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EVALUATION OF FUNGICIDES FOR CONTROL OF *Gremmeniella abietina*

I. Laboratory and Preliminary Field Assays

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CENTRE DE RECHERCHES FORESTIÈRES DES LAURENTIDES

Pêches et Environnement Canada
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ABSTRACT

The effect of 20 fungicides on *Gremmeniella abietina* (Lgbg.) Morelet was investigated in the laboratory and field. A strain from jack pine was generally less sensitive in laboratory to fungicides than a strain from black spruce. In the field, Phygon 50-W was the most effective fungicide on jack pine and red pine against the former strain. It suppressed infection completely after one to three applications of 20,000 or 40,000 ppm suspensions. Partial protection of jack pine was provided by C-O-CS, Cyprex 65-W. Difolatan 4.8 flowable suspension, Dithane M-22, Dithane M-45, Dithane Z-78, microfine sulfur, and Phaltan. The latter was similarly effective also on red pine. Two applications of stove oil completely inhibited ascospore discharge in the field from apothecia occurring on jack pine. On black spruce, three applications of 20,000 or 40,000 ppm suspensions of C-O-CS, Dithane M-22, or Z-C Spray resulted in partial control of the strain from black spruce.

RESUME

On a étudié l'effet de 20 fongicides sur le *Gremmeniella abietina* (Lgbg.) Morelet en laboratoire et sur le terrain. La lignée prélevée sur le pin gris en laboratoire, s'est généralement révélée plus résistante aux fongicides que celle prélevée sur l'épinette noire. En milieu naturel toutefois, le Phygon 50-W s'est révélé le fongicide le plus efficace, à la fois sur la lignée du pin gris et celle de l'épinette noire. En effet, deux ou trois applications d'une suspension faite de 20,000 ou 40,000 ppm neutralisent complètement l'infection. Le pin gris reçoit une protection partielle, avec le C-O-CS, le Cyprex 65-W, le Difolatan 4.8 en suspension liquide, le Dithane M-22, le Dithane M-45, le Dithane Z-78, le sulfure microcrystallin et le Phaltan. Le Phaltan est aussi efficace sur le pin rouge. En milieu naturel, deux applications d'huile de charbon ont suffi pour empêcher les apothécies fixées au pin gris de projeter des ascospores. On a réussi à enrayer partiellement une lignée prise sur une épinette noire, au moyen de trois applications d'une suspension faite de 20,000 ou 40,000 ppm de C-O-CS, de Dithane M-22 ou d'aérosol Z-C.

INTRODUCTION

Gremmeniella abietina (Lgbg.) Morelet, a pathogenic Discomycete (Smerlis, 1967, 1968b), is the cause of mortality of young pines (*Pinus* spp.) and spruces (*Picea* spp.) in Quebec. The fungus has been reported in this Province on jack pine (*Pinus banksiana* Lamb.), lodgepole pine (*P. contorta* Dougl.), red pine (*P. resinosa* Ait.), Scots pine (*P. sylvestris* L.), eastern white pine (*P. strobus* L.), black spruce (*Picea mariana* [Mill.] BSP), and white spruce (*P. glauca* [Moench] Voss) (Smerlis, 1967, 1968b). More recently, *G. abietina* was collected on Norway spruce (*P. abies* (L.) Karst.), red spruce (*P. rubens* Sarg.) and a hybrid of white spruce and sitka spruce (*P. glauca* X *P. sitchensis* [Bong.] Carr.).

Chemical control of *G. abietina* was investigated by Skilling and Waddell (1970, 1974) in the United States and Slettan (1971) in Norway. In their initial tests Skilling and Waddell (1970) reduced infection rates with 12 applications of 3% Maneb 80-W and Ziram 76-W. In 1974 they demonstrated that 0.3% chlorothalonil or a mixture of the latter with cycloheximide, applied seven times, were superior to either Maneb 80-W or Ziram 76-W. Slettan (1971) obtained statistically significant results with several applications of 0.8% Fungiman (Maneb, 80%). Skilling and Waddell (1974) tested their fungicides on red pine, Slettan on Scots pine. To develop chemical control methods effective for Quebec, a number of fungicides were assayed in the laboratory from 1972 to 1974 and in the field from 1973 to 1974. Two strains of *G. abietina*, one occurring on jack pine and the other on black spruce, were investigated. The two strains were considered as distinct because an earlier study (Smerlis, 1968a) had shown that they differ in the timing of their spore discharge period.

MATERIALS AND METHODS

Fungicides tested, and origin of *G. abietina* material

The fungicides assayed in this study are listed with their trade and alternate names and their manufacturers in Table 1.

G. abietina occurring on jack pine used in the laboratory and field was collected in a young, natural jack pine stand near Cap-de-la-Madeleine, Champlain County, each year at the end of May and early June. Scattered black spruce were present in the collection area, but an intensive search on this tree species failed to reveal any infection by *G. abietina*. Part of the collection from jack pine was used immediately in the field to infect jack pine and red pine, and the rest was stored in a dark cold-room at 3°C, ± 1° for later use in laboratory tests. The stored material remained viable and of discharging ascospores at least until November of the year collected.

The strain of *G. abietina* from black spruce was collected each year, 1972-1974, on regeneration of this tree species in black spruce-white spruce-tamarack stands at Lac Jacques Cartier, Laurentide Park, Montmorency County, at the end of July and early August. The area infected at Lac Jacques Cartier is approximately 8 x 8 km. The nearest known jack pine to this infection centre is located 48 km east at St. Urbain, Charlevoix Ouest County. Part of the material collected was used immediately to infect black spruce in the field, and the rest stored in a dark cold-room at 3°C, ± 1. The material remained viable at least until November of the year collected.

Lethal dosage of fungicides

To determine the lethal dosage which inhibits 100% of potentially viable spores from germinating (LD-100) a series of solutions or suspensions of progressively increasing concentrations of fungicides were prepared, tested, and the presence or absence of germinating spores noted. The tests, carried out in duplicate, were continued until the desired accuracy was achieved (Table 1). The fungicides were weighed with a Sartorius[R1] 2400 analytical balance to ± 0.1 mg, and added to 25 ml of sterile, distilled water, or, in the case of Actidione BR Concentrate, to stove oil, which were measured with a 25 ml burete. Germination tests were carried out on 75 x 25 x 1.5 mm microscope slides with a concavity of 0.064 mm. They were autoclaved in steam for 15 min and, while still hot, 0.1 ml of 1.5% malt agar deposited in the cavities with a 0.1 ml volumetric pipete. The slides were placed in dry, sterile, 150 x 15 mm Petri dishes on v-shaped glass rods and dried in an

[R1] Sartorius-Werke GMBH, Göttingen, The Federal Republic of Germany.

oven for 24 h at 40°C, ± 1°. After drying, 10 ml of distilled water were poured into the bottom of the Petri dish. A minute piece jack pine or black spruce bark bearing mature apothecium of *G. abietina* was attached with grafting wax to the inside of the Petri dish cover situated directly above the cavity of the slide when the Petri dish is closed, and the interior of the cover sprayed with approximately 0.5 ml of distilled water utilizing a DeVilbiss Atomizer No. 82[R2]. One tenth of a ml of fungicide tested was deposited on the cavity with a 0.1 ml volumetric pipete and the dish was closed with a cover and sealed with a rubber band. Dishes were placed in an incubator at 20°C, ± 0.5°C for 24 h. Slides were examined under a compound microscope at x 100. and the presence or absence of germination among the first 100 spores seen noted. Sterile, distilled water was substituted for fungicides on the control slides. Spores were arbitrarily defined as germinated if the length of the germ tube exceeded half the diameter of the spore. Tests were carried out with both strains simultaneously from August to November. In preliminary tests with five slides for each strain prepared as those of controls, the percentages of germinated spores of the strains from jack pine and black spruce ranged from 98 to 100 and 99 to 100, respectively.

Effect of LD-100 concentrations on ascospore discharge in laboratory

A sterile, standard microscope slide was coated in the center with a thin layer of 1.5% malt agar to facilitate detection of discharged spores and placed on a v-shaped glass rod in a sterile 150 x 15 mm Petri dish containing 10 ml of distilled water. A small piece of jack pine or black spruce bark with a mature *G. abietina* apothecium was immersed in a fungicide suspension of LD-100 concentration for 2 min and attached to the inside of a Petri cover with grafting wax. The cover was closed over the bottom after its interior had been sprayed with 0.5 ml of distilled water. The Petri dish was sealed with a rubber strip. For controls, the apothecia were submerged in distilled water. The dishes were placed in an incubator at 20°C, ± 0.5° for 24 h. The slides were scanned under a compound microscope at x 100.

[R2] The DeVilbiss Co., Somerset, Pa., U.S.A.

Effect of fungicides on field infections

Plots, 50 x 50 cm, were established at 1 m spacing in a sandy, abandoned farm meadow at Valcartier, Quebec County, in 1973 and 1974. They were arranged in a number of sets of two randomized blocks. Each block in each set consisted of a control plot and, depending on the number of different concentrations tried, from two to eight plots treated with a fungicide. Nine seedlings of 2-1 conifers of the same species, either jack pine, red pine, or black spruce, were planted on each plot either in the fall or in the spring prior to the application of fungicides. Light mortality in spring reduced the number of seedlings in some plots to eight. To provide uniform conditions between paired blocks, the number of seedlings on the remaining plots of affected blocks was also reduced to eight by removing a seedling selected at random prior to application of fungicides. Planted jack pine, red pine and black spruce ranged in height from 15 to 41 cm, 12 to 25 cm, and 6 to 12 cm, respectively. In addition to the randomized plots in blocks, two plots of each of the investigated tree species were established as uninoculated controls approximately 300 m from the nearest source of inoculum. To provide support for the material containing inoculum, four 2 x 2 x 90 cm wooden pickets, with a nail partially driven into one side 15 cm below the top, were hammered into the ground at each corner of the plot. A wooden or wire frame, measuring 55 x 55 cm with six strings of cord strung across in a form of a net, was placed above the seedlings on the protruding nails of the pickets. The frames were removed from the plots when applying fungicides. The fungicides were prepared with the same accuracy as the concentrations tested in laboratory. Each treated plot was sprayed with 25 ml (1,000 l/ha) by means of a hand-operated Smith Cub Sprayer[R3]. A corresponding amount of distilled water was used on the subsequently inoculated control plots. The concentrations of fungicides investigated in 1973 varied from LD-100 to arbitrarily selected values. In 1974, 20,000 and 40,000 ppm were the most frequently tested strengths. A complete list of concentrations investigated is given in Table 2. The fungicides were assayed at the following frequencies of applications and dates: 1) jack pine - one (June 11), two (June 11, 26),

[R3] D.B. Smith & Company, Utica, N.Y., U.S.A.

and five (June 11, 18, 26, July 3, 9) in 1973; one (June 3) and three (June 3, 10, 17) in 1974; 2) red pine - two (June 27 and July 9) in 1973; one (June 3) in 1974; 3) black spruce - three (August 13, 19, 26) in 1974. The timing of applications on pines and black spruce was selected to coincide with the natural period of spore discharge of the two strains of *G. abietina* occurring in Quebec (Smerlis, 1968a). The day following the initial application of fungicides 15-25-cm-long branches of jack pine, bearing mature apothecia of *G. abietina*, were attached to the netting of frames placed over jack pine and red pine plots. Similar branches of black spruce were suspended over the black spruce plots. The branches of jack pine were removed from the plots on October 23, 1973 and October 24, 1974, and those of black spruce on October 24, 1974. The exact length of spore discharge period from the suspended branches was not determined. However, six spore traps, consisting of petroleum jelly coated 75 x 25 x 1.5 mm microscope slides suspended below the jack pine branches on August 9, 1973 and August 8, 1974, showed that spore discharge had terminated by these dates. Moreover, fruiting bodies taken from six randomly selected branches of this tree species from plots were found to be empty when examined in the laboratory. Similar studies showed that spore discharge from black spruce had terminated by October 2, 1974. The grass between the rows, plots, and seedlings was cut several times during the growing season. The plots were examined in the spring following the year of treatments. The infected seedlings were tallied and 25 of each tree species selected at random, cut, examined in laboratory, and the fungi identified when found. Three to six isolations per infected tree were made. A small section of necrotic tissue was surface-sterilized in 1% $HgCl_2$ solution for 1 min, washed in sterile, distilled water, and placed on 3% malt agar in 16 x 150 mm culture tubes. The tubes were incubated in darkness at 15°C, ± 0.5°. To determine the significance of variations in infection percentages observed between the randomized plots in each set of blocks, the percentages were transferred into angles (Snedecor and Cochran, 1967) and subjected to analyses of variance. Where statistical significance was indicated, differences between the means in plots treated with fungicides and controls were tested at the 5 and 1% levels with Duncan's multiple range test (LeClerg *et al* 1962).

Effect of Orthorix and stove oil on ascospore discharge in field of *G. abietina* occurring on jack pine

Plots identical to those described earlier were established at 10 m spacing in a young, sparsely stocked black spruce-balsam fir stand at Valcartier in 1974. They were arranged in three sets of pairs of randomized blocks. Nine seedlings of 2-1 jack pine were planted in the spring on each plot. Two 15-25-cm-long jack pine branches bearing apothecia of *G. abietina* were attached to the netting of frames and sprayed on both sides with 25 ml of Orthorix, stove oil, or distilled water using a Smith Cub sprayer. Frames with the treated *G. abietina* material were suspended above the plots on four pickets. Solutions of Orthorix were prepared and volumes of stove oil and distilled water measured with the same degree of accuracy as in laboratory tests. Treatments were as follows: 1) one application (July 11, 1974) of 300, 500, 1,000, 1,500 ppm of Orthorix, and distilled water (control); 2) two applications (July 11, 18) of the previously mentioned concentrations; 3) one application of stove oil (July 11), two applications of stove oil (July 11, 18), and distilled water (control). The plots were examined for results in June 1975. Treatment of the data has already been described in the previous subsection.

RESULTS

The LD-100 values of the fungicides investigated on *G. abietina* occurring on jack pine ranged from 9 ppm for Cyprex 65-W to 559,500 ppm for microfine sulfur (Table 1). Although a number of compositions were tested, attempts to determine the LD-100 value for Bordeaux mixture remained unsuccessful. Several of the investigated fungicides inhibited ascospore discharge at their LD-100 concentrations, notably Orthorix at 350 ppm and Actidione BR Concentrate diluted in stove oil at 1,150 ppm. The inhibition in the latter case was probably caused entirely by stove oil since subsequent tests with the diluent showed that it was capable of inhibiting spore discharge (Table 1).

The strain of *G. abietina* from black spruce was generally more sensitive to fungicides than that occurring on jack pine (Table 1). Actidione BR Concentrate diluted in stove oil inhibited germination at all concentrations.

Additional tests with stove oil alone and Actidione BR Concentrate diluted in water, however, demonstrated that stove oil was the sole effective ingredient in dilutions containing Actidione BR Concentrate in concentrations below 9 ppm (Table 1). The LD-100 values of the other fungicides ranged from 7 ppm for Orthocide to 519,500 ppm for microfine sulfur. Bordeaux mixture of 0.8 - 0.8 - 100 composition, ineffective against the strain from jack pine, suppressed completely germination of spores originating from apothecia occurring on black spruce. Ascospore discharge was inhibited by more fungicides at their LD-100 values and at lower concentrations as compared to the strain from jack pine. For example, Orthorix suppressed ascospore discharge at 180 ppm, whereas the same concentration tested on the strain from jack pine was ineffective.

None of the investigated fungicides tried, in the field, at or below their LD-100 concentrations completely suppressed spore germination on jack pine (Table 2). However, C-O-Cs, Difolatan 4.8 Flowable Suspension, microfine sulfur, Phaltan, and Phygon 50-W caused reductions in the frequencies of infections which were statistically significant at the 5 or 1% levels. Microfine sulfur was the only fungicide which was effective, although not consistently, at these concentrations at one application. The others required more than one spraying to be effective. Treatments with the remaining fungicides tested at or below their LD-100 values were statistically insignificant. Actidione BR Concentrate diluted in stove oil was toxic to jack pine at 50 and 100 ppm. Stove oil alone at one and three applications was neither injurious to jack pine nor effective as a protectant.

At concentrations exceeding the LD-100 values, Phygon 50-W was the most effective fungicide tested on jack pine and red pine. At 20,000 and 40,000 ppm concentrations, it completely suppressed infection at one and three applications. Partial protection of jack pine was obtained with Cyprex 65-W, Difolatan 4.8 Flowable Suspension, Dithane M-22, Dithane M-45, and Dithane Z-78. At 20,000 ppm or higher concentrations, they caused reductions in frequencies of infections which were statistically significant at the 5 or 1% levels. Phaltan at corresponding concentrations was similarly effective on jack pine and red pine. Bordeaux mixture of 1.6 - 1.6 - 100 and

2.0 - 2.0 - 100 compositions, ineffective in the laboratory against *G. abietina* from jack pine, only provided partial protection for this tree species in the field. The reduction in infection frequencies caused by Bordeaux mixture fungicide was significant at the 5% level. Bordeaux mixture, Cyprex 65-W, Dithane M-22, Dithane M-45, and Dithane Z-78 required more than one spraying to be effective; Difolatan 4.8 Flowable Suspension was the only fungicide which provided partial control at these concentrations with one application. Treatments with the remaining fungicides investigated at 20,000 ppm or higher concentrations resulted in statistically insignificant variations. Jack pine and red pine controls which were not inoculated were not infected. Cyprex 65-W, found to cause foliage injuries on red pine at concentrations ranging from 0.3 to 3.0% by Skilling and Waddell (1970), was not phytotoxic to any of the tree species at the concentrations tested in Quebec.

Two applications of stove oil on jack pine branches bearing apothecia of *G. abietina* completely inhibited ascospore discharge in the field, that is, no seedlings became infected. A single application of the same substance caused reduction in the frequency of infected trees to 5.6% from 72.3% of controls. The reduction was significant at the 5% level. Orthorix at concentrations ranging from 300 to 1,500 ppm and at one and two applications failed to produce statistically significant results. Non-inoculated controls were free of any disease symptoms.

Three applications of 20,000 or 40,000 ppm suspensions of C-O-CS, Dithane M-22, or Z-C Spray on black spruce resulted in partial control of the fungus (Table 2). The results were significant at the 5% level. Treatments with the other investigated fungicides, including Phygon 50-W which was effective on jack pine and red pine, were unsuccessful in preventing infections. Controls of black spruce not inoculated were not infected. Actidione BR Concentrate diluted in stove oil was slightly phytotoxic at the two concentrations, 500 and 1,000 ppm, investigated, causing slight discoloration of foliage on some leaders of stems and branches. The damage, however, was not permanent.

Gremmeniella abietina was isolated from 80% of diseased jack pine inoculated and sampled in the spring of 1973 and 1974. Pycnidia of the fungus were present on 4.0% of seedlings at the time of sampling. They were

confined to cream-colored foliage located at the apices of stem leaders. No fruiting bodies were found on the reddish brown needles or the necrotic bark of stems and branches. Of 25 additional diseased seedlings of 1973 inoculations left intact on plots, pycnidia and apothecia of *G. abietina* were present on 88.0% and pycnidia only on 8.0% of the samples in the spring of 1975. One seedling was without any fruiting bodies of *G. abietina*. Of seedlings treated in 1974, *G. abietina* was isolated from 92.0% of the samples. Pycnidia of the fungus were found on 8.0% of the necrotic seedlings examined.

The percentage of red pine of 1973 inoculations yielding cultures of *G. abietina* in 1974 was identical to that of jack pine sampled the same year. The fungus, however, fruited more readily on red pine. Of 25 necrotic red pine examined at the beginning of the growing season, pycnidia of *G. abietina* were found on all samples ranging from one to six per needle, mainly on the cream-colored bases of foliage fascicles situated at the tip of the principal leader. Few pycnidia were found on the bark of jack pine just below the terminal bud, but they were absent from other necrotic parts of the stem and branches and reddish brown foliage. Of 25 additional necrotic seedlings of 1973 inoculations left on plots, pycnidia and apothecia of *G. abietina* were found on all samples in the spring of 1975. The fungus was isolated from 96.0% of red pine inoculated in 1974 and sampled in the spring of 1975. Pycnidia of *G. abietina* were found on all samples examined. On May 30, 1975, discharge of conidia of *G. abietina* began from fruiting bodies formed on diseased red pine and jack pine inoculated in 1974. Discharge was determined with petroleum jelly coated 75 x 25 x 1.5 mm microscope slides suspended below the infected foliage bearing pycnidia.

Twenty-four per cent of the infected black spruce sampled in 1975 yielded cultures of *G. abietina*. Since infected black spruce leaders and branches loose their foliage rather suddenly at the beginning of the growing season, relatively few needles from the infected tree parts were collected and examined in laboratory. These needles, ranging in color from yellowish green to light brown, as well as the bare, necrotic leaders and branches were free of fruiting bodies of *G. abietina*. Of 25 additional infected leaders and branches collected on July 7, pycnidia of the fungus were found on 28.0% of samples. Discharge of conidia of *G. abietina* from black spruce inoculated in 1974 began on July 22, 1975, seven weeks later than on jack pine and red pine. This difference in the start of spore discharge between the two strains at Valcartier in 1975 substantiates information reported earlier (Smerlis, 1968a).

The publication of accumulated data should not be interpreted as an endorsement of usage of any of the investigated fungicides as control agents of *G. abietina*. They were assayed with a varying degree of success under certain experimental and environmental conditions. Additional research on chemical control of *G. abietina* is currently under progress at the Laurentian Forest Research Centre.

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Table 1. Fungicides assayed in laboratory, their LD-100 values, and the effect of LD-100 concentrations on ascospore discharge of *G. abietina* occurring on jack pine and black spruce

Fungicide			Fungus			
			Host: jack pine		Host: black spruce	
Trade name	Manufacturer	Alternate name	LD-100, ppm	Ascospore discharge[a]	LD-100, ppm	Ascospore discharge
tidione BR oncentrate	Upjohn[b]	Cycloheximide				
water			550 ± 50[c]	N.i.[d]	9 ± 1	N.i.
stove oil			1,150 ± 50	I.	All concentrations	I.
tove oil			Germination not inhibited	I.	Germination inhibited	I.
tidione PM	"	"	550 ± 50	N.i.	90 ± 5	N.i.
nlate	Du Pont	Benomyl	50,550 ± 50	I.	6,650 ± 50	I.
rdeaux mixture	Local preparation	-	Not established	-	0.8 - 0.8 - 100[e]	I.
O-CS	Niagara Chemicals	Copper oxychloride sulfate	366,500 ± 500	N.i.	262,500 ± 500	I.
prex 65-W	American Cyanamid	Dodine	9 ± 1	N.i.	9 ± 1	N.i.
folatan 4.8 lowable Suspension	Chevron Chemical	Tetrachloroethylmercapto-cyclohexenedicarboximide	750 ± 50	N.i.	45 ± 5	N.i.
thane A-40	Rohm & Haas	Nabam	45 ± 5	N.i.	45 ± 5	N.i.

Table 1. (Cont'd)

Fungicide			Fungus			
			Host: jack pine		Host: black spruce	
Trade name	Manufacturer	Alternate name	LD-100, ppm	Ascospore discharge	LD-100, ppm	Ascospore discharge
Dithane M-22	Rohm & Haas	Maneb	45 ± 5	N.i.	45 ± 5	N.i.
Dithane M-45	"	Mancozeb	3,950 ± 50	N.i.	450 ± 50	N.i.
Dithane Z-78	"	Zineb	3,850 ± 50	N.i.	2,150 ± 50	N.i.
Ferbam 76-W	Niagara Chemicals	Ferbam	2,850 ± 50	N.i.	1,150 ± 50	N.i.
Karathane	Rohm & Haas	Dinitrocaprylphenyl crotonate	5,950 ± 50	I.	3,950 ± 50	I.
Microfine sulfur	Chipman Chemicals	Sulfur	559,500 ± 500	I.	519,500 ± 500	I.
Orthocide	Chevron Chemical	Captan	45 ± 5	N.i.	7 ± 1	N.i.
Orthorix	"	Lime sulfur	350 ± 50	I.	180 ± 10	I.
Phaltan	"	Folpet	180 ± 10	N.i.	9 ± 1	N.i.
Phygon 50-W	Niagara Chemicals	Dichlone	450 ± 50	N.i.	9 ± 1	N.i.
Polyram 80-W	"	Metiram	2,750 ± 50	N.i.	450 ± 50	N.i.
Z-C Spray	"	Ziram	7,550 - 50	N.i.	6,450 ± 50	N.i.

[a] Ascospore discharge from apothecia soaked for 2 min in LD-100 suspensions.

[b] Upjohn Inter-American Corp., Kalamazoo, Mich., U.S.A.; American Cyanamid Co., Princeton, N.J., U.S.A.; Chevron Chemical (Canada) Ltd., Oakville, Ont.; Chipman Chemicals Ltd., Hamilton, Ont.; E.I. DuPont De Nemours & Co. Inc., Wilmington, Del., U.S.A.; Rohm & Haas Co. of Canada Ltd., West Hill, Ont.; Niagara Chemicals, Burlington, Ont.

Table 1. (Cont'd)

[c] Average of two replicates of LD-100 values and accuracy of each in ppm for all fungicides but Bordeaux mixture. In the latter case, 0.8 - 0.8 - 100 composition, assayed in duplicate, caused inhibition of germination of ascospores of the strain from black spruce while 0.4 - 0.4 - 100 was ineffective.

[d] N.i. = not inhibited; I. = inhibited.

[e] Copper sulfate, 0.8 kg; lime, 0.8 kg; water, 100 l.

Table 2. Effect in the field of composition, concentration, and frequency of application of fungicides on the frequencies of jack pine, red pine, and black spruce infected by *G. abietina*

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Actidione BR Concentrate + stove oil	50	1, 1973	Jack pine	18	Phytotoxic	-	-
	100			"	"		
	Control			"	94.5 ± 7.9[a]		
	50	2, 1973	Red pine	18	100.0 ± 0.0	N.s.[b]	-
	100			"	83.4 ± 23.6		
	Control			"	100.0 ± 0.0		
	500	3, 1974	Black spruce	18	50.0 ± 7.9	N.s.	-
	1,000			"	38.9 ± 7.9		
	Control			"	61.2 ± 7.9		
Actidione PM	600	1, 1973	Jack pine	18	100.0 ± 0.0	N.s.	-
	700			"	77.8 ± 15.7		
	Control			"	94.5 ± 7.9		
	600	2, 1973	Jack pine	18	94.5 ± 7.9	N.s.	-
	700			"	66.7 ± 0.0.		
	Control			"	83.3 ± 7.9		
	600	5, 1973	Jack pine	18	55.6 ± 0.0	N.s.	-
	700			"	50.0 ± 0.0		
	Control			"	66.7 ± 0.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Actidione PM	600	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	700			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	20,000	1, 1974	Jack pine	18	62.5 ± 17.7	N.s.	-
	40,000			"	81.2 ± 8.8		
	Control			"	62.5 ± 17.7		
	20,000	3, 1974	Jack pine	18	66.7 ± 15.7	N.s.	-
	40,000			"	61.2 ± 7.9		
	Control			"	61.2 ± 7.9		
	20,000	3, 1974	Black spruce	18	66.7 ± 0.0	N.s.	-
	40,000			"	72.3 ± 7.9		
	Control			"	83.3 ± 7.9		
Benlate	20,000	3, 1974	Black spruce	18	94.5 ± 7.9	N.s.	-
	40,000			"	94.5 ± 7.9		
	Control			"	94.5 ± 7.9		
	25,000	1, 1973	Jack pine	18	94.5 ± 7.9	N.s.	-
	30,000			"	88.9 ± 0.0		
	Control			"	94.5 ± 7.9		
	25,000	2, 1973	Jack pine	18	94.5 ± 7.9	N.s.	-
	30,000			"	88.9 ± 0.0		
	Control			"	88.9 ± 15.7		
	25,000	5, 1973	Jack pine	18	77.8 ± 0.0	N.s.	-
	30,000			"	72.3 ± 7.9		
	Control			"	72.3 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Benlate	25,000	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	30,000			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	50,000	1, 1974	Jack pine	18	83.3 ± 7.9	N.s.	-
	60,000			"	83.4 ± 23.6		
	Control			"	72.3 ± 7.9		
	50,000	3, 1974	Jack pine	16	81.2 ± 8.8	N.s.	-
	60,000			"	81.2 ± 8.8		
	Control			"	62.5 ± 17.7		
Bordeaux mixture	1.6 - 1.6 - 100	1, 1973	Jack pine	16	81.2 ± 8.8	N.s.	-
	2.0 - 2.0 - 100			"	81.2 ± 8.8		
	Control			"	93.8 ± 24.4		
	1.6 - 1.6 - 100	2, 1973	Jack pine	16	81.2 ± 8.8	N.s.	-
	2.0 - 2.0 - 100			"	87.5 ± 0.0		
	Control			"	87.5 ± 0.0		
	1.6 - 1.6 - 100	5, 1973	Jack pine	18	22.2 ± 16.5	*	*
	2.0 - 2.0 - 100			"	50.0 ± 7.9	*	*
	Control			"	88.9 ± 0.0		
	1.6 - 1.6 - 100	1, 1974	Jack pine	16	18.8 ± 8.8	N.s.	-
	2.0 - 2.0 - 100			"	43.8 ± 8.8		
	Control			"	75.0 ± 17.7		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Bordeaux mixture	1.6 - 1.6 - 100	3, 1974	Jack pine	18	27.8 ± 7.9	*	*
	2.0 - 2.0 - 100			"	22.2 ± 0.0		*
	Control			"	72.3 ± 7.9		
	1.6 - 1.6 - 100	1, 1974	Red pine	18	88.9 ± 0.0	N.s.	-
	2.0 - 2.0 - 100			"	94.6 ± 0.0		
	Control			"	94.5 ± 7.9		
	1.6 - 1.6 - 100	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	2.0 - 2.0 - 100			"	72.3 ± 23.6		
	Control			"	100.0 ± 0.0		
	1.6 - 1.6 - 100	3, 1974	Black spruce	18	44.5 ± 15.8	N.s.	-
	2.0 - 2.0 - 100			"	27.8 ± 7.9		
	Control			"	100.0 ± 0.0		
C-O-CS	50	1, 1973	Jack pine	18	72.3 ± 7.9	N.s.	-
	100			"	72.3 ± 7.9		
	200			"	88.9 ± 0.0		
	300			"	94.5 ± 7.9		
	400			"	72.3 ± 7.9		
	Control			"	72.3 ± 7.9		
	50	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
C-O-CS	1,000	1, 1974	Jack pine	18	94.5 ± 7.9	N.s.	-
	20,000			"	50.0 ± 7.9		
	40,000			"	50.0 ± 7.9		
	100,000			"	72.3 ± 7.9		
	Control			"	66.7 ± 15.7		
	1,000	3, 1974	Jack pine	18	66.7 ± 0.0	*	N.s.
	20,000			"	44.5 ± 15.8		N.s.
	20,000			"	5.6 ± 7.9		**
	100,000			"	5.6 ± 7.9		**
	Control			"	72.3 ± 7.9		
	20,000	3, 1974	Black spruce	18	22.2 ± 0.0	*	*
	40,000			"	16.7 ± 7.9		*
	Control			"	61.2 ± 7.9		
Cyprex 65-W	10	1, 1973	Jack pine	18	88.9 ± 0.0	N.s.	-
	100			"	66.7 ± 15.7		
	Control			"	61.2 ± 7.9		
	10	2, 1973	Jack pine	18	83.3 ± 7.9	N.s.	-
	100			"	77.8 ± 15.7		
	Control			"	66.7 ± 15.9		
	10	5, 1973	Jack pine	18	88.9 - 0.0	N.s.	-
	100			"	77.8 - 15.7		
	Control			"	66.7 - 15.9		
	10	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Cyprex 65-W	10,000	1, 1974	Jack pine	18	27.8 ± 7.9	N.s.	-
	20,000			"	16.7 ± 23.6		
	20,000			"	22.2 ± 0.0		
	Control			"	50.0 ± 7.9		
	10,000	3, 1974	Jack pine	18	16.7 ± 7.9	*	* *
	20,000			"	16.7 ± 7.9		* *
	40,000			"	16.7 ± 7.9		* *
	Control			"	83.4 ± 7.9		
	20,000	3, 1974	Black spruce	18	50.0 ± 7.9	N.s.	-
	40,000			"	72.3 ± 7.9		
	Control			"	94.5 ± 7.9		
Difolatan 4.8 Flowable Suspension	50	1, 1973	Jack pine	18	88.9 ± 0.0	N.s.	-
	100			17	82.7 ± 6.9		
	200			18	94.5 ± 7.9		
	300			"	83.3 ± 7.9		
	400			"	88.9 ± 0.0		
	500			17	64.6 ± 3.0		
	600			18	72.3 ± 7.9		
	700			"	72.3 ± 7.9		
	Control			"	83.3 ± 7.9		
	50	2, 1973	Red pine	18	94.5 ± 7.9	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Difolatan 4.8 Flowable Suspension	800	1, 1974	Jack pine	18	50.0 ± 7.9	*	N.s.
	1,000			"	61.2 ± 7.9		N.s.
	20,000			"	22.2 ± 15.7		*
	40,000			"	16.7 ± 7.9		*
	Control			"	50.0 ± 7.9		
	800	3, 1974	Jack pine	18	27.8 ± 7.9	*	* *
	1,000			"	22.2 ± 7.9		* *
	20,000			"	16.7 ± 7.9		* *
	40,000			"	16.7 ± 7.9		* *
	Control			"	72.3 ± 7.9		
	20,000	3, 1974	Black spruce	18	38.9 ± 7.9	N.s.	-
	40,000			"	33.3 ± 0.0		
	Control			"	50.0 ± 7.9		
Dithane A-40	50	1, 1973	Jack pine	16	93.8 ± 24.0	N.s.	-
	100			"	87.5 ± 0.0		
	Control			"	93.8.± 24.0		
	50	2, 1973	Jack pine	16	87.5 ± 0.0	N.s.	-
	100			"	81.2 ± 8.8		
	Control			"	81.2 ± 8.8		
	50	5, 1973	Jack pine	18	72.3 ± 7.9	N.s.	-
	100			"	77.8 ± 15.7		
	Control			"	72.3 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Dithane A-40	50	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	83.4 ± 23.6		
	1,000	1, 1974	Jack pine	18	38.9 ± 23.6	N.s.	-
	10,000			"	50.0 ± 23.6		
	20,000			"	77.8 ± 15.7		
	40,000			"	72.3 ± 7.9		
	Control			"	50.0 ± 23.6		
	1,000	3, 1974	Jack pine	18	55.6 ± 0.0	N.s.	-
	10,000			"	38.9 ± 7.9		
	20,000			"	50.0 ± 7.9		
	40,000			"	50.0 ± 7.9		
	Control			"	44.5 ± 15.8		
	20,000	3, 1974	Black spruce	18	38.9 ± 7.9	N.s.	-
	40,000			"	33.3 ± 0.0		
	Control			"	62.5 ± 17.7		
Dithane M-22	50	1, 1973	Jack pine	16	93.8 ± 24.0	N.s.	-
	100			"	75.0 ± 35.4		
	200			"	68.8 ± 26.5		
	300			"	75.0 ± 0.0		
	400			"	68.8 ± 8.8		
	Control			"	81.2 ± 8.8		
	50	2, 1973	Jack pine	18	83.3 ± 7.9	N.s.	-
	100			"	72.3 ± 7.9		
	200			"	72.3 ± 7.9		
	300			"	88.9 ± 0.0		
	400			"	72.3 ± 0.0		
	Control			"	72.3 ± 0.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Dithane M-22	50	5, 1973	Jack pine	18	83.3 ± 7.9	N.s.	-
	100			"	83.4 ± 23.6		
	200			"	72.3 ± 23.6		
	300			"	83.3 ± 7.9		
	400			"	83.3 ± 7.9		
	Control			"	83.3 ± 7.9		
	50	2, 1973	Red pine	18	94.5 ± 7.9	N.s.	-
	100			"	94.5 ± 7.9		
	200			"	83.4 ± 23.6		
	300			"	100.0 ± 0.0		
	400			"	94.5 ± 7.9		
	500			"	100.0 ± 0.0		
	600			"	100.0 ± 0.0		
	700			"	100.0 ± 0.0		
	Control			"	94.5 ± 7.9		
	10,000	1, 1974	Jack pine	18	33.3 ± 15.7	N.s	-
	20,000			"	38.9 ± 23.6		
	40,000			"	44.5 ± 15.8		
	Control			"	44.5 ± 15.8		
	10,000	3, 1974	Jack pine	18	38.9 ± 7.9	*	N.s.
	20,000			"	16.7 ± 7.9		*
	40,000			"	5.6 ± 7.9		* *
	Control			"	50.0 ± 7.9		
	20,000	1, 1974	Red pine	18	66.7 ± 31.5	N.s.	-
	40,000			"	83.3 ± 7.9		
	Control			"	94.5 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Dithane M-22	20,000	3, 1974	Black spruce	18	11.1 ± 0.0	*	*
	40,000			"	16.7 ± 7.9	*	*
	Control			"	83.3 ± 7.9		
Dithane M-45	50	1, 1973	Jack pine	18	72.3 ± 7.9	N.s.	-
	100			"	77.8 ± 0.0		
	200			"	94.5 ± 7.9		
	300			"	83.3 ± 7.9		
	400			"	72.3 ± 7.9		
	Control			"	72.3 ± 7.9		
	50	2, 1973	Red pine	18	94.5 ± 7.9	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	4,000	1, 1974	Jack pine	16	87.5 ± 17.7	N.s.	-
	6,000			"	37.5 ± 0.0		
	20,000			"	50.0 ± 0.0		
	40,000			"	43.8 ± 8.8		
	Control			"	68.8 ± 8.8		
	4,000	3, 1974	Jack pine	18	50.0 ± 7.9	*	N.s.
	6,000			"	61.2 ± 7.9		N.s.
	20,000			"	27.8 ± 7.9		*
	40,000			"	16.7 ± 7.9		* *
	Control			"	61.2 ± 7.9		
	20,000	3, 1974	Black spruce	18	27.8 ± 23.6	N.s.	-
	40,000			"	22.2 ± 15.7		
	Control			"	38.9 ± 23.6		
Dithane Z-78	4,000	1, 1973	Jack pine	16	87.5 ± 17.7	N.s.	-
	5,000			"	93.8 ± 24.0		
	Control			"	93.8 ± 24.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Dithane Z-78	4,000	2, 1973	Jack pine	16	75.0 ± 0.0	N.s.	-
	5,000			"	87.5 ± 0.0		
	Control			"	81.2 ± 8.8		
	4,000	5, 1973	Jack pine	16	81.2 ± 8.8	N.s.	-
	5,000			"	87.5 ± 0.0		
	Control			"	75.0 ± 0.0		
	4,000	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	5,000			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	20,000	1, 1974	Jack pine	18	38.9 ± 23.6	N.s.	-
	40,000			"	44.5 ± 15.8		
	Control			"	38.9 ± 7.9		
	20,000	3, 1974	Jack pine	18	38.9 ± 7.9	*	N.s.
	40,000			"	16.7 ± 7.9		*
	Control			"	72.3 ± 7.9		
	20,000	3, 1974	Black spruce	18	66.7 ± 0.0	N.s.	-
	40,000			"	66.7 ± 15.7		
	Control			"	72.3 ± 7.9		
Ferbam 76-W	3,000	1, 1973	Jack pine	18	94.5 ± 7.9	N.s.	-
	4,000			"	88.9 ± 15.7		
	Control			"	94.5 ± 7.9		
	3,000	2, 1973	Jack pine	18	83.3 ± 7.9	N.s.	-
	4,000			"	83.3 ± 7.9		
	Control			"	94.5 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Ferbam 76-W	3,000	5, 1973	Jack pine	16	81.2 ± 8.8	N.s.	-
	4,000			"	75.0 ± 0.0		
	Control			"	68.8 ± 8.8		
	3,000	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	4,000			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	20,000	1, 1974	Jack pine	18	50.0 ± 7.9	N.s.	-
	40,000			"	33.3 ± 15.7		
	Control			"	38.9 ± 7.9		
	20,000	3, 1974	Jack pine	18	27.8 ± 7.9	N.s.	-
	40,000			"	44.4 ± 0.0		
	Control			"	72.3 ± 7.9		
	20,000	3, 1974	Black spruce	18	50.0 ± 7.9	N.s.	-
	40,000			"	55.6 ± 0.0		
	Control			"	72.3 ± 7.9		
Karathane	6,000	1, 1973	Jack pine	16	93.8 ± 24.0	N.s.	-
	7,000			"	87.5 ± 0.0		
	Control			"	93.8 ± 24.0		
	6,000	2, 1973	Jack pine	16	93.8 ± 24.0	N.s.	-
	7,000			"	81.2 ± 8.8		
	Control			"	93.8 ± 24.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Karathane	6,000	5, 1973	Jack pine	16	87.5 ± 0.0	N.s.	-
	7,000			"	81.2 ± 8.8		
	Control			"	81.2 ± 8.8		
	6,000	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	7,000			"	94.5 ± 7.9		
	Control			"	94.5 ± 7.9		
	20,000	1, 1974	Jack pine	16	50.0 ± 17.7	N.s.	-
	40,000			"	37.5 ± 17.7		
	Control			"	50.0 ± 0.0		
	20,000	3, 1974	Jack pine	18	33.3 ± 0.0	N.s.	-
	40,000			"	27.8 ± 7.9		
	Control			"	38.9 ± 7.9		
	20,000	3, 1974	Black spruce	18	72.3 ± 7.9	N.s.	-
	40,000			"	77.8 ± 0.0		
	Control			"	83.3 ± 7.9		
Microfine sulfur	40,000	1, 1973	Jack pine	18	94.5 ± 7.9	N.s.	-
	80,000			"	83.3 ± 7.9		
	Control			"	72.3 ± 7.9		
	40,000	2, 1973	Jack pine	18	88.9 ± 0.0	N.s.	-
	80,000			"	77.8 ± 0.0		
	Control			"	77.8 ± 0.0		
	40,000	5, 1973	Jack pine	18	16.7 ± 7.9	*	* *
	80,000			"	11.1 ± 0.0		* *
	Control			"	72.3 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Microfine sulfur	40,000	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	80,000			"	94.5 ± 7.9		
	Control			"	100.0 ± 0.0		
	20,000	1, 1974	Jack pine	18	33.3 ± 15.7	*	* *
	40,000			"	27.8 ± 7.9		* *
	60,000			"	38.9 ± 7.9		*
	80,000			"	27.8 ± 7.9		* *
	100,000			"	38.9 ± 7.9		*
	200,000			"	38.9 ± 7.9		*
	300,000			"	22.2 ± 7.9	*	* *
	Control			"	72.3 ± 7.9	*	* *
	20,000	3, 1974	Jack pine	18	16.7 ± 7.9	* *	* *
	40,000			"	16.7 ± 7.9		* *
	60,000			"	11.1 ± 0.0		* *
	80,000			"	16.7 ± 7.9		* *
	100,000			"	22.2 ± 0.0		* *
	200,000			"	16.7 ± 7.9		* *
	300,000			"	16.7 ± 7.9		* *
	Control			"	72.3 ± 7.9		
	20,000	3, 1974	Black spruce	18	87.5 ± 0.0	N.s.	-
	40,000			"	93.8 ± 8.8		
	Control			"	87.5 ± 17.7		
Orthocide	50	1, 1973	Jack pine	18	83.4 ± 23.6	N.s.	-
	100			"	77.8 ± 15.7		
	Control			"	61.2 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Orthocide	50	2, 1973	Jack pine	18	72.3 ± 7.9	N.s.	-
	100			"	72.3 ± 7.9		
	Control			"	83.3 ± 7.9		
	50	5, 1973	Jack pine	16	75.0 ± 0.0	N.s.	-
	100			"	75.0 ± 0.0		
	Control			"	62.5 ± 0.0		
	50	2, 1973	Red pine	18	94.5 ± 7.9	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	1,000	1, 1974	Jack pine	16	68.8 ± 8.8	N.s.	-
	10,000			"	62.5 ± 17.7		
	20,000			"	68.8 ± 8.8		
	40,000			"	56.1 ± 8.8		
	Control			"	56.1 ± 8.8		
	1,000	3, 1974	Black spruce	18	38.9 ± 7.9	N.s.	-
	10,000			"	38.9 ± 23.6		
	20,000			"	38.9 ± 7.9		
	40,000			"	38.9 ± 7.9		
	Control			"	44.5 ± 15.8		
	20,000	3, 1974	Black spruce	18	66.7 ± 0.0	N.s.	-
	40,000			"	50.0 ± 7.9		
	Control			"	50.0 ± 7.9		
Orthorix	400	1, 1973	Jack pine	18	88.9 ± 0.0	N.s	-
	500			"	83.3 ± 7.9		
	Control			"	61.2 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Orthorix	400	2, 1973	Jack pine	18	88.9 ± 15.7	N.s.	-
	500			"	72.3 ± 7.9		
	Control			"	72.3 ± 7.9		
	400	5, 1973	Jack pine	18	94.5 ± 7.9	N.s.	-
	500			"	83.3 ± 7.9		
	Control			"	72.3 ± 7.9		
	400	2, 1973	Red pine	18	94.5 ± 7.9	N.s.	-
	500			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	20,000	1, 1974	Jack pine	18	61.2 ± 7.9	N.s.	-
	40,000			"	55.6 ± 7.9		
	Control			"	44.5 ± 15.8		
	20,000	3, 1974	Jack pine	18	38.9 ± 7.9	N.s.	-
	40,000			"	38.9 ± 7.9		
	Control			"	61.2 ± 7.9		
	20,000	3, 1974	Black spruce	18	72.3 ± 7.9	N.s.	-
	40,000			"	83.3 ± 7.9		
	Control			"	66.7 ± 15.7		
Phaltan	200	1, 1973	Jack pine	18	83.3 ± 7.9	N.s.	-
	300			"	77.8 ± 0.0		
	Control			"	83.3 ± 7.9		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Phaltan	200	2, 1973	Jack pine	18	50.0 ± 7.9	N.s.	-
	300			"	55.6 ± 0.0		
	Control			"	66.7 ± 0.0		
	200	5, 1973	Jack pine	18	50.0 ± 7.9	* *	*
	300			"	11.1 ± 0.0		* *
	Control			"	77.8 ± 0.0		
	200	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	300			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	600	1, 1974	Jack pine	18	27.8 ± 7.9	*	N.s.
	800			"	44.4 ± 0.0		N.s.
	1,000			"	22.2 ± 15.7		*
	2,000			"	38.9 ± 7.9		N.s.
	20,000			"	5.6 ± 7.9		* *
	40,000			"	5.6 ± 7.9		* *
	60,000			"	11.1 ± 15.7		*
	Control			"	72.3 ± 7.9		
	600	3, 1974	Jack pine	18	38.9 ± 7.9	*	N.s.
	800			"	33.3 ± 15.7		N.s.
	1,000			"	61.2 ± 7.9		N.s.
	2,000			"	50.0 ± 7.9		N.s.
	20,000			"	16.7 ± 7.9		*
	40,000			"	5.6 ± 7.9		* *
	60,000			"	5.6 ± 7.9		* *
	Control			"	61.2 ± 7.9	*	* *

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs.
			Species	Total treated, No.	Average infected, %		
Phaltan	600	1, 1974	Red pine	18	100.0 ± 0.0	* *	N.s.
	800			"	100.0 ± 0.0		N.s.
	1,000			"	94.5 ± 7.9		N.s.
	2,000			"	94.5 ± 7.9		N.s.
	20,000			"	50.0 ± 7.9		* *
	40,000			"	33.3 ± 0.0		* *
	Control			"	94.5 ± 7.9		* *
	20,000	3, 1974	Black spruce	18	81.2 ± 8.8	N.s.	-
	40,000			"	87.5 ± 17.7		
	Control			"	93.8 ± 8.8		
Phygon 50-W	500	1, 1973	Jack pine	18	94.5 ± 7.9	N.s.	-
	600			"	83.3 ± 7.9		
	Control			"	88.9 ± 0.0		
	500	2, 1973	Jack pine	18	33.3 ± 0.0	*	*
	600			"	16.7 ± 7.9		*
	Control			"	94.5 ± 7.9		
	500	5, 1973	Jack pine	18	27.8 ± 7.9	* *	* *
	600			"	11.1 ±± 0.0		* *
	Control			"	88.9 ± 0.0		
	500	2, 1973	Red pine	18	100.0 ± 0.0	*	N.s.
	600			"	72.3 ± 7.9	*	*
	Control			"	100.0 ± 0.0		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2) Species	Total treated, No.	Average infected, %	Variance ratio between treatments, F	Duncan's test, control vs. fungicide
Phygon 50-W	800	1, 1974	Jack pine	18	27.8 ± 23.6	* *	*
	1,000			"	50.0 ± 7.9		N.s.
	2,000			"	38.9 ± 7.9		N.s.
	3,000			"	22.2 ± 0.0		* *
	20,000			"	0.0 ± 0.0		* *
	40,000			"	0.0 ± 0.0		* *
	Control			"	61.2 ± 7.9		
	800	3, 1974	Jack pine	18	38.9 ± 7.9	* *	*
	1,000			"	22.2 ± 0.0		* *
	2,000			"	16.7 ± 7.9		* *
	3,000			"	22.2 ± 0.0		* *
	20,000			"	0.0 ± 0.0		* *
	40,000			"	0.0 ± 0.0		* *
	Control			"	61.2 ± 7.0		
	800	1, 1974	Red pine	18	88.9 ± 0.0	* *	N.s.
	1,000			"	72.3 ± 7.9		*
	2,000			"	38.9 ± 7.9		* *
	3,000			"	50.0 ± 7.9		* *
	20,000			"	0.0 ± 0.0		* *
	40,000			"	0.0 ± 0.0		* *
	Control			"	94.5 ± 7.9		
	20,000	3, 1974	Black spruce	18	38.9 ± 7.9	N.s.	-
	40,000			"	50.0 ± 7.9		
	Control			"	62.5 ± 17.7		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Polyram 80-W	50	1, 1973	Jack pine	18	83.3 ± 7.9	N.s.	-
	100			"	66.7 ± 0.0		
	200			"	66.7 ± 0.0		
	300			"	83.4 ± 23.6		
	400			"	77.8 ± 0.0		
	Control			"	88.9 ± 0.0		
	50	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	100.0 ± 0.0		
	3,000	1, 1974	Jack pine	18	38.9 ± 7.9	N.s.	-
	5,000			"	38.9 ± 7.9		
	20,000			"	27.8 ± 7.9		
	40,000			"	22.9 ± 0.0		
	Control			"	61.2 ± 7.9		
	3,000	3, 1974	Jack pine	18	66.7 ± 0.0	N.s.	-
	5,000			"	77.8 ± 31.4		
	20,000			"	66.7 ± 15.7		
	40,000			"	22.2 ± 15.7		
	Control			"	50.0 ± 7.9		
	20,000	3, 1974	Black spruce	18	33.3 ± 15.7	N.s.	-
	40,000			"	27.8 ± 23.6		
	Control			"	38.9 ± 23.6		

Table 2. (Cont'd)

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Z-C Spray	50	1, 1973	Jack pine	16	68.8 ± 8.8	N.s.	-
	100			"	75.0 ± 0.0		
	200			"	68.8 ± 8.8		
	300			"	68.8 ± 8.8		
	400			"	62.5 ± 0.0		
	Control			"	68.8 ± 8.8		
	50	2, 1973	Red pine	18	100.0 ± 0.0	N.s.	-
	100			"	100.0 ± 0.0		
	Control			"	94.5 ± 7.9		
	1,000	1, 1974	Jack pine	18	77.8 ± 15.7	N.s.	-
	10,000			"	50.0 ± 7.9		
	20,000			"	38.9 ± 7.9		
	40,000			"	61.2 ± 7.9		
	Control			"	55.6 - 0.0		
	1,000	3, 1974	Jack pine	18	72.3 ± 7.9	N.s.	-
	10,000			"	72.3 ± 7.9		
	20,000			"	66.7 ± 15.7		
	40,000			"	66.7 ± 15.7		
	Control			"	61.2 ± 7.9		
	20,000	3, 1974	Black spruce	18	11.1 ± 0.0	*	*
	40,000			"	5.5 ± 7.9	*	*
	Control			"	61.2 ± 7.9		
Controls not inoculated		1973	Jack pine	18	0.0		
			Red pine	"	0.0		
		1974	Jack pine	"	0.0		
			Red pine	"	0.0		
			Jack pine	"	0.0		

[a] Average and standard error.

[b] Significance: * * = 0.01 level; * = 0.05 level; N.s. = not significant.

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Erratum: Table 2.

Fungicide	Concentration, ppm	Frequency and year of application	Seedlings (Blocks 1 & 2)			Variance ratio between treatments, F	Duncan's test, control vs. fungicide
			Species	Total treated, No.	Average infected, %		
Bordeaux mixture	2.0 - 2.0 - 100	5, 1973	Jack pine	18	50.0 ± 7.9	*	*
C-O-CS	40,000	3, 1974	Black spruce	18	16.7 ± 7.9		*
Dithane M-22	50	2, 1973	Jack pine	18	83.3 ± 7.9	N.s.	-
Dithane M-22	40,000	3, 1974	Black spruce	18	16.7 ± 7.9	*	*
Microfine sulfur	300,000	1, 1974	Jack pine	18	22.2 ± 7.9	*	**
	Control	1, 1974	Jack pine	18	72.3 ± 7.9	*	
~~Phal~~tan	Control	3, 1974	Jack pine	18	61.2 ± 7.9	*	
Phygon 50-W	600	2, 1973	Red pine	18	72.3 ± 7.9	*	*
Z-C Spray	40,000	3, 1974	Black spruce	18	5.5 ± 7.9	*	*