Fungicidal Drench Trials for the Control of Damping-off in Conifer Seedbeds

by

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ABSTRACT

Seventeen fungicidal formulations, plus several combinations containing two or more active ingredients, were tested for control of damping-off under field, greenhouse and laboratory conditions. Many of the single chemicals had a narrow spectrum of activity against the damping-off fungi and consequently failed to control seedling mortality where several pathogenic fungi were present. Others were phytotoxic, thereby causing seedling mortality to the same extent as damping-off. None of the single compounds were consistently beneficial under the rigorous conditions of these tests. Combinations of a systemic benzimidazole with ethazole or chloroneb were promising, significantly increasing seedling survival.

RESUME

On a essayé 17 formules de fongicides et plusieurs combinaisons contenant deux ingrédients actifs ou plus pour lutter contre la fonte des semis sur le terrain, en serre et en laboratoire. Bon nombre de produits chimiques individuels se révélèrent peu actifs à cause de leur champ d'activité réduit contre la fonte des semis et ne purent, par conséquent, empêcher la mortalité des semis, en présence de nombreux champignons pathogènes. D'autres produits étaient phytotoxiques, causant, par le fait même, une mortalité des semis tout aussi élevée que la fonte des semis. Aucun des composés individuels n'a donné un rendement soutenu sous les rigoureuses conditions de ces tests. Les combinaisons d'un benzimidazole systémique avec l'éthazole ou avec le chloroneb sont de bon augure, car elles ont augmenté sensiblement la survie des semis.

INTRODUCTION

Each year, some forest nurseries suffer substantial losses in conifer seedbeds from damping-off caused by the soil-borne fungi *Rhizoctonia solani* Kuehn, *Pythium* spp., and *Fusarium oxysporum* Schlect. Damping-off due to fungi is prevalent on seedbeds established on old farmland. In contrast, mortality in greenhouse operations using sphagnum peat as a growth medium is more often caused by adverse physical and chemical factors (Wall 1974); one such cause of mortality is the excessive or ill-timed application of fungicides, usually captan, designed to prevent epidemics of fungal damping-off. Some of the conventional fungicides are often phytotoxic (Carlson 1970, Denne and Atkinson 1973, McDonald *et al.* 1973), thereby creating the need for safer materials or better methods of application. New fungicides are continually being placed on the market and their application in controlling forest nursery diseases requires testing under operational conditions.

Control of pathogenic damping-off is complicated by its diverse causes, involving at least three fungal genera. Various indirect methods of control, e.g. soil acidification, soil amendments with specific organic materials, or the addition of chemicals to stimulate certain antagonists, might be effective against one or two fungi but might enhance the activity of another (Roth and Riker 1943, Vaartaja 1964). Similarly, application of narrow-range fungicides may control part of the disease complex but fail to control the disease. Since there are few broad-range fungicides that are not phytotoxic, it seems logical to use combinations of materials specific for different groups of fungi.

Persistence of a chemical throughout the period of susceptibility to damping-off is also important. Vaartaja *et al.* (1964) found that pelleting of seeds with fungicides followed by repeated drenching was often required to control damping-off. This is costly in time and materials and carries the danger of seriously contaminating soil and drainage systems. The newer systemic fungicides such as benomyl, thiabendazole, and thiophanate persist for a time within the seedling (Gremlin 1973), but they are not fungistatic to a full spectrum of pathogens and consequently resistant strains of fungi may arise. Therefore, these fungicides probably should only be used in combination with other compounds.

This report describes and presents the results of a series of laboratory, greenhouse, and field tests to compare some of the newer fungicides with conventional materials and to determine the compatibility of certain fungicide combinations. Methods corresponded as closely as possible to present practices in local nurseries.

MATERIALS AND METHODS

Seventeen commercial fungicides, containing as many active ingredients, were tested (Table 1).[1] All had been purchased within the preceding three years and most within the previous six months. Chemicals were stored at room temperature and applied immediately after preparation of the aqueous suspensions.

Seeds of red pine, jack pine, balsam fir, red spruce, and black spruce (Table 1b) which had been stored at 4°C in air-tight containers after collection, were used in the experiments.

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[1]Trade names are used throughout this report. Their use does not imply their endorsement by the Department of the Environment.

The fungi used in the laboratory and greenhouse tests, *Pythium* spp., *Rhizoctonia solani*, *Fusarium oxysporum*, and *Cylindrocarpon* sp. were maintained on 2% malt agar slants at 4°C (Table 1c). Their pathogenicity was confirmed prior to use by inoculating aseptically-grown red pine seedlings, following the method of Vaartaja and Cram (1956). To obtain pure cultures for inoculating greenhouse soils, the fungi were grown on cornmeal-sand media (500 g coarse quartz sand + 20 g cornmeal in 1-litre flasks). After 2-3 weeks incubation the contents of the flasks were mixed with soil in a ratio of 1 part cornmeal sand inoculum to 7 parts soil mix.

The soil mix used in greenhouse experiments consisted of 3 parts fine sandy loam, 3 parts beach sand, and 1 part sphagnum peat. A small quantity of dolomitic limestone was added to raise the pH to between 4.5 and 5.0. The sandy loam had natural populations of *Pythium* and *Fusarium*. After inoculation, the soil mix contained 40 to 60 thousand propagules of *Fusarium* per gram, estimated by the soil-suspension plating method of Wensley and McKeen (1962).

Three types of tests were performed: (1) laboratory, to determine the fungistatic activity of each formulation; (2) greenhouse, to test the effectiveness of the fungicides against damping-off in soil inoculated with all the major causal fungi; and (3) field, to measure the relative usefulness of each formulation under operational conditions. The phytotoxicity of each fungicide formulation was not measured directly but was evident from data on seedling survival in the field and greenhouse tests.

Laboratory tests

Fungistatic activity was assayed on 2% malt agar containing 100, 10, 1, or 0.1 ppm of the active ingredient of each formulation. The chemicals were suspended in acetone and pipetted into the warm agar medium prior to being poured into 9-cm plates. The plates were inoculated with 3-mm discs from actively growing cultures of test fungi and daily measurements were made of radial growth of the resulting colonies. Growth consistently slower than on control plates (malt agar + 1% acetone) indicated a fungistatic effect. If no growth occurred, the possibility of a lethal effect was checked by transferring the inoculum discs to fresh malt agar plates and checking for growth after several days. Experiments were duplicated for each test fungus and were repeated for materials fungistatic at 10 ppm or less.

Greenhouse tests

To evaluate the effectiveness of the fungicides in controlling damping-off, 15 seeds were planted in styrofoam cups with a top surface area of 35 cm^2. The seeds were placed on the inoculated soil mix and covered with 0.5 cm beach sand. The cups were then placed in replicate blocks in a glass compartment with a 20°C night temperature, 20-30°C day temperature, and a 16-hr daylength, extended by 300 watt incandescent lights. The required concentration of fungicide was applied to the soil surface in 17.5 ml of aqueous suspension (5ℓ/m^2, 5000 gal/acre). This amount was sufficient to drench most of the soil. Water was withheld for at least one day after drenching to prevent immediate leaching of the fungicide. After seedling emergence a second dosage or drench of each fungicide was applied in the same manner.

Counts of living and dead seedlings were made at 3-4 day intervals until seedling numbers stabilized; at each count dead and dying seedlings were examined microscopically for fungi or were cultured on malt agar.

Field tests

Trials were carried out at the Provincial Nursery at Kingsclear, New Brunswick, on seedbeds which had been planted with red pine on the previous day (June 19, 1975) and treated with vapam (670 ℓ/ha, 460 gal/acre) three weeks before planting. Vapam-treated soils were used for these tests because of previous experience with the occurrence of damping-off in such soils (Wall 1974). Suspensions of fungicides were applied with a watering can at the rate of 1.23 ℓ/m^2 ($\doteqdot$ 1000 gal/acre) to 1.2 x 1.5 m plots. Untreated check plots were left between each treatment in each of four replicate blocks. After emergence, healthy and diseased seedlings were counted in 200-cm^2 microplots in the centre of each treatment or check plot and diseased seedlings were cultured on malt agar. In late autumn, a final count of surviving seedlings was made in two 500-cm^2 transects across each plot.

In greenhouse and field experiments, fungicide efficacy was expressed in terms of percentage postemergence mortality and ultimate survival of healthy seedlings. Analyses of variance of postemergence mortality were done on arcsin$\sqrt{\%}$ transformed values of dead over emerged seedlings for each replicate. Seedling survival (emergence minus post-emergence mortality) gave equal weighting to preemergence and postemergence losses and was based on a final count taken after damping-off had ceased.

RESULTS

Laboratory Tests

Minimum concentrations of active ingredients required to inhibit fungal growth are presented in Table 2. The active ingredients of Dithane Z78 (zineb), Dowicil 100, Orthocide 50 (captan) and Plantco 35 (dexon) were not highly fungistatic. The systemic fungicides contained in Benlate and Mertect 160 inhibited the growth of *Fusarium*, *Cylindrocarpon*, and *Rhizoctonia* at 10 ppm but did not affect *Pythium* spp. Truban at 10 ppm inhibited the growth of *Pythium* spp. but was relatively ineffective against the other fungi. Terrachlor and Tersan SP were more active against *Rhizoctonia* than against other fungi. Most of the formulations inhibited the growth of *Pythium* and *Rhizoctonia* more than that of *Fusarium* and *Cylindrocarpon*. Banrot (a combination of ethazole and thiophanate methyl), Busan, and No Damp were the best general fungicides. Busan and No Damp at 100 ppm, were lethal to *Pythium* and *Rhizoctonia*, whereas the same concentrations of Banrot and Manzate 200 were lethal only to *Pythium*. Bunema, Terrachlor and Tersan SP had no lethal effects and were only mildly inhibitory at all levels tested.

Greenhouse Tests

Assays of fungicide activity against seedling damping-off were commenced in February (Tables 3 and 4) and May (Tables 5 and 6) 1975. In both tests extensive postemergence mortality occurred, with over 90% of the dead seedlings showing symptoms typical of pathogenic damping-off (i.e. rotting of tissues and the presence of intercellular hyphae). Few of the fungicides controlled damping-off significantly, and several actually caused an increase in mortality. In the first test, applications of Benlate, Dithane M22, and Mertect 160 were associated with significantly

increased mortality in one or more tree species (Table 3); in the second test, increased mortality in black spruce was caused by Bunema, Orthocide 50, Truban, and combinations of Orthocide 50 + Benlate or Mertect 160 (Table 5). Banrot, even at the low rate ($0.7g/m^2$), was the only formulation which was consistently effective. Other promising products were No Damp, Tersan SP, and combinations of Benlate with Tersan SP or Truban.

In the first test, decayed tissues were incubated for 24 hours in a moist chamber and examined microscopically for fungi (Table 3). At first, spores of *Cylindrocarpon* were most frequently observed but in later infections, the sickle shaped spores typical of *Fusarium* were common. Often, two or more genera could be distinguished in the same seedling. As expected from laboratory tests, *Pythium* was seldom identified in seedlings treated with Truban, and *Rhizoctonia* was seldom seen in seedlings treated with Tersan SP or Terrachlor.

In the second test, diseased tissues were cultured on malt extract agar and the recovered fungi were identified (Table 6). Again, mixed cultures of *Rhizoctonia* + *Fusarium*, *Rhizoctonia* + *Pythium* or other combinations were as common as pure cultures. *Cylindrocarpon* was not isolated, possibly because of its sensitivity to conventional surface sterilization techniques (Bloomberg and Sutherland 1971). *Pythium* was recovered in higher proportions, relative to other fungi, from seedlings treated with Benlate but was suppressed in No Damp and Truban treatments. *Rhizoctonia* was not recovered from seedlings treated with Tersan SP, Terrachlor, or Mertect 160 + Orthocide 50. Few treatments appeared to consistently suppress *Fusarium*.

A more practical expression of fungicide performance is seedling survival at the end of the experiment (6-8 weeks after emergence). This provides an estimate of preemergence losses and expresses performance in terms of interest to the nurseryman. Results are given in Tables 4 and 5. Again, the combined formulations Banrot, Benlate + Tersan SP, Benlate + Truban, Mertect 160 + Truban, and Terrachlor + Truban were most effective. Bunema and Busan inhibited emergence and did not prevent postemergence damping-off (Table 5). In the first test (Table 4), the Dithane M22 and Mertect 160 treatments reduced seedling survival.

The efficacy of different fungicides varied with tree species, with only the most or the least effective fungicides effecting a consistent response. Data on seedling survival showed a non-significant correlation for distantly related species, e.g. red pine and balsam fir. However, mean values for red pine and jack pine survival were significantly correlated ($r = 0.77$) as were those for red and black spruce ($r = 0.66$); in other words, a fungicide that is effective for one tree species can usually be expected to be equally effective for a closely related species. In interpreting this observation, it should, however, be emphasized that species differed in rates of emergence, susceptibility to the different fungi, and primary points of invasion by damping-off fungi. For example, balsam fir emerged more slowly than other species and was often invaded through the seed cap and cotyledons rather than at the soil line as were other species. In addition, *Fusarium* was observed more frequently in diseased fir seedlings than in other tree species.

Field Tests

In the red pine seedbeds at the Kingsclear Nursery, damping-off occurred in circular patches within two weeks of seedling emergence. In untreated areas outside of the experiment these patches enlarged and

coalesced, while in the fungicide test plots, the patches remained small, and usually were confined to the 1.8 m^2 check plots. Cultures from diseased seedlings were mainly *Rhizoctonia solani*. Seedling survival was significantly increased as compared to the check plots by the following treatments: Banrot; Mertect 160 + Tersan SP; Mertect 160 + Truban; Orthocide 50 + Truban (Table 7). Contrary to previous experience in the greenhouse (Wall 1975), Terrachlor caused considerable seedling injury.

CONCLUSIONS AND RECOMMENDATIONS

Damping-off control is difficult to evaluate experimentally. Toxicity tests on fungi in the laboratory do not give a true indication of the activity of a fungicide in the soil. Artificially inoculated soils often have abnormally high populations of pathogenic fungi. Field plots have an uneven distribution of fungi and soil conditions. In spite of these limitations, the tests indicated some promising fungicidal formulations. In greenhouse and field tests, seedling survival was significantly greater in the following treatments than in the untreated checks (see Tables 4, 5, and 7):

Banrot - 6.7 g/m^2 (60 lb/acre) - 4 out of 8 tests
- 0.7 g/m^2 (6 lb/acre) - 1 out of 8 tests
No Damp - 50 ml/m^2 (45 gal/acre) - 1 out of 7 tests
PP395 - 2.5 g/m^2 (22 lb/acre) - 1 out of 8 tests
Tersan SP - 1.5 g/m^2 (13 lb/acre) - 1 out of 8 tests
Truban - 0.4 ml/m^2 (3 pints/acre) - 1 out of 8 tests
Benlate + Tersan SP - 0.2 + 1.5 g/m^2 - 2 out of 3 tests
Benlate + Truban - 0.2 + 4 g/m^2 - 2 out of 3 tests
Mertect 160 + Tersan SP - 1.7 + 1.5 g/m^2 - 1 out of 1 test
Mertect 160 + Truban - 1.7 + 4.0 g/m^2 - 2 out of 3 tests
Mertect 160 + Truban - 0.85 + 2.0 g/m^2 - 1 out of 1 test
Mertect 160 + Truban - 0.2 + 0.4 g/m^2 - 1 out of 2 tests
Orthocide 50 + Truban - 2.0 + 4.0 g/m^2 - 1 out of 3 tests
Terrachlor + Truban - 13.4 + 4.0 g/m^2 - 2 out of 3 tests

Combinations of a systemic fungicide (benomyl, thiabendazole or thiophanate methyl) with chloroneb or ethazole appeared to be the most beneficial, e.g. Banrot, Benlate + Tersan SP, Benlate + Truban, Mertect 160 + Tersan SP, or Mertect 160 + Truban. Usually the ingredients of these combinations were of little value alone. Benlate and Mertect 160 did not suppress *Pythium*, either in laboratory tests or in greenhouse experiments and their application alone often resulted in increased damping-off. Truban at 10 ppm suppressed *Pythium* spp. but was much less active against other fungi (Table 2). Tersan SP suppressed all of the damping-off pathogens under study except *Cylindrocarpon* but was inconsistent in the control of damping-off when applied alone.

Despite the above, it cannot be assumed that all or even most fungicidal combinations with complementary fungistatic spectra will be beneficial. The usefulness of the combinations must be determined by testing on a wide variety of crops. Phytotoxicity, mutual inactivation, or destruction of antagonistic soil microflora can render many combinations ineffective. For example, in these tests, combinations of captan with systemic benzimidazoles were of no value and in some cases, detrimental. Vaartaja (1964) has discussed other detrimental combinations. Therefore, mixing of products by the grower cannot be recommended except on an experimental basis.

The effectiveness of a fungicide partly depends on its formulation with so-called "inactive" ingredients (Carlson 1970). Since all formulations could not be tested here, it cannot be recommended that popular fungicides such as captan be discarded. Instead, some of the more effective new fungicides should be added to the arsenal of available materials, so as to minimize the risk that continued application of a single fungicide will lead to a buildup of resistant pathogens and a

resultant loss of effectiveness.

The question of which products to use in damping-off control depends on how, where, and when they are applied. This study concentrated on preventative pre- and postemergence drenches, but fungicides may also be incorporated into the soil prior to planting, pelleted onto the seeds with a latex or cellulose sticker, or applied as a curative treatment after damping-off has begun.

Preplanting treatments are necessary only when using highly toxic compounds and are usually designed to eliminate weed seeds, nematodes, resistant resting spores, and sclerotia of fungi. Soils sterilized in such a manner can in some cases be reinvaded by pathogens such as *Rhizoctonia* (Vaartaja 1967). In this study, vapam treatment before seeding certainly did not prevent, and may have enhanced, damping off at the Kingsclear Nursery. However, certain partial soil sterilants such as mylone are proving to be effective and free of any recolonization effect (Low 1974, Vaartaja 1958). Because of their phytotoxicity, Bunema and Busan might be more useful as preplanting than postplanting treatments.

Seed treatment is standard practice in some nurseries. Early claims (Cockerill 1955, Kahler 1955) for the effectiveness of pelleting seeds with large dosages of fungicide were very promising but later work (Belcher and Carlson 1968, Peterson 1970) pointed out the danger of phytotoxicity when dosages effective against damping-off were applied. Vaartaja *et al.* (1964) found that control was often temporary and had to be followed by postemergence drenches.

Total dependence on curative treatments is advisable only in soils where the likelihood of fungi occurring is low, e.g. newly cleared forest soils or sphagnum peat. Continuous monitoring is essential and symptoms (rotting and collapse of tissues, presence of pathogenic fungi)

must be rapidly distinguished from other cuases of mortaltiy.

In Maritime nurseries, damping-off has been a problem mainly in seedbeds established on agricultural land. Preplant soil sterilization with vapam or vorlex has in many cases appeared to aggravate the problem. On these soils, a fungicide treatment is recommended; preferably this should consist of a drench at planting time followed, if necessary, by a second application after emergence. Instead of relying entirely on captan, some of the more promising formulations mentioned in this report should be tried.

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Table 1 (cont.)

(a) Fungicides

Trade name and Manufacturer or Supplier	Active ingredient			Formulation
	Chemical name	Common name	%	
Orthocide 50 (Chevron)	N-trichloromethyl mercapto-4-cyclohexonol 2-dicarboximide	Captan	50	Wettable powder
Plantco 35 (Plant Products)	Sodium-p-dimethyl aminobenzenediazo sulfonate	Dexon	35	Soluble powder
PP395 (Chipman)	4-(3-chlorophenylhydrazono) -3-methyl-5-isoxazolone	Metazoxolon	40	Flowable
Terrachlor (Olin)	1,2,3,4,5 pentachloro nitrobenzene	Quintozene or PCNB	75	Wettable powder
Tersan SP Turf Fungicide (Dupont)	1,4, dichloro-2,5-dimethoxybenzene	Chloroneb	65	Wettable powder
Truban (Mallinckrodt)	5-ethoxy-3-trichloromethyl -1,2,4-thiadiazole	Ethazole	25	Emulsifiable concentrate

(b) Seed sources

Common name	Scientific name	Germination (%)	Source
Red pine	*Pinus resinosa* Ait.	86	Wisconsin, U.S.A.
Jack pine	*Pinus banksiana* Lamb.	73	Northumberland County, N.B.
Balsam fir	*Abies balsamea* (L.) Mill.	59	Madawaska County, N.B.
Red spruce	*Picea rubens* Sarg.	13	Sunbury County, N.B.
Black spruce	*Picea mariana* (Mill.) B.S.P.	93	Queens County, N.S.

Table 1 (cont.)

(c) Fungus cultures

Name	Host	Disease	Location
Pythium irregulare	Red pine	Damping-off	Fredericton, N.B., greenhouse
Pythium debaryanum	(donated by Dr. O. Vaartaja, Forest Ecology Res. Inst., Ottawa, Ont.)		
Pythium salpingophorum	(donated by Dr. O. Vaartaja, Forest Ecology Res. Inst., Ottawa, Ont.)		
Rhizoctonia solani	Red pine	Damping-off	Kingsclear, N.B., nursery
Fusarium oxysporum	Red pine	Damping-off	Fredericton, N.B., greenhouse
Fusarium oxysporum	White spruce	Seedling root rot	Lawrencetown, N.S., nursery
Cylindrocarpon sp.	Black spruce	Damping-off	Juniper, N.B., greenhouse

Table 2. Tolerance of damping-off fungi to fungicides in malt agar culture

Fungicide	Lowest inhibitory concentration[1] (ppm active ingredient)				
	Pythium irregulare	*Pythium salpingophorum*	*Fusarium oxysporum*	*Cylindrocarpon* sp.	*Rhizoctonia solani*
Banrot[2] (Thiophanate + ethazole)	1[3]	1[3]	1	10	10
Benlate (Benomyl)	100	100	1	1	1
Bunema	1[4]	1[4]	100	100	0.1[4]
Busan	1[3]	1[3]	10[3]	10[3]	1[3]
Dithane M22 (Maneb)	100	100	100	100	1[2]
Dithane Z78 (Zineb)	>100	100	>100	>100	100
Dowicil 100	100	100	100	100	>100
Manzate 200 (Mancozeb)	10[3]	10[3]	100	100	10[4]
Mertect 160 (Thiabendazole)	100	100	10	10	1
No Damp	1[3]	1[3]	10	10	1[3]
Orthocide 50 (Captan)	100	100	100	100	100
Plantco 35 (Dexon)	>100	100	>100	100	100
PP395 (Metazoxolon)	10	10	10[4]	100	10
Terrachlor (Quintozene)	10[4]	10[4]	10[4]	10[4]	1
Tersan SP (Chloroneb)	10[4]	10[4]	10[4]	>100	1
Truban (Ethazole)	10	10	100	>100	100

[1]Actual lowest inhibitory concentration is between that indicated and its tenfold dilution.

[2]Active ingredient concentration in terms of the ethazole component.

[3]Lethal at 100 ppm.

[4]Growth occurred at 100 ppm.

Table 3. Seedling mortality in greenhouse soil inoculated with *Pythium* spp., *Fusarium oxysporum*, *Cylindrocarpon* sp., and *Rhizoctonia solani* and drenched with fungicides at the time of seeding and after emergence (test 1, Feb. 1975)

Fungicide	Rate (g/m^2)[1]	Postemergence mortality, %[2]				
		Red pine	Jack pine	Balsam fir	Red spruce	Black spruce
Banrot	6.7(1.0 + 1.7)	6	0	14	9	3
(ethazole +	0.7(0.1 + 0.17)	40	6	32	6	17
thiophanate methyl)	0.0 (check)	21	63(Fu)[3]	62(Fu)	54	46
Benlate	0.2(0.1)	68(Cy)	86	43(Fu)	25	41
(benomyl)	0.02(0.01)	81(Fu,Cy)	25	26	26	37(Rh,Cy)
	0.0 (check)	61	20	40(Fu)	48	43
Baymeb	2.0(0.5)	75	46(Cy)	46	18	86(Fu,Cy)
6447	0.2(0.05)	100(Py,Cy)	40	30	37	66(Cy)
	0.0 (check)	56(Fu,Cy)	70(Cy)	79	13	43
Dithane	1.3(1.0)	100	100	90	0	100
M22	0.13(0.1)	64(Cy)	41	54	10	100
(Maneb)	0.0 (check)	75(Fu)	30	47(Fu)	33	48
Dithane	1.3(1.0)	57(Fu)	17(Fu)	89	25	68
Z.78	0.13(0.1)	34	40	64	10	47
(Zineb)	0.0 (check)	83(Fu)	26	47(Fu)	8	15
Manzate	1.3(1.0)	40(Cy)	94(Rh,Fu,Cy)	57	18	73
200	0.13(0.1)	64(Cy)	55	53	50	69(Py,Cy)
(Mancozeb)	0.0 (check)	52(Fu,Cy)	30(Rh)	36	30	48(Cy,Rh)
Mertect	1.7(1.0)	100	100(Py)	46	30	54
160	0.17(0.1)	86	57(Cy)	46(Fu)	26	76
(thiabendazole)	0.0 (check)	46	78(Cy)	70	23	17
No Damp	50.0 ml (1.0)	23	35	38(Fu)	0	28
	5.0 ml (0.1)	60(Cy,Fu)	28	43(Fu)	0	88(Cy)
	0.0 (check)	85(Cy,Fu)	94(Fu)	54	21	40
Orthocide	2.0(1.0)	75(Cy)	55	43	60(Cy)	61
50	0.2(0.1)	54	36(Cy)	27	0	100(Cy)
(Captan)	0.0 (check)	72	29(Cy)	58(Cy)	18	65(Cy)
Plantco 35	2.9(1.0)	55(Cy)	28	36	0	31
(dexon)	0.3(0.1)	41	11	36	23	15
	0.0 (check)	52(Cy)	43	53	26	23

Table 3 (cont.)

Fungicide	Rate (g/m^2)[1]	Postemergence mortality, %[2]				
		Red pine	Jack pine	Balsam fir	Red spruce	Black spruce
PP395	2.5(1.0)	48(Cy)	20	54	8	28(Cy)
(metazoxolon)	0.25(0.1)	75(Fu,Cy)	40	34	13	53(Cy)
	0.0 (check)	43	25	30	11	16
Terrachlor	13.4(10.0)	92(Cy)	95(Cy)	58	23	86(Cy)
(Quintozene)	1.3(1.0)	76(Cy)	67	54	57	76
	0.0 (check)	93(Cy,Fu)	30	57	18	25
Tersan SP	1.5(1.0)	42(Cy)	8	100	50	14
(chloroneb)	0.15(0.1)	56	38	28	41	41
	0.0 (check)	33	19	51	65	22
Truban	4.0 ml(1.0)	35(Fu)	54(Rh)	74	54	70(Fu,Cy)
(ethazole)	0.4 ml(0.1)	32	16	48	35	36
	0.0 (check)	53(Fu)	50	47	54	76

[1]Grams of commercial formulation per 5 litres of suspension per square metre of soil surface; rate of active ingredient in brackets.

[2]Percentage of seedlings emerged, underlined figures significantly different from check at P=0.05.

[3]Organisms observed in three or more microscopic examinations of diseased tissues; Fu = *Fusarium oxysporum*, Cy = *Cylindrocarpon* spp.; Py = *Phycomycetes* resembling *Pythium* spp., Rh = *Rhizoctonia* spp.

Table 4. Seedling survival in greenhouse soil inoculated with *Pythium* spp., *Fusarium oxysporum*, *Cylindrocarpon* sp., and *Rhizoctonia solani* and treated at seeding and after emergence with test fungicides (test 1, Feb. 1975)

Fungicide	Rate (g/m^2)[1]	% Survival[2]				
		Red pine	Jack pine	Balsam fir	Red spruce	Black spruce
Banrot	6.7(1.0 + 1.7)	78	73	42	20	71
	0.7(0.1 + 0.17)	40	72	29	29	55
Benlate	0.2(0.1)	13	7	18	20	29
(benomyl)	0.02(0.01)	7	33	25	13	45
Baymeb	2.0(0.5)	7	29	13	9	7
6447	0.2(0.05)	0	22	18	11	20
Dithane M22	1.3(1.0)	0	0	2	9	0
	0.13(0.1)	18	31	11	18	0
Dithane Z78	1.3(1.0)	25	33	9	27	15
	0.13(0.1)	29	18	11	18	25
Manzate 200	1.3(1.0)	38	5	13	22	7
	0.13(0.1)	20	18	18	7	18
Mertect 160	1.7(1.0)	0	0	15	15	15
	0.17(0.1)	5	20	15	13	11
No Damp	50.0 ml(1.0)	51	47	25	22	47
	5.0 ml(0.1)	27	38	11	15	5
Orthocide 50	2.0(1.0)	13	22	15	13	22
(captan)	0.2(0.1)	15	35	18	15	0
Plantco 35	2.9(1.0)	31	47	20	18	45
(dexon)	0.3(0.1)	31	58	20	7	49
PP395	2.5(1.0)	29	47	11	22	51
(metazoxolon)	0.25(0.1)	11	27	27	13	18
Terrachlor	13.4(10.0)	2	2	11	7	5
(quintozene)	1.3(1.0)	9	15	11	7	9
Tersan SP	1.5(1.0)	18	58	0	7	42
(chloroneb)	0.15(0.1)	13	40	22	7	29
Truban	4.0 ml(1.0)	25	27	5	5	13
(ethazole)	0.4 ml(0.1)	29	47	9	9	20

[1]Grams of commercial formulation per 5 litres per square metre; rate of active ingredient in brackets.

[2]Percentage of seedlings surviving out of 45 planted seeds, 80 days after planting; underlined figures significantly different from untreated check at 5% level.

Table 5. Postemergence mortality and seedling survival of jack pine and black spruce sown in inoculated greenhouse soil and treated with fungicides at the time of seeding and after emergence (test 2, May 1975)

Fungicide	Rate[1] g/m²	Postemergence mortality, %[2]		Seedling survival, %[3]	
		Jack pine	Black spruce	Jack pine	Black spruce
Banrot	6.7(1.0 + 1.7)	2	2	78	73
	0.7(0.1 + 0.17)	44	59	35	22
Benlate	0.2(0.1)	39	52	40	17
(benomyl)	0.02(0.01)	66	79	20	5
Bunema	2.5 ml(1.0)	76	91	15	2
	0.25 ml(0.1)	63	78	27	13
Busan 30	0.3 ml(0.1)	39	81	12	12
	0.03 ml(0.01)	55	84	30	10
Dowicil 100	0.11(0.1)	52	65	28	10
	0.01(0.01)	41	79	33	10
Mertect 160	1.7(1.0)	42	68	30	8
(thiabendazole)	0.17(0.1)	37	53	35	28
No Damp	50.0 ml(1.0)	28	31	43	18
	5.0 ml(0.1)	38	55	37	20
Orthocide 50	2.0(1.0)	59	91	27	7
(Captan)	0.2(0.1)	58	79	13	13
PP395	2.5(1.0)	26	43	58	22
	0.25(0.1)	48	74	27	13
Terrachlor	13.4(10.0)	85	67	13	13
(Quintozene)	1.3(1.0)	88	43	12	27
Tersan SP	1.5(1.0)	7	50	73	32
(chloroneb)	0.15(0.1)	47	55	35	12
Truban	4.0 ml(1.0)	43	86	40	7
(ethazole)	0.4 ml(0.1)	49	70	33	18
Benlate +	Full rate	38	59	37	28
Orthocide 50	1/10 rate	66	85	22	10
Benlate +	Full rate	27	18	62	40
Tersan SP	1/10 rate	69	66	22	17
Benlate +	Full rate	24	19	53	48
Truban	1/10 rate	38	67	27	18

Table 5 (Cont.).

Fungicide	Rate[1] g/m²	Postemergence mortality, %[2] Jack pine	Postemergence mortality, %[2] Black spruce	Seedling survival Jack pine	Seedling survival Black spruce
Mertect 160	Full rate	52	95	25	3
+ Orthocide 50	1/10 rate	60	63	28	10
Mertect 160	Full rate	32	25	47	32
+ Truban	1/10 rate	23	82	60	12
Orthocide 50	Full rate	32	63	42	27
+ Truban	1/10 rate	23	63	45	20
Terrachlor	Full rate	42	33	47	43
+ Truban	1/10 rate	50	56	33	27
Untreated Check		61	37	23	17

[1]Weight of product applied in 5 litres of water per square metre; weight of active ingredient in brackets.

[2]Percentage of seedlings emerged.

[3]Percentage of seeds planted (emergence minus damping-off); underlined figures significantly different from untreated check at P = 0.05.

Table 6. Recovery of *Pythium* spp., *Rhizoctonia solani* and *Fusarium oxysporium* from diseased seedlings grown in greenhouse soil inoculated with these fungi and treated with fungicides (test 2, May 1975).

Fungicide	Rate[1] g/m^2	Incidence of recovery[2]					
		Jack pine			Black spruce		
		Pythium	*Rhizoctonia*	*Fusarium*	*Pythium*	*Rhizoctonia*	*Fusarium*
Banrot	6.7(1.0 + 1.7)	0	0	0	0	0	0
Benlate	0.2(0.1)	16	1	0	9	0	0
Bunema	2.5 ml(1.0)	12	4	9	0	0	6
Busan 30	0.3 ml(0.1)	1	1	4	7	2	9
Dowicil 100	0.11(0.1)	4	6	13	5	4	7
Mertect 160	1.7(0.1)	4	3	6	4	0	0
No Damp	50.0 ml(1.0)	1	5	6	1	1	3
Orthocide 50	2.0(1.0)	7	10	9	4	5	10
PP395	2.5(1.0)	3	5	6	3	1	6
Terrachlor	13.4(10.0)	19	0	13	7	0	5
Tersan SP	1.5(1.0)	2	0	4	2	0	5
Truban	4.0 ml(1.0)	0	6	9	2	1	14
Benlate + Orthocide 50[3]		6	2	4	9	2	2
Benlate + Tersan SP[3]		5	0	7	3	0	0
Benlate + Truban[3]		0	2	1	2	3	1
Mertect 160 + Orthocide 50[3]		12	0	3	7	0	0
Mertect 160 + Truban[3]		3	5	9	0	1	1
Orthocide 50 + Truban[3]		0	4	8	1	3	17
Terrachlor + Truban[3]		4	0	13	1	0	6
Untreated Check		3	7	6	2	2	1

[1]Weight of product applied in 5 litres of water per square metre; weight of active ingredient in brackets.

[2]Incidence of isolation of *Pythium* spp., *Rhizoctonia solani*, and *Fusarium oxysporium* from damped-off pine and spruce seedlings; does not reflect the actual incidence of damping-off as some seedlings yielded two or more cultures, other fungi, bacteria, or sterile cultures.

[3]Some rates as applied for individual formulations.

Table 7. Postemergence mortality and final seedling stand in red pine seedbeds treated 1-2 days after sowing, Kingsclear Nursery, June 1975

Fungicide	Rate[1]		Postemergence mortality, %[2]			Final stand, % of check[3]	
	g/m^2	lb/acre	Full rate	Half rate	Check	Full rate	Half rate
Banrot	6.7(1.0 + 1.7)	60(8.9 + 15.2)	0[4]	1	5	125	128
Benlate	0.2(0.1)	2(0.9)	2	8	4	95	94
Bunema	1.0 ml(0.4)	7 pts(3.6)	5	1	13	110	102
Busan 30	0.14 ml(0.04)	1 pt(0.4)	1	8	16	94	110
Mertect 160	1.7(1.0)	15(8.9)	3	5	6	103	114
PP395	2.5(1.0)	22(89)	2	1	1	96	94
Orthocide 50	2.0(1.0)	18(8.9)	3	1[5]	4	114[5]	97[5]
Terrachlor	13.4(10.0)	119(89.1)	65[5]	33[5]	29	42[5]	58[5]
Tersan SP	1.5(1.0)	13(8.9)	5	9	22	110	109
Truban	4.0 ml(1.0)	28 pts(8.9)	0	1	1	129	89
Benlate + Orthocide 50[6]			3	1	2	124	117
Benlate + Tersan SP[6]			5	6	3	109	107
Benlate + Truban[6]			7	2	7	82	97
Benlate + Truban + Orthocide 50[6]			0	1	7	110	97
Mertect 160 + Tersan SP[6]			1	3	2	133	138
Mertect 160 + Truban[6]			2	1	2	115	116
Orthocide 50 + Truban[6]			4[5]	3[5]	6	124[5]	107[5]
Terrachlor + Truban[6]			31	36	3	50	50

[1]Weight of product applied in 1.2 ℓ/m^2 (1000 gal/acre) of water; weight of active ingredient in brackets.

[2]Based on number of emerged seedlings; mortality caused mainly by *Rhizoctonia solani*.

[3]Measured 5 months after seeding in two 0.05 m^2 transects across each plot; average density of checks = 672 seedlings/m^2.

[4]Underlined figures significantly different from check at P = 0.05.

[5]Chemical injury to seedlings.

[6]Same rates as applied for individual formulations.