery soils to cause the observed root lesions, or that DD-mencs interacted with the *Fusarium* to produce the disease.

In 1978, one of the two nurseries, the Great Southern Paper Company Nursery near Cedar Springs, GA, was chosen to study which of two soil fumigants—DD-mencs and methyl bromide-33% chloropicrin (Dowfume MC-33)—and two soil drenches—thiabendazole and benomyl—were more efficacious for control of the root disease (4) and to determine their effects on ectomycorrhizal development.

METHODS

Three blocks, each containing three 1.2 × 137.1 m seedbeds, were used for the experiment. The treatments were arranged in a split-plot design; fumigation treatments were applied to whole plots (three beds wide by 27.4 m long),

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followed by soil drench treatments applied to subplots (one bed wide by 27.4 m long).

On the nine seedbeds, five soil fumigation treatments were applied to whole plots: 1) control (no fumigant), 2) methyl bromide-33% chloropicrin (MC-33) chisel-injected at the rate of 392 kg/ha under plastic cover (25 March), 3) DD-mencs chisel-injected at 281 L/ha and sealed with 13 mm of water (30 March), 4) DD-mencs at 374 L/ha and sealed with water (30 March), and 5) DD-mencs at 561 L/ha and sealed with water (30 March). On 30 April, all beds were sown with loblolly pine seed at a rate calculated to produce three seedlings per dm^2.

Immediately after sowing, three soil drench treatments were applied to subplots: 1) control (no drench), 2) benomyl at 1.8 kg active ingredient (a.i.) per hectare in water and irrigated with 13 mm of water, and 3) thiabendazole at 184 g a.i./ha with a second application 4 wk later, each application irrigated with 13 mm of water. The split-plot design resulted in a total of 14 treatments on 45 subplots. All treatments were replicated three times.

Composite soil samples were taken from each block before fumigation and from each subplot 3 mo after fumigation. The pretreatment soil samples were assayed by established methods for populations of *Fusarium* spp. (1), *M. phaseolina* (7), *Pythium* spp. (2,6), *Phytophthora* spp. (2,6), plant-parasitic nematodes (5), *Rhizoctonia* spp. (3), and for phytotoxic residues of DD-mencs (8). As in 1977, pathogens other than *Fusarium* spp. were few or absent in pretreatment samples; therefore, posttreatment samples were assayed only for *Fusarium* spp. and phytotoxic residues of DD-mencs.

Seedling samples were lifted monthly from May through September and examined for root rot. Few lesions appeared before September, and no attempt was made to isolate fungi from these samples.

In December (8 mo after seeds were sown), seedling samples were lifted from 10 randomly chosen 9.3 dm^2 areas of each plot and combined to make two composite samples from each group of five 9.3 dm^2 areas. Every fifth seedling was then selected from each composite sample until 25 seedlings were obtained for detailed measurement.

Numbers of primary and secondary roots, number of primary and secondary roots with one or more root rot lesions, length of primary and secondary roots, length of root rot lesions, height, and fresh weight of tops and roots were recorded for each seedling. Fungi were isolated from 15 randomly selected 1-cm lesion-bearing root sections from each composite sample. No more than one root section was selected from any seedling.

The root rot index was calculated as the percentage of primary and secondary root length with lesions per unit of fresh weight of the total root system. This index gave a better measure of disease severity than one based solely on the percentage of root length with lesions because it distinguished between large and small roots with equal percentages of their lengths bearing lesions. Measurement of smaller roots (tertiary, etc.) was judged unnecessary because they, too, were diseased and because root rot indexes remained essentially the same whether all roots were measured or not. Mycorrhizal development was assessed visually in July and December as the percentage of feeder roots with ectomycorrhizae.

RESULTS AND DISCUSSION

Residues of DD-mencs were not detectable in soil samples collected before or 3 mo after the soil was fumigated at rates up to 561 L/ha. Because lesions developed on new roots that grew after the concentration of the chemical had reached a very low level, it seems unlikely that the fumigant caused the root lesions.

In the three blocks, populations of *Pythium* spp. and *M. phaseolina* were very low in soil collected before soil fumigation, whereas *Fusarium* spp. were present at a relatively high level (Table 1). Populations of parasitic nematodes, *Rhizoctonia* spp., and *Phytophthora* spp. were below detectable limits in soil samples collected before and 3 mo after the soil was fumigated.

Blocks differed in soil populations of *Fusarium* spp. before soil fumigation (Table 1) but not 3 mo after fumigation. However, differences in populations were apparent as a result of soil fumigation and fungicide drenches (Table 2). *F. oxysporum* was not generally distributed over the study area (Table 2) 3 mo after fumigation but was consistently isolated from symptomatic seedling roots from all plots after 8 mo (December). The reason for this distribution of *F. oxysporum* is not understood but may have been caused by an absence of suitable substrate in soil and an abundance of it in seedling roots.

M. phaseolina was not isolated from any of 675 root pieces plated onto potato-dextrose agar in December, while *F. oxysporum* was isolated from 670. Numbers of *Fusarium* spp. in soil fumigated with 561 L/ha of DD-mencs and drenched with benomyl or thiabendazole were comparatively high (Table 2), but root rot was not unusually severe on these plots (Table 3). The apparent lack of correlation between soil populations of *Fusarium* spp. and root rot severity is not understood.

The severity of root rot was significantly reduced by soil fumigation with 374 L or more of DD-mencs, but fumigation with MC-33 gave superior results (Table 3). The benomyl drench reduced root rot in

Table 1. Populations of selected fungi in soil samples collected before soil fumigation

Soil sample (block)	*Pythium* spp. (PPG)[a]	*Fusarium* spp. (PPG)	*Macrophomina phaseolina* (PPG)
1	0.6	600	1.0
2	1.4	300	0.2
3	0.0	200	3.8

[a] PPG = propagules per gram of oven-dried soil.

Table 2. Populations of *Fusarium* spp. in soil samples collected 3 mo after soil fumigation and soil drenches were applied

Fumigant Fungicide drench	*Fusarium* spp. (PPG)[a]	*F. oxysporum* (PPG)
No fumigant		
Control	628	0
Thiabendazole	466	0
Benomyl	785	785
DD-mencs, 281 L/ha		
Control	0	0
Thiabendazole	159	0
Benomyl	161	0
DD-mencs, 374 L/ha		
Control	624	157
Thiabendazole	779	0
Benomyl	631	0
DD-mencs, 561 L/ha		
Control	629	0
Thiabendazole	2,018	0
Benomyl	2,035	0
MC-33, 392 kg/ha		
Control	157	0
Thiabendazole	0	0
Benomyl	310	0

[a] PPG = propagules per gram of oven-dried soil.

Table 3. Severity of black root rot and root growth of loblolly pine seedlings 8 mo after treatment with soil fumigants and fungicidal drenches

Fumigant Fungicide drench	Root rot index[y]	Average primary and secondary roots/seedling	
		Number	Length (cm)
No fumigant			
Control	73.3 ab[z]	14.3 f	211 j
Thiabendazole	84.2 a	15.7 de	233 h
Benomyl	64.5 c	16.0 de	237 h
Average	75.3 A	15.3 A	227 A
DD-mencs, 281 L/ha			
Control	85.3 a	15.1 ef	223 i
Thiabendazole	75.4 b	15.2 ef	224 i
Benomyl	55.4 d	16.9 cd	249 g
Average	72.0 A	15.7 A	232 A
DD-mencs, 374 L/ha			
Control	42.2 e	17.4 bc	256 f
Thiabendazole	39.9 e	17.6 bc	261 e
Benomyl	35.6 e	18.0 bc	266 d
Average	39.3 B	17.7 B	261 B
DD-mencs, 561 L/ha			
Control	51.0 d	16.9 cd	250 g
Thiabendazole	39.8 e	17.5 bc	258 ef
Benomyl	26.8 f	18.4 b	272 c
Average	39.2 B	17.3 B	260 B
MC-33, 392 kg/ha			
Control	10.8 g	21.1 a	312 a
Thiabendazole	6.5 g	21.4 a	316 a
Benomyl	5.5 g	20.8 a	307 b
Average	7.6 C	21.1 C	312 C

[y] Percentage of primary and secondary root length with lesions per unit of fresh weight of the total root system.

[z] Means in each column followed by common capital or lowercase letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

all plots except those fumigated with 374 L of DD-mencs or with MC-33 (Table 3). The excellent control of root rot obtained with the fumigation treatments (especially MC-33) on these plots may have precluded potentially beneficial effects of benomyl. The reduced severity of disease obtained with the benomyl drench further suggests that *F. oxysporum* caused the root rot, because benomyl is reported to control diseases incited by several species of *Fusarium* (10).

Seedling root growth—number and length of primary and secondary roots—was highest with the same soil fumigant and soil drench combinations that reduced root rot (Table 3). Although root weight was not significantly affected by any treatment, fumigation with MC-33 increased seedling height and top weight (seedling height and weight data are not shown). Root growth was not closely correlated with top growth, and only the MC-33 treatment significantly increased top growth.

Ectomycorrhizae appeared to involve primarily *Thelephora terrestris* Ehrh. Ectomycorrhizal development was not affected by any treatment 3 mo after fumigation or by any of the fumigants. However, 8 mo after the fumigants were applied, mycorrhizal development was significantly lower in plots drenched with thiabendazole (61%) and benomyl (58%) than in control plots (68%).

The results of this study indicate that methyl bromide-33% chloropicrin is more effective than DD-mencs for the control of black root rot of pine seedlings.

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