Fungicide Treatment of Seeds for Damping-off Control in British Columbia Forest Nurseries

The problem was to find a nonphytotoxic fungicide which would insure against severe damping-off losses. Benlate pellets worked best without affecting germination.

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Pre- and post-emergence (early and late) damping-off usually occur at endemic levels (1, 2) in British Columbia Forest Service nurseries, but occasionally disease losses are severe (1, 3). All major conifer seedling species grown are susceptible to these diseases. In recent years, the practice has been to pellet seeds with the fungicide Captan for control of pre-emergence and early post-emergence forms of the disease. However, there is some evidence that the phytotoxic effects of Captan may outweigh its beneficial effects of protecting seed and seedlings from disease, particularly in years with low damping-off incidence. Also, it is more difficult to obtain uniform sowing densities with Captan-pelleted seeds to which the fungicide is adhered with methyl cellulose.

We surmised that soaking seeds in fungicide solutions might overcome the problem of sowing uniformity, while the use of some other fungicides in the pelleting procedure might eliminate the problem of phytotoxicity. Moreover, some of the newer, systemic fungicides might provide additional protection of older seedlings against late damping-off. To test these ideas, a series of field trials were carried out in 1971 at the Koksilah nursery, and in 1972 and 1973 at the Koksilah, Surrey and Red Rock nurseries.

Materials and Methods

Seeds used were those of the coastal form of Douglas-fir *[Pseudotsuga* menziesii (Mirb.) Franco], Sitka spruce *[Picea sitchensis (Bong.)* Carr], white spruce *[Picea glauca* (Moench) Voss] and lodgepole pine *(Pines contorta* Dougl.), which had relatively high germination percentages of 87, 81.5, 78, and 69.5, respectively.

The fungicides (used at least once during the 3 study years), their application rates, mode of application, and cost (stated in Canadian dollars whose value fluctuated plus-minus three percent in relation to the U.S. dollar when these studies were made) to treat 1 pound of seed were:

(1) Arasan 75 W [Bis (dimethyl-thiocarbamoyl) disulfide] was applied by soaking seeds for 24 hours at 30°C (86°F) in a 0.2 percent (wt to wt basis) aqueous suspension of wettable Arasan powder. One hundred grams (3.5 oz) of stratified seeds were soaked in 400 ml (16.8 fluid oz) of Arasan-water suspension. The cost to treat 454 grams (1 lb) of seed (Arasan purchased at $1.80 per pound) was 1.4¢.

(2) Benlate 50 W [Methyl(1-butyl carbamoyl)-2-benzimidazole carbamate], a systemic fungicide, was applied to methyl cellulose (1 percent solution, wt: volume) stickertreated, stratified seed at a rate of 337 mg (0.018 oz) Benlate to 100 g (3.5 oz) of seed. To obtain the necessary dilution of the fungicide, each 454 grams (1 lb) of Benlate was mixed with 454 grams (1 lb) of talc. Excluding the cost of the talc, Benlate (purchased at $8 per pound) seed pelleting cost 2.6c per pound of seed.

(3) Busan 72; 60 percent active ingredient [2-(thiocyanomethylthio) benzothiazole] and 40 percent inert ingredients (not specified). Seed quantities and fungicide solution were prorated according to experimental needs and unstratified seeds were treated according to the manufacturer's recommendation of adding a solution of 15.1 cc (0.53 fluid oz) of liquid fungicide in 1.26 liters (1.33 quarts) of water to 35.24 liters (1 bushel) of seed for 24 hours. No prices were available for the Busan.

(4) Captan 50 W [r.-trichloromethylthio-4 cyclohexene-1, 2-dicarboximide] was applied to methyl cellulose, sticker-treated seeds at a rate of 15.3 g (0.54 oz) fungicide to 100 g (3.5 oz) of stratified seed. The cost of treating 1 lb of seed was 12.50 (Captan purchased a $1 per pound).

(5) Captan 50 W was applied by soaking stratified seeds for 24 hours at 30°C (86°F) in a 0.2 percent

aqueous (wt:wt basis) suspension of wettable Captan powder. One hundred grams (3.5 oz) of seed were soaked in 400 ml (16.8 fluid oz) of Captan-water suspension. This treatment cost 0.8¢ to treat 1 lb of seed, based upon a purchase price of $1 per pound for Captan.

(6) Polyram 80 W (Zinc-activated polyethylene thiuram disulphide) was applied to methyl cellulose sticker-treated, stratified seeds at a rate of 15.3 g (0.54 oz) fungicide to 100 g (3.5 oz) seed. The Polyram cost 700 per pound and the cost of treating 1 lb of seed was 1.4¢.

(7) Vitavax 75 W (5, 6-Dihydro2-methyl-1, 4-oxathiin-3-carboxanilide), a systemic fungicide, was applied to methyl cellulose stickertreated, stratified seeds at a rate of 100 g (3.5 oz) fungicide to 2 g (0.07 oz) of seed. It cost 12.5¢ to treat 1 lb of seed with Vitavax (purchased at $6.25 per pound).

(8) Zineb 85 W (Zinc ethylene bisdithio carbamate) was applied to methyl cellulose sticker-treated, stratified seeds at a rate of 15.3 g (0.54 **oz)** fungicide to 100 g (3.5 oz) of seed. It cost 15.2¢ to treat 1 lb of seed with Zineb (cost $1 per pound).

(9) Control. Stratified seeds only (no sticker or fungicide applied).

Each replicate of each treatment and control consisted of 100 seeds replicated 15 times in a randomized block design (6). Either before or after treatment, seeds were stratified and sown in drill rows (7). Sowing was done in alternate drill rows separated by unsown buffer drills between May 7 and June 7, depending upon weather conditions and nursery location. After sowing, the seeds were covered with 0.64 centimeters (0.25 inch) of washed, coarse sand. Throughout the growing season, fertilizing, irrigation, and plot care followed normal nursery practice (7). Experiments were located in areas with representative nursery soil and environmental conditions; the soils had not been fumigated within the previous 3 years.

Weekly during the early part of the growing season and less frequently as damping-off declined, counts were made of germinants and seedlings killed by either early or late damping-off; and the seedlings were removed from the plots. For statistical analyses, the data for each parameter were cumulated for the entire growing season; i.e., in each plot, the number of damped-off seedlings at each counting date was added together and expressed as a percentage of the total number of seedlings (healthy plus killed) that had germinated in that plot over the entire season.

Germination data were obtained by expressing all germinants (healthy plus diseased) as a percentage of number of seeds sown, and survival percentage was calculated as the number of healthy seedlings at the end of the growing season based on the number of seeds sown. The percentage data were transformed to the arcsin of the square root for analysis of variance and the treatment means were compared, using the Student NewmanKeuls'-test (6).

Results and Discussion

To simplify presentation and interpretation, the results for the various treatments, seedling species, years and nurseries are shown (tables 1 and 2) as being significantly (P = .05) better (B), worse (W) or the same (S) as the control.' Except where noted, all differences listed in the tables were better or worse than the control by at least 3 percent, a value selected, as being important in nursery practice.

Trials made in the coastal nurseries at Koksilah and Surrey (table 1) showed that none of the fungicide treatments improved final seedling stand (survival) of Douglas-fir over that in control plots. Some treatments such as Busan and Captan soak, and Vitavax pellet were in general detrimental to Douglas-fir germination, and damping-off losses in the 1973 Captan soak plots were worse than in the control plots. Final stands (survival), the most important factor to the nurseryman, were generally worse following Busan soak, Captan pellet and soak, and Vitavax pellet plots than in plots sown with untreated seeds.

Benlate pellet was the only treat. ment that consistently produced final stands of Douglas-fir as good as those in the control plots, mainly because Benlate did not reduce germination. Douglas-fir damping-off losses usually amount to less than 10 percent of the germinants, but in some years, such as 1971 at Koksilah, they may exceed 20 percent. Based on results over 3 years, we feel that Benlate pellet could be used to treat Douglasfir seeds each year because it does not reduce seedling stands in years with low disease risk and it would serve as an insurance measure in years when damping-off losses are serious.

Sitka spruce germination was reduced by several of the treatments; i.e., Busan soak, and pelleting with Polyram, Vitavax, Captan, and Zineb. Usually this inhibition of germination resulted in poorer final stands of seedlings (table 1). Except for the 1971 trial at Koksilah, Benlate pelleting of seeds had no ill effects and, at Surrey in 1973, this treatment gave sufficient disease control to cause final seedling numbers to be higher than in control plots. Similarly, Benlate was the only treatment that did not reduce stands of interior spruce

' Results of the analyses of variance and multiple range tests are available from the senior author.

TABLE 1.—Comparison of total germination, damping-off and survival of treated with untreated seeds in 1971, 1972 and 1973 field trials in the coastal (Koksilah and Surrey) nurseries [1]

Nurseries and treatments	Year	Germination			Total damping-off			Survival		
		DF	*SS*	*WS*	*DF*	*SS*		*DF*	*SS*	*WS*
Koksilah										
Arasan soak	71	S	S	–	S	S	–	S	S	–
Benlate pellet	71	S	S	–	S	S	–	S	W	–
	72	S	S	–	S	S	–	S	S	–
	73	S	S	–	S	S	–	S	S	–
Busan soak	71	W	W	–	S	S	–	W	W	–
Captan pellet	73	S	S	–	S	S	–	W	S	–
Captan soak	71	S	S	–	S	S	–	S	S	–
	72	W	S	–	S	S	–	S	S	–
	73	W	S	–	W	S	–	W	S	–
Polyram pellet	73	S	W	–	S	S	–	S	W	–
Vitavax pellet	71	S	W	–	B	S	–	S	W	–
	72	S	S	–	S	S	–	S	S	–
	73	S	W	–	S	S	–	W	W	–
Zineb pellet	72	S	S	–	S	S	–	S	S	–
Surrey										
Benlate pellet	72	S	S	–	S	S	–	S	S	–
	73	S	S	S	S	B	S	S	B	S
Captan pellet	73	S	W	W	S	S	W	S	W	W
Captan soak	72	W	S	–	S	S	–	W	S	–
	73	W	S	W	S	S	S	W	S	W
Polyram pellet	73	S	W	W	S	W	W	S	W	W
Vitavax pellet	72	S	S	–	S	W	–	S	W	–
	73	W	S	W	W	S	W	W	S	W
Zineb pellet	72	S	W	–	S	W	–	S	W	–

[1] Legend: – = no trial; *S*, *B* and *W* = statistically (5 percent level) the same, better or worse than the control by at least 3 percent; *DF* = Douglas-fir, *SS* = Sitka spruce and *WS* = white spruce.

TABLE 2.—Comparison of total germination, (early plus late) damping-off and survival of treated with untreated seeds in the 1972 and 1973 field trials at Red Rock (interior) nursery [1]

Treatment	Year	Germination		Total damping-off		Survival	
		LP	*WS*	*LP*	*WS*	*LP*	*WS*
Benlate pellet	72	S	S	S	S	S	S
	73	S	S	S	S	S	S
Captan pellet	73	W	W	S	S	W	W
Captan soak	72	S	S	S	S	S	S
	73	S	S	S	S	S	S
Polyram pellet	73	W	W	S	S	W	W
Vitavax pellet	72	S	S	S	S	S	S
	73	W[2]	W	S	S	W	W
Zineb pellet	72	S	S	S	S	S	S

[1] Legend: – = no trial, *S*, *B* and *W* = statistically (5 percent level) the same, better or worse than the control by at least 3 percent; *LP* = lodgepole pine, *WS* = white spruce.

[2] Significantly worse than the control by less than 3 percent.

in the 1972 Surrey trial (table 1). Thus, we feel that Benlate pellet could be used as an insurance measure on both of these spruce species in coastal nurseries.

Results of the trials at the interior nursery (table 2) demonstrated that both Benlate pellet and Captan soak could be used without detrimental effects on lodgepole pine and interior spruce seeds. However, since Captan soak proved to be harmful to interior spruce seed of this same seedlot at Koksilah (table 1), we feel that it would be advisable only to use Benlate on seeds of this species.

To date, our trials have shown that none of the fungicides tested have consistently increased stands above those in plots sown with untreated seeds. Thus the primary reason for using a fungicide to treat seeds would be to ensure against severe losses in years when damping-off is epidemic. In the past, Captan has been used for this purpose, but our studies have demonstrated that the phytotoxicity problem associated with Captan pelleting of seeds for damping-off control can be avoided by using Benlate. This fungicide has provided some protection against damping-off pathogens without reducing germination of any species of seedlings grown in B.C. forest nurseries.

The inherent disadvantage of using Benlate is that it is ineffective against certain pathogenic fungi, such as *Pythium* and *Phytophthora* (4) ; however, these fungi have not been serious pathogens in B.C. forest nurseries (5; and W. J. Bloomberg, personal communication). Future trials are planned with mixtures of Benlate and other fungicides, such as Thiram, to see if additional disease control can be obtained without harming germination. None of the fungicide soaks proved to be beneficial; consequently, the problem of obtaining

(Continued on page 28)

(Continued from page 15)

nating from low elevation and southern Oregon seed sources. The greater sensitivity to frost damage exhibited by the southern Oregon seed sources when compared to more northern sources has been reported in the literature (1).

Terminal frost damage may not handicap future seedling growth, and the multiple tops resulting from frost injury may be relatively unimportant (2) ; Edgren (2) warns against heavy culling of frost damaged trees that may exhibit good juvenile growth potential.

Frost control is practiced at the nursery by watering with an overhead sprinkler system and by adding straw mulch to seedling beds; however, considerable numbers of trees are still damaged or killed each year by frost and winter injury. The use of water for frost control has at least two disadvantages. It requires close monitoring to prevent freeze damage to the seedlings. Also, the addition of water during the normally very wet winter months can result in flooding and erosion of nursery beds. This type of damage was noted at the nursery during the 1972-1973 season.

Evaluations of seed protectants and nursery bed treatments are warranted. Damping-off losses vary from year-to-year at the nursery, as the activities of this group of fungi are closely related to local weather conditions. During cool, wet springs, damage has been quite high. Sampling nursery beds for pathogenic soil fungi in the fall, prior to sowing, may be helpful to predict problem areas and make recommendations for nursery bed treatments.

TABLE 1.—Germination [1] and field emergence [2] of several tree species seeds sown at the Wind River Nursery in 1972

Tree species	No. seed lots sown	Germination % (average for all seed lots)		Field emergence (percent of seeds sown)
		None chilled	Chilled	
Douglas-fir (East Side)	14	73.1	74.2	71.7
Douglas-fir (West Side)	60	76.2	81.1	77.6
Douglas-fir (BLM stock)	5	84.2	N.T.[3]	87.6
Douglas-fir (Wind River County)	1	89.0	90.0	77.1
Noble fir	13	36.6	34.3	N.A.[4]
Pacific silver fir	2	17.0	28.0	24.9
Shasta red fir	6	17.2	17.2	18.3
White fir	1	42.0	64.0	25.0

[1] Data on seed germination was provided by Wind River Nursery personnel. Laboratory tests were conducted at the Oregon State University Seed Laboratory, Corvallis, Oregon.

[2] Data on field emergence of seeds determined from plots at the Wind River Nursery, 1972.

[3] N.T. = Seed lot not tested.

[4] N.A. = Data not available.

TABLE 2.—Numbers of seeds sown per linear foot of row for the major tree species at the Wind River Nursery 1972

Tree species	Number of one-foot-long plots excavated	Seeds sown per plot (range)	Seeds sown per plot (average)	Standard error
Douglas-fir (West Side)	115	1 to 48	28.76	0.83
Douglas-fir (East Side)	21	11 to 44	26.57	2.10
Douglas-fir (BLM stock)	8	18 to 45	30.38	3.42
Pacific silver fir	2	97 to 112	104.50	7.50
Shasta red fir	2	86 to 111	98.50	12.50

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(Continued from page 18)

uniform seedling densities when sowing pelleted seeds still remains.

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