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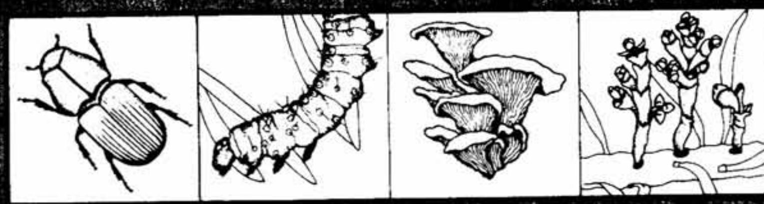

Report 84-9 July 1984

EVALUATION OF FUNGICIDES TO CONTROL ROOT DISEASES AT THE CHAMPION TIMBERLANDS NURSERY, PLAINS, MONTANA

by

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ABSTRACT

Metalaxyl, Banrot[R], captan, and benomyl were evaluated to reduce mortality of lodgepole pine, ponderosa pine, and Douglas-fir seedlings due to damping-off and root diseases at the Champion Timberlands Nursery. Fungicides were applied as drenches before sowing and after seedling emergence. Seedling mortality and soil populations of *Fusarium* and *Pythium* were measured. Metalaxyl was the most effective fungicide in improving seedling survival. All fungicides initially reduced population levels of *Fusarium* and *Pythium* in the soil; however, levels increased in presence of susceptible conifer seedlings throughout the first growing season. Soil fungicides should only be used if the need to control damping-off and root diseases has been clearly demonstrated and other more effective measures cannot be done.

INTRODUCTION

Production of bareroot conifer planting stock at the Champion Timberlands Nursery, Plains, Montana, has been difficult because of severe losses from damping-off and root diseases. Damping-off occurs either before or shortly after seedling emergence and root diseases occur primarily during the first growing season. Both types of diseases are caused primarily by species of *Fusarium* and *Pythium*.

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Land used to grow bareroot conifer seedlings at the nursery formerly produced grain crops, such as wheat and oats. Treatments specifically designed to reduce soil pathogen populations were not conducted prior to sowing with conifer seed. As a result, bareroot seedling production was usually sparse, and surviving seedlings were often stunted and chlorotic.

Soil is often fumigated with chemical sterilants prior to sowing in nurseries to prevent damping-off or root disease problems (Munnecke and Van Gundy 1979; Smith and Bega 1966). Unfortunately, such treatments are very expensive and problems with toxicity to seedlings and reinvasion by pathogens have occurred (Stewart and Beebe 1974; Vaartaja 1967).

Because of severe root disease problems at the Champion Timberlands Nursery and the high cost of soil fumigation, alternative methods to reduce losses were sought. Since fungicides applied as soil drenches have been used to successfully control root diseases in seedbeds at other nurseries (Vaartaja 1964; Wall and Cormier 1976), several promising chemicals were evaluated at the Champion Timberlands Nursery.

MATERIALS AND METHODS

Site Preparation. Newly formed seedbeds not previously used to grow conifer seedlings were used in tests. After the final grain crop (oats) was harvested, the remaining stubble was burned and the site treated with Roundup® (N-phosphonomethyl glycine; manufactured by Monsanto) and Modown® (Methyl 5-(2,4-dichlorophenoxy)-2 nitrobenzoate; manufactured by Rhone-Poulenc) herbicides. About 10 months after herbicide treatment the site was leveled with approximately uniform distribution of the clay-loam topsoil. Four months after leveling, the soil was "deep ripped" to about 90 cm (36 in.) to improve water percolation. The following fertilizers were then applied: ammonium sulfate at 560 kg/ha (500 lbs/acre), murate of potash at 336 kg/ha (300 lbs/acre), treble superphosphate at 336 kg/ha (300 lbs/acre), and elemental sulfur and bentonite clay (90 percent sulfur and 10 percent clay mixture) at 1,120 kg/ha (1,000 lbs/acre). After fertilization, the soil was disked and 1.2 m (4 ft.) wide seedbeds were formed.

Test 1. Four fungicides (table 1) were evaluated for their ability to improve seedling emergence and survival during the first growing season and to reduce levels of *Fusarium* and *Pythium* in the soil. Fungicides were applied as drenches at recommended label rates (table 1) shortly after sowing and 14 days after seedling emergence (table 2). A total of 11 treatments, including a water application check, were conducted.

Table 1.--Fungicides tested to reduce damping-off and root diseases and soil pathogen populations at the Champion Timberlands Nursery.

Fungicide	Trade name	Chemical name	Application rate	Manufacturer
terrazole & topsin M	Banrot®	5-Ethoxy-3-trichloromethyl-1,2,4-thiadiazole; Dimethyl 4, 4'-O-phenylenebis (3-thioallophanate).	44 kg/ha (40 lb/acre)	Mallinckrodt
metalaxyl	Subdue®	N-(2,6-dimethylphonyl)-N-(methoxyacetyl)alaninemethyl ester	2½ pt/50 gal water/acre	Ciby-Geigy
benomyl[1]	Benlate®	Methyl 1-(butylcarbamoyl)-2 benzimidazole carbamate	22.4 kg/ha	DuPont
captan	Captan	N-(Trichloromethylthio)-4 cyclohexene-1,2-dicarbozimide	14.6 g/ha (13 lb/acre)	Stauffer

[1]Not used in Test #2.

Table 2.--Treatments for Test 1 to evaluate efficacy of fungicides to reduce damping-off and root diseases and soil pathogen populations at the Champion Timberlands Nursery.

Treatment number	Treatment
1	Banrot® applied at time of sowing (one application).
2	Banrot® applied at time of sowing and 14 days after seedling emergence (two applications).
3	Banrot® applied 14 days after seedling emergence (one application).
4	Captan applied at time of sowing (one application).
5	Captan applied at time of sowing and 14 days after seedling emergence (two applications).
6	Benlate® applied at time of sowing (one application).
7	Benlate® applied at time of sowing and 14 days after seedling emergence (two applications).
8	Benlate® applied 14 days after seedling emergence (one application).
9	Subdue® applied at time of sowing (one application).
10	Subdue® applied at time of sowing and 14 days after seedling emergence.
11	Water-check.

Treatment blocks consisted of 1.8 m (6 linear ft.) of seedbed with 0.6 m (2 ft.) of untreated bed as a buffer between blocks. A randomized block design was used to assign treatments to blocks. Each treatment was replicated five times for each of three conifer species tested: lodgepole pine (*Pinus contorta* Dougl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and ponderosa pine (*Pinus ponderosa* Laws.).

Seed was collected and stored from 2 to 4 years prior to being sown. Seed was initially soaked in standing tap water for 7 hrs. after which floating seed was discarded. Remaining seed was soaked in a 1 percent hydrogen peroxide solution for 1 hr., then placed on fine mesh screens and rinsed with tap water for 16 hrs. Seed was air separated (based on density) to remove probable empty seed and stratified at 0.5-1.5°C (33-35°F) for 30-45 days.

Seed were sown in newly formed seedbeds as uniformly as possible without use of a precision seeder. Modown® herbicide was applied shortly after seeding at standard label rates. Then fungicides were applied and sawdust mulch added to a thickness of about 2 cm on seedbeds. Mesurol® (3,5-Dimethyl-4 (methylthio) phenol methyl carbamate; manufactured by Mobay) was applied to seedbeds to control bird damage after seedling emergence.

Seedling emergence was sampled about 1 month after sowing. Number of emerged live and damped-off seedlings were counted within three 1 ft^2 sample plots located within the center of each treatment block. A second count of seedling survival was made about 2 months after the first count using the same sample plots. Following the second count, seedlings were thinned to standard densities. Number of seedlings within each sample plot were counted after thinning. A final survival count was made at the end of the first growing season (November) using the same sample plots used in previous counts.

Soil populations of Fusarium spp. and Pythium spp. were sampled before and after fungicide treatments and at the end of the first growing season to determine fungicide effects amd correlate with seedling survival. Two of the 5 replicate treatment blocks for each conifer species were randomly selected for soil sampling. Three 40-80 g samples were collected using a soil sampling tube (2 cm diameter) at 0.5 m intervals in the center of each sampled block and mixed together. Soil dilutions of 1:2 were made in 0.5% water agar (WA) and 1 ml dispensed onto plates of selective media for Pythium (Hendrix and Kuhlman 1965). Plates were incubated in the dark at 24°C for 72 hrs. after which Pythium colonies were counted. For determining Fusarium populations, soil dilutions of 1:400 were made in 0.1 percent WA and 1 ml dispensed onto plates of selective media for Fusarium (Nash and Snyder 1962). Plates were incubated under cool, white fluorescent light continuously for 5 days at 24°C after which Fusarium colonies were counted. Pythium and Fusarium populations were calculated as propagules per gm of soil on the basis of each propagule giving rise to one fungal colony.

Effects of treatments on seedling survival and soil populations of Pythium and Fusarium were determined using an analysis of variance. Significant treatment differences were located using Duncan's Multiple Range Comparison Test.

Test 2. A second test was conducted in different seedbeds to supplement and run concurrently with the first test. Both tests were similarly designed with these changes for test 2: treatment blocks were 5.5 m (18 ft.) long and replicated three times (randomized block design). There were only seven treatments (table 3); benomyl was not evaluated, primarily because it was difficult to obtain sufficient infiltration of chemical into the soil without extensive runoff. The same seedling emergence and survival counts were made in both tests. Soil populations of *Pythium* and *Fusarium* were also sampled similarly and the same statistical tests were conducted.

Table 3.--Treatments for Test 2 to evaluate efficacy of fungicides to reduce damping-off and root diseases and soil pathogen populations at the Champion Timberlands Nursery.

Treatment number	Treatment
1	Banrot® applied at time of sowing (one application).
2	Banrot® applied at time of sowing and 14 days after seedling emergence (two applications).
3	Captan® applied at time of sowing (one application).
4	Captan® applied at time of sowing and 14 days after seedling emergence (two applications).
5	Subdue® applied at time of sowing.
6	Subdue® applied at time of sowing and 14 days after seedling emergence.
7	Untreated check.

RESULTS

Comparisons of seedling mortality percentages among fungicide treatments are summarized in tables 4 and 5 for test 1 and test 2, respectively. In test 1, one or two applications of metalaxyl (Subdue®), treatments 9 and 10, respectively, significantly reduced mortality of lodgepole pine and ponderosa pine seedlings (table 4). This trend was also similar for Douglas-fir seedlings, although differences were not statistically different. Two applications of captan (treatment 5) significantly improved lodgepole pine seedling survival. One or two applications of Banrot® (treatments 1 and 2) and one application of captan (treatment 4) significantly improved ponderosa pine seedling survival in test 1.

Table 4.--Comparisons of seedling mortality percentages among fungicide treatment blocks at the Champion Timberlands Nursery, Plains, Montana (Test 1).[1]

Treatments[2]	Lodgepole pine	Douglas-fir	Ponderosa pine
1	3.6 AB	1.2 BC	0.3 B
2	1.7 BC	1.8 ABC	0.1 B
3	2.6 B	0.9 BC	1.7 AB
4	1.8 BC	2.0 BC	0.8 B
5	1.2 C	1.9 AB	1.9 AB
6	5.6 A	1.0 BC	3.0 A
7	5.2 A	1.5 ABC	3.5 A
8	3.9 AB	2.3 A	2.8 A
9	1.1 C	2.0 AB	0.8 B
10	0.6 C	0.6 C	0.5 B
11	2.2 B	1.2 BC	2.5 A
Overall means	2.7	1.4	1.6

[1]Values in table are percent of seedlings that were dead as a result of damping-off or root disease. With each column, percentages followed by the same capital letter are not significantly different (P = 0.05) using Duncan's Multiple Range Comparison Test (percentages underwent arc-sin transformation for analyses).

[2]See table 2 for treatment descriptions.

In test 2, all fungicide treatments significantly improved lodgepole pine seedling survival (table 5). Also, five of six treatments reduced ponderosa pine seedling mortality. However, no significant treatment effects were found for Douglas-fir in this test.

Table 5.--Comparisons of seedling mortality percentages among fungicide treatment blocks at the Champion Timberlands Nursery, Plains, Montana (Test 2).[1]

Treatments[2]	Lodgepole pine	Douglas-fir	Ponderosa pine
1	2.1 BC	1.0 A	2.7 BC
2	0.6 CD	1.6 ABC	1.5 C
3	2.6 B	1.2 A	3.8 AB
4	1.5 BCD	0.9 A	3.0 BC
5	0.7 CD	0.7 A	0.7 C
6	0.2 D	1.1 A	0.9 C
7	6.3 A	0.5 A	5.4 A
8	3.9 AB	2.3 A	2.8 A
11	2.2 B	1.2 BC	2.5 A
Overall means	2.0	1.0	2.6

[1]Values in table are percent of seedlings that were dead as a result of damping-off or root disease. Within each column, percentages followed by the same capital letter are not significantly different (P = 0.05) using Duncan's Multiple Range Comparison Test (percentages underwent arc-sin transformation for analyses).

[2]See table 2 for treatment descriptions.

Effects of fungicide treatments on soil populations of Fusarium and Pythium are summarized in tables 6 and 7 for tests 1 and tables 8 and 9 for test 2. For both tests, all fungicides generally decreased soil populations of both Fusarium and Pythium as compared with untreated checks. None of the fungicide treatments completely eliminated these soil fungi and population levels usually increased to high levels by the end of the first growing season. In some tests with some fungi, e. g., several fungicide treatments on Fusarium (test 1 - lodgepole pine), soil populations did not exceed pretreatment levels. However, in others, e.g., several fungicide treatments on Pythium (test 2), soil populations at the end of the growing season exceeded pretreatment levels. Differential selectivity of certain fungicides against certain fungi were not evident; statistical comparisons among the different treatments could not be made because of non-uniformity of soil Fusarium and Pythium populations in sampled beds.

Table 6.—**Effects of fungicide treatments on** soil populations of *Fusarium*[1] at the Champion Timberlands Nursery, Plains, Montana (Test 1).

Lodgepole pine counts[2]	Treatments[3] 1	2	3	4	5	6	7	8	9	10	11
1	6000A	5800A	6300A	6900A	8100A	4700A	7100A	11000A	8700A	9100A	8100A
2	130B	330B	1130B	130B	470B	130B	730B	70B	330B	130B	1800B
3	800B	2270C	2930B	5600A	1670B	6070B	2870B	4000B	3530C	2330B	2330B
Mean	1850	2425	3100	3875	2825	3500	3125	5020	3625	3200	3575
Douglas-fir											
1	4700A	12000A	14000A	13600A	10700A	6500A	8200A	8000A	7300A	9500A	6000A
2	530B	530B	1070B	1470B	2000B	2130B	1930B	330B	470B	1600B	1470A
3	930B	1270B	130B	3670B	1070B	2130B	1270B	4930C	1670B	1130B	5330A
Mean	1725	3675	3950	5325	3825	3225	13250	3975	2625	3400	4425
Ponderosa pine											
1	6900A	9200A	6300A	5330A	3670A	9900A	10300A	6900A	8800A	9700A	5000A
2	1330A	1200B	470B	2330A	600B	800B	870B	530B	1000B	1000B	7870A
3	8270A	1800B	870B	5000A	2870A	1530B	330B	530B	3980C	870B	3800A
Mean	5325	3425	2075	4290	2380	3350	3025	2125	4070	3125	5550

[1] Values in table are propagules of *Fusarium* per gram of soil. Within each column for each individual species, means followed by the same capital letter are not significantly different (P = 0.05) using Duncan's Multiple Range Comparison Test.

[2] Counts: 1. taken before fungicide application
2. taken a few days after fungicide application
3. taken at the end of the first growing season.

[3] For treatments see table 2.

Table 7.—Effects of fungicide treatments on soil populations of Pythium at the Champion Timberlands Nursery, Plains, Montana (Test 1).[1]

Lodgepole pine counts[2]	Treatments[3]										
	1	2	3	4	5	6	7	8	9	10	11
1	100AB	58A	108A	87A	133A	83A	100AB	54A	54A	158A	75A
2	29A	33A	100A	75A	42B	108A	46A	17A	37A	92A	79A
3	217A	67A	100A	125A	121A	75A	129B	154B	112B	112A	100A
Mean	115	53	103	96	99	89	92	75	68	121	85
Douglas-fir											
1	83A	62	129AB	100A	142AB	100AB	83A	42A	87A	25A	58A
2	58A	54A	71A	4B	75A	46A	58A	33A	62A	17A	46A
3	87A	79A	217B	108A	221B	144B	137A	112B	92A	46A	167B
Mean	76	65	139	71	146	97	93	62	81	29	90
Ponderosa pine											
1	54A	117A	104A	137A	121A	75A	108A	79A	75AB	58A	121A
2	79A	54A	25B	67B	50A	58A	62A	58A	25A	25A	100A
3	117A	108A	104A	187A	87A	122A	108A	229B	150B	67A	121A
Mean	83	93	78	131	86	89	93	122	83	50	114

[1]Values in table are propagules of Pythium per gram of soil. Within each column for each individual species, means followed by the same capital letter are not significantly different (P = 0.05) using Duncan's Multiple Range Comparison Test.

[2]Counts:
1. taken before fungicide application
2. taken a few days after fungicide application
3. taken at the end of the first growing season.

[3]For treatments see table 2.

Table 8.--Effects of fungicide treatments on soil populations of _Fusarium_ at the Champion Timberlands Nursery, Plains, Montana (Test 2).[2]

Counts[2]	Treatments[3]						
	1	2	3	4	5	6	7
1	2090 A	3150 A	3870 A	2930 A	3200 A	3240 A	2180 A
2	1020 A	2180 A	890 B	1420 B	1420 A	1150 B	1820 A
3	1910 A	3550 A	3200 A	3600 A	6710 B	2800 AB	3600 A
Mean	1675	2960	2650	2650	3780	2400	2530

[1]Values in table are propagules of _Fusarium_ per gram of soil. Within each column for each individual species, means followed by the same capital letter are not significantly different (P = 0.05) using Duncan's Multiple Range Comparison Test.

[2]Counts:
1. taken before fungicide application
2. taken a few days after fungicide application
3. taken at the end of the first growing season.

[3]For treatments see table 2.

Table 9.--Effects of fungicide treatments on soil populations of *Pythium* at the Champion Timberlands Nursery, Plains, Montana (Test 2).[2]

Counts[2]	Treatments[3]						
	1	2	3	4	5	6	7
1	97 A	89 A	86 A	136 AB	64 AB	89 AB	153 A
2	42 A	61 A	69 A	78 A	31 A	50 A	133 A
3	183 B	189 B	131 A	189 B	92 B	117 B	167 A
Mean	107	113	95	134	62	85	151

[1]Values in table are propagules of *Pythium* per gram of soil. Within each column for each individual species, means followed by the same capital letter are not significantly different (P = 0.05) using Duncan's Multiple Range Comparison Test.

[2]Counts: 1. taken before fungicide application
2. taken a few days after fungicide application
3. taken at the end of the first growing season.

[3]For treatments see table 2.

DISCUSSION

Our tests indicated that fungicide applications have the potential to reduce losses from damping-off and root diseases in non-fumigated nursery seedbeds. However, the fungicides we tested varied in their ability to reduce seedling mortality.

Metalaxyl was one of the most effective fungicides in our tests. This fungicide, developed especially to control water mold fungi such as Pythium and Phytophthora (Malajczuk et al. 1983), has shown promise in a number of field crops. Improved seedling survival in seedbeds treated with metalaxyl may be due to the importance of Pythium spp. in causing seedling mortality at the Champion Nursery. Although isolations from diseased seedlings were not done, soil sampling indicated relatively high populations of Pythium. The levels we found approximated those reported for naturally infested field soils (Hendrix and Campbell 1973; Lumsden et al. 1976; Schmitthenner 1970). Although Pythium levels were significantly reduced by treatment with metalaxyl and other fungicides, populations greatly increased during the first growing season. Levels at the end of the year often exceeded pretreatment levels.

Banrot®, captan, and benomyl were generally less effective than metalaxyl in reducing seedling mortality. Benomyl application was especially difficult because the large volume of solution required could not effectively be drenched into the rather impervious soils of the nursery; large amounts of the solution ran off the sides of treated beds resulting in limited penetration of the chemical into the soil. Benomyl is a wide spectrum systemic fungicide that has been used in attempts to control several nursery seedling diseases, including damping-off (Erwin 1973). It has often been ineffective as a soil drench (Cooley 1980; Lock et al. 1974; Williams 1975), primarily because of the high dosages required and problems of leaching. In previous tests, Banrot® was not effective as a soil drench in controlling Fusarium root disease of sugar pine seedlings (Cooley 1980; Cooley 1982), although it did reduce damping-off of red pine seedlings (Wall and Cormier 1976). Captan has generally been more effective as a soil drench, particularly if applied before sowing (Filer and Peterson 1975; Lock et al. 1974; Watson 1966). Our results indicated that captan was generally more effective in most tests than either Banrot® or benomyl.

In our tests, fungicides did not entirely eliminate populations of *Fusarium* and *Pythium* as soil fumigation with methyl bromide and chloropicrin often do (Munnecke and Van Gundy 1979; Smith and Bega 1966). Populations also tended to increase rapidly in the presence of susceptible host roots. We would expect soil populations of *Fusarium* and *Pythium* to increase unless frequent fungicide applications were made to keep populations low.

Initial populations of *Fusarium* and *Pythium* were near levels generally considered capable of causing extensive disease (Edmonds and Heather 1973; Ferriss 1982; Lumsden et al. 1976; Smith 1970). Such high populations can be expected in soils previously supporting grasses or grain crops (Lumsden et al. 1976; Smith 1970). When such high soil populations of *Fusarium* or *Pythium* exist, it is necessary to reduce them in order to grow an adequate crop of conifer seedlings.

CONCLUSIONS AND RECOMMENDATIONS

1. Soils at the Champion Timberlands Nursery have high resident populations of *Fusarium* and *Pythium*. Without soil treatment, recurring losses from damping-off and root diseases can be expected.

2. Soil fumigation with methyl bromide and chloropicrin would provide the best control of damping-off and root diseases. Such treatments have been very effective at numerous forest tree nurseries in the United States. Seed treatment with fungicides, such as captan, might also help control these problems.

3. Fungicides reduce soil populations of *Fusarium* and *Pythium*, probably to levels where disease risk is significantly reduced. However, populations increase in the presence of susceptible host roots and may remain high unless additional treatments are made.

4. Fungicide drenches, especially metalaxyl, can improve bareroot seedling survival by reducing losses from damping-off and root diseases at the Champion Timberlands Nursery. The effect was greatest for lodgepole pine and ponderosa pine. It was not as great for Douglas-fir.

5. A program of soil monitoring for Fusarium and Pythium population levels is recommended to predict potential disease losses and provide a basis for instituting control measures.

6. Soil fungicides should only be used if a clear need to control damping-off and root diseases has been demonstrated. Drenches should be applied before sowing and perhaps at several intervals during the first growing season. Specific fungicides should be geared toward specific target organisms, e.g., metalaxyl to control Pythium.

ACKNOWLEDGEMENTS

Assistance of personnel of the Champion Timberlands Nursery throughout the course of this study is appreciated. Special thanks go to Verna Reedy and her staff and C. J. Gilligan and C. A. Stewart for assistance with field measurements and laboratory analyses.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended. CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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