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CONTROL TRIALS WITH FUNGICIDES APPLIED TO DIFFERENT QUALITY SEEDS

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by

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ABSTRACT

Nursery and growth room experiments were made with high, intermediate and poor quality (based on germination capacity and rate) seeds of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], Sitka [*Picea sitchensis* (Bong.) Carr.], and white (interior) spruce [*P. glauca* (Moench) Voss] treated with: Captan, Benlate, and Benlate T fungfcides and talc (all applied as post-stratificatfon dusts), and MBC-P (pre-stratiffcatfon seed soak) fungicide. In the British Columbia Forest Service nurseries at Koksflah and Surrey, none of the treatments had any effects of practical importance on emergence percentage or rate, early and late damping-off incidence or seedling shoot growth of any seedling species or seed quality, Seed quality effects were readily discernible at both nurseries and for all seed species, At Surrey, Douglas-fir shoot growth decreased and early damping-off incidence increased as seed quality decreased. In the growth room, germination capacity and germination speed of treated seeds were improved by some of the fungicides; these effects were not evident in the field. Must gemination failure ~~in vitro~~ was attributable to seed decay, but the percentage, based on the number of ungerminated seeds, of decayed seeds was seldom reduced by seed treatments.

Résumé

Des expériences en pépinière et en chambre de croissance furent effectuées avec des semences de Douglas taxifolié (Pseudotsuga menziesii (Mirb.) France), d'Épinette de Sitka (Picea sitchensis (Bong.) Carr.), et d'Épinette blanche (de l'intérieur) (P. glauca (Moench) Voss). Les diverses semences étaient de qualité élevée, intermédiaire ou pauvre (selon leur taux et capacité de germination) et elles furent traitées au Captan, au Benlate, au Benlate T et au talc (tous appliqués à état poussiéreux après la stratification) et au MBC-P (dont les semences furent imbibées avant la stratification). Dans les pépinières du Forest Service de la Colombie-Britannique situées à Koksilah et Surrey, aucun des traitements n'affecta drastiquement le pourcentage et le taux de germination des semences, ou l'incidence tôt ou tardive de fonte ou la croissance des pousses de semis de toutes essences ou de toute qualité de semences. On attribue cette inefficacité probablement à des doses de traitement trop basses. On put discerner les effets de la qualité des semences aux deux pépinières et ceci pour toutes les essences. A Surrey, la croissance des pousses du Douglas taxifolié a décru et l'incidence du tôt de fonte augmenta en rapport direct avec la qualité des semences. Dans les chambres à croissance, certains des fungicides ont amélioré la capacité et la vitesse de germination des semences traitées; on n'a pas signalé ces effets dans les pépinières. Les auteurs attribuent la plupart des échecs de germination à la maladie; mais le traitement des semences a rarement réduit le pourcentage de semences atteintes, pourcentage basé sur le nombre de semences qui n'ont pas germé.

Introduction

Damping-off usually occurs at endemic levels in British Columbia forest nurseries, but occasionally the disease causes severe losses of seedlings. Early work on damping-off control in the Province (11) dealt with several factors, such as sowing stratified vs. non-stratified seeds, and adjustment of soil acidity. Subsequently, fungicide treatment of seeds prior to sowing came into use for control of pre- and post-emergence damping-off. Initially seed treatment probably had merit, but as a result of several cultural practice changes (e.g. covering sown seeds with sand rather than soil which improved seedling emergence), its usefulness became questionable. Thus, in 1971, a series of annual field trials was begun to determine if the seed treatments then being used on the major nursery species, i.e., pelleting of spruces with captan and Douglas-fir with thiram, were still of value, or if newer fungicides, application rates and methods, or a combination of these would increase numbers of seedbed seedlings, Three years of studies (9) at various nurseries with seeds *of* several tree species, fungicides, and application methods showed that none of *the* treatments increased the seedling stand, primarily because fungicide-caused mortality (phytotoxicity) usually exceeded disease losses, especially when disease severity was low.

The problem of fungicide phytotoxicity outweighing the beneficial effect of disease control is well known (3, 13). Attempts *to* overcome it usually resulted in extensive fungicide screening programs to find the ideal (highly toxic to pathogens and non-toxic to seeds) fungicide. The difficulty of this approach was demonstrated by Vaartaja (13) and Carlson (3) who, between them, screened 326 chemicals and found only six new materials suitable for use on tree seeds; four *of* these contained the already widely used fungicides captan and thiram (Arasan), Besides the chemical itself, or its dosage rate, several other soil- and fungicide-related factors affect phytotoxicity of fungicides to forest tree seeds (14). Only one study (2) has considered the possibility that phytotoxicity and disease control, or both, may vary according to seed quality (germination capacity and rate). Since the quality of locally sown forest tree seeds is so diverse, it seemed likely that disease control and phytotoxicity might also vary according to seed quality. Consequently, field and growth room experiments were made to determine the phytotoxicity and disease control effectiveness of several fungicides on conifer seeds of different qualities.

Materials and Methods

Field studies: These were made at the Koksilah and Surrey nurseries of the B.C. Forest Service. The seed species used were Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], coastal form, and Sitka spruce [*Picea sitchensis* (Bong.) Carr, 3 at both nurseries, plus white (interior) spruce [*P. glauca* (Moench) Voss at Surrey. To determine seed quality, stratified (15) seeds from 12 seedlots (B.C. Forest Service) of each species were germinated (5,6) and the germination capacity, germination value *(4)*, and R_{50} (1) (see Appendix I for formulas) of each seedlot was calculated, Based on these parameters, the seedlots were ranked, and high, intermediate and poor quality seedlots were selected for use (Table A, Appendix II).

The treatments (all applied as post-stratification treatments and by dusting the seeds, except where noted) and their application rates were: captan 50 W (10) at 1 g per 16 g of seed; Benlate 50 W, Du Pont (10) applied at 42 g plus 42 g of talc U.S.P. (to provide sufficient surface coverage) per 12.7 Kg of seed; Benlate T, Du Pont 30% benomyl (10), 30% thiram (10), 40% inert ingredients; MBC-phosphate (8) a soluble phosphate salt of MBC (methyl-2-benzimidazole carbamate, the breakdown product of benomyl) used as a 48-hour pre-stratification seed soak (MBC-P at 1,000 PFM); talc U.S.P. at 1 g to 16 g of seed, and control, stratified seeds only.

Each replicate of each treatment and control consisted of 100 seeds (sown in a 1-m-long drill row) replicated 10 times in a randomized, split (once for each seed quality) block design laid out along a seedbed row. Seeds were sown (9) during the weeks of 22 May and 29 May 1975 at Surrey and Koksilah, respectively. The plots at each nursery were located in a seedbed row in an area with representative nursery soil and received routine nursery care (15).

Weekly, during the early part of the growing season, and less frequently as emergence and damping-off declined, counts were made of germinants and seedlings killed by either early or late damping-off; dead seedlings were removed from the plots (see Appendix III for counting dates). For statistical analyses, the data for each parameter were cumulated for the entire growing season, and expressed as a percentage of the total number (healthy plus killed) of seedlings that had emerged in that plot over the entire season. Emergence was calculated by expressing all germinants (healthy plus diseased) as a percentage of the number of seeds sown, and survival was calculated as the percentage of healthy seedlings at the end of the growing season based on the number of seeds sown. The emergence data for the first three counting times (about 30 days) following seed sowing were used to calculate emergence percentage, germination value [calculations carried to the second decimal place (4)] and peak value (4), and R_{50} values (1) for each treatment in each sub-block (one for each seed quality). The formulas used to calculate all the emergence, germination and pest-caused (damping-off, birds, Insects) losses are given in Appendix I. At the end of the growing season, shoot growth (soil line to tip of apical bud) was measured for six randomly selected seedlings (per species) from each treatment in each plot of the split-plot experimental design.

For analysis of variance, the percentage data were transformed, when needed (12) to the arcsin of the square root while, for the other data, a log transformation was used to correct for heterogeneity of error variance, Treatment means were compared, using the Student-Newman-Keuls' test (12).

Growth room studies: The materials and methods (seed species, seedlots, qualities and treatments) used were the same as those for field studies, except that germination tests were conducted in a growth room, using the growth room lighting and temperatures described by Edwards (5) and a version of the Jacobsen germinators (6). Each treatment and control were replicated four times (50 seeds per replicate) in a completely random design. Germinants were counted daily, using the international seed testing rules (7). The germination data were used to calculate germination capacity, germination value, peak value and R_{50} parameters, At the end of the 28-day germination period, ungerminated seeds were cut longitudinally and classified as rotted, firm, empty orinsectfilled. These data were then expressed as a percentage

of the ungerminated seed, All data, transformed when needed to correct for heterogeneity of variances were subjected to analysis of variance and the means compared using the Student–Newman–Keuls' test (12),

Results

The results of these studies are given according to seed species, with the field results followed by those obtained in the growth room, e.g. Douglas-ffr, field results (both Koksilah and Surrey nurseries), then the growth room results, To facilitate comparisons, the field and growth room findings for each species are presented in successive tables. Values in the tables are €or the seed quality x fungicide response which indicates whether or nut fungicide effects varied with seed quality, The simple (e.g. seed quality), the other two–factor interaction (time x treatment), and the three-factor interaction effect(s) are available from the authors. To conserve space, the behavior of individual parameters (e.g. emergence) over time are excluded, i.e., no data are included to show the progression of emergence, etc., throughout the growing season, Time effects are shown, in part, by the germination parameters such as R_{50}. Numbers of abnormal germinants were minimal in the growth room experiments, thus these table values are for all germinants (normal plus abnormal), Also, for brevity, the peak value data are omitted from the tables for the field experiments.

Douglas–fir, field results, both nurseries. At Koksilah (Table 1), none of the fungicides improved emergence, disease control or seedling growth. The factor of most interest to the nurseryman was that seedling yield based on survival of number of seeds sown tended *to* be improved by the treatments, but these differences were not significantly different from the control. Although seed quality effects by themselves were very pronounced, none of the seed quality-fungicide interactions as determined by analysis of variance were significant (F= 0.39). The situation at Surrey nursery (Table 2) was similar to Koksilah, in that none of the seed treatments produced any practical effects, either beneficial or harmful, Although captan reduced emergence (by 16%) and germination value, these germination parameters were not significantly different (P= .05) from those for untreated seeds. Seed quality effects were evident for emergence responses and, contrasting to Koksilah, seedling growth was related to seed quality. Shoot growth of Surrey seedlings was about twice that for Koksilah (Table 1). Early damping-off losses tended *to* be greater in plots sown with intermediate and poor quality seeds.

Douglas-fir, growth room results. Captan, Benlate and Benlate T increased germination capacity of high quality, but *not* intermediate or poor quality, Douglas–fir seeds (Table 3). Treatment effects on other gemination responses (germination value and peak value, R_{50}) were slight, As in the field, differences between seed qualities were readily discernible. The cutting tests on ungerminated seeds showed the amount of disease (rot) of poor quality seeds was reduced by the fungicides, particularly captan.

Sitka spruce, field results, both nurseries, At Koksilah (Table 4), emergence of intermediate quality seeds exceeded that of high quality seeds; this contrasts with our ~~in vitro~~, pre–experiment germination data (Table A,

Appendix II) which were used to assign qualities, However, the fungicide treatments did not improve emergence. Early damping-off losses were large, and tended to be higher in the treated than in the control plots, but their severity was not reduced significantly (P=.05) by the fungicide seed-treatments, Late damping-off losses did not exceed 6.9% and were not affected significantly (P=.05) by the fungicides, Neither shoot growth nor any of the remaining germination parameters were affected by the treatments. Seed quality had an effect on emergence and, consequently, on survival based on number of seeds sown. Seed quality differences were also evident and followed the expected trend for the R_{50} values in the MBC-P, talc and control plots,

Emergence at Surrey (Table 5) adhered to the same pattern as *at* Koksilah and was unaffected by the seed treatments. Early damping-off was very severe, but disease incidence did not differ significantly (P=.05) among fungicides or between seed qualities in the plots with high and intermediate quality seeds. The MBC-P seed soak reduced early damping-off losses of poor quality seeds, Percentage survival, shoot growth, and the germination responses such as R_{50} were best with the intermediate quality seeds, None of the treatments caused these parameters to differ significantly from the control.

Sitka spruce, growth room results. Gemination capacity of Sitka spruce in the growth room (Table *6)* was much better than the emergence percentage at either nursery (Tables *4* and 5). Germination capacity, germination and peak values, and the R_{50} data were not affected by the seed treatments. The cutting tests showed that most ungerminated seeds were rotted; however, these losses were not reduced by the seed treatments.

White (interior) spruce, field results, The results (Table 7) for white spruce, sown only at Surrey, showed that the seed treatments produced no improvement in emergence, germination value, R_{50} value, disease control, final seedling stand (survival based on number of seeds sown) or seedling growth. Seed quality affected those parameters measuring emergence percentage and speed.

White (interior) spruce, growth room results. Germination percentage (capacity), speed (peak value and R_{50}) and the parameter (gemination value) describing the combined effect on both, were not altered drastically by any of the seed treatments (Table 8). Germination capacity in the growth room was 15 to 20% higher than emergence in the *field* (Table 7) and, interestingly, germination speed of poor quality seeds was faster in the field (where R_{50}, or days to reach 50% germination values were attained) than in the growth room (where poor quality seeds failed to reach 50% germination in 28 days). As expected, all germination responses, except R_{50} paralleled seed quality differences. No fungicide or seed quality effects were detected by the seed cutting *test* results from ungerminated seeds.

Discussion

This study shows *that* fungicide seed-treatments, far the dosage rates used here, are of little or no benefit, regardless of the quality of the seeds to which they are applied (Tables 1 to 8). Although some of the seed treatments seemed *to* improve seedling emergence and damping-off control in the

field (Tables 1, 2, 3, 5 and 7) these differences were non-significant when tested statistically. This lack of significance was probably caused by between-plot variation. Originally we thought the fungicides would either (i) be of more benefit to poor quality seeds, which are slower to germinate and thus more susceptible to pre-emergence and the early form of post-emergence damping-off, or (ii) be more detrimental to them because of their longer pre-emergence exposure to the phytotoxic effects of the fungicides, One of these effects might have occurred if we had used higher dosages of the fungicides or varied the density of the sown seeds (2), as is done in nursery practise, to compensate for differences in seedlot viability, The latter practice may produce the same effect as increasing fungicide dosage. Besides affecting emergence percentage and rate, seed quality sometimes influenced seedling growth and disease, e.g. *at* Surrey, Douglas-fir shoot length decreased and early damping-off increased (in several treatments) with decreasing seed quality (Table 2). The shoot growth difference occurred despite the lower competition (fewer seedlings) in the plots sown with poor quality seeds, We do not know why damping-off losses for all seed qualities were less severe at Koksilah (Tables 1 and *4)* than at Surrey (Tables 2, 5 and 7).

Overall, the seed quality effects as determined in the growth room germination tests (Tables 3, 6 and 8) correlated well with the field performance of specific seedlots; however, some of the germination-detected responses to the fungicides were absent in the field plots, e.g. most of the treatments improved gemination capacity of high qualfty Douglas-fir seeds in the laboratory (Table 3), but not in the field (Tables 1 and 2). The seed cutting tests made following the growth room germination experiments showed (Tables 3, 6 and 8) that, irrespective of quality, *most* ungerminated seeds were diseased. Moreover, except for captan on poor quality Douglas-fir seeds (Table 3), neither the post-stratification treatments nor the pre-stratification MBC-P seed soak reduced disease losses. Probably these losses were caused by internally-borne microbes which would not be killed by externally applied fungicides. The MBC-P seed soak was either ineffective or failed to penetrate the seeds.

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We thank B.C. Forest Service personnel at the Koksilah and Surrey nurseries for sowing seeds, making seedling counts and for taking care of the plots. Without their help, we could not have made the experiments,

Literature Cited

1. Allen, G.S. 1958. Factors affecting the viability and germination behavior of coniferous seed. I. Cone and seed maturity, *Tsuga heterophylla* (Rafn.) Sarg. Forest, Chron. *34:* 266-274.

2. Bloomberg, W.J., and J. Trelawny. 1970. Effect of thiram on gemination of Douglas-fir seed. Phytopathology 60: 1111-1116.

3. Carlson, L.W. 1972. Forest tree nursery disease control. In Proc. Joint Meeting West. Forest Nursery Council and Intermountain Forest Nurserymen's Assoc. Edited by H.W. Anderson, J.A. Bryan and R.P. Eide. Olympia, Washington, pp. 111-114.

4. Czabator, F.J. 1962. Germination value: An index combining speed and completeness of pine seed germination, Forest Sci. 8: *386-396,*

5. Edwards, D.G. 1973. Effect of a soil wetting agent on germination of four important British Columbia conifers. Forest. Chron. *49:* 126-129.

6. Edwarde, D.G.W., and P.E. Olsen. 1973. A photoperiod response in germination of western hemlock seeds. Can. J. Forest, Res. 3: *146-148.*

7. International Rules Seed for Testing. 1966. Proc. Int. Seed Test. Assoc. 31(1): 1-152.

8. Kondo, E.S., D.N. Roy, and E. Jorgensen. 1973. Salts of methyl-2-benzimidazole carbamate (MBC) and assessment of their potential in Dutch elm disease control. Can, J. Forest. Res. 3: 548-555.

9, Lock, W., J.R. Sutherland, and L.J. Sluggett. 1975, Fungicide treatment of seeds fur damping-off control in British Columbia forest nurseries. Tree Planter's Notes (in press).

10. Pesticide manual. 1974, Edited by Martin, H., and C.R. Worthington. Brit. Crop Protection Council, (printed by The Boots Co., Ltd., Nottingham, England), 565 pages.

11. Salisbury, P.J. *1954.* A review of damping-off of Douglas fir seedlings in British Columbia, Forest. Chron. 30: *407-410,*

12. Steel, R.G.D., and J.H. Torrie. 1960. Principles and procedures of statistics, McGraw-Hill Book Co., New York, pages 481,

13, Vaartaja, O. 1956. Screening fungicides fur controlling damping-off of tree seelings. Phytopathology *46:* 387-390.

14. Vaartaja, Om. 1964. Chemical treatment of seedbeds to control nursery diseases. Botan. Rev, 30: 1-91.

15, van den Driessche, R, 1969. Forest nursery handbook. Res. Notes No. *48,* B.C. Forest Serv., Victoria, pages 44.

Table 1. **Effects of seed treatments on germination,** damping-off incidence **and** growth **of** different **quality Douglas-fir seeds *at* Koksilah nursery,**

Response measured[2/]	Seed quality[3/]	Seed treatments[1/]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Emergence, %	H	R87.3a	R84.4a	R83.9a	R84.6a	R84.0a	R82.0a
	I	S59.2a	S58.3a	S58.1a	S58.9a	S56.0a	S60.2a
	P	T36.8a	T35.4a	T33.3a	T33.9a	T36.8a	T34.2a
Early damping-off, %	H	R1.7a	R1.8a	R2.6a	R2.3a	R1.6a	R1.9a
	I	S6.2a	R3.2a	R5.2a	S6.2a	R4.6a	R4.4a
	P	RS3.7a	R2.9a	R2.7a	RS4.1a	R3.5a	R3.2a
Late damping-off, %	H	R1.1a	RS1.6a	R2.2a	R0.7a	R2.8a	R1.3a
	I	S3.3a	R2.9a	R2.7a	S3.1a	R4.5a	R2.5a
	P	R0.6a	S0.3a	R0.5a	R0.0a	S0.9a	R2.0a
Survival as percentage of seeds as sown	H	R84.7a	R81.6a	R79.9a	R81.9a	R80.4a	R79.3a
	I	S52.9a	S54.3a	S53.6a	S53.8a	S51.4a	S55.8a
	P	T35.2a	T34.1a	T32.2a	T32.2a	T35.0a	T31.8a
Shoot length, mm	H	R60.9a	R63.1a	R71.8a	R63.7a	R61.8a	R65.2a
	I	R52.4a	R62.0a	R58.1a	R57.8a	R49.6a	R43.3a
	P	R39.3a	R46.5a	R52.8a	R53.1a	R46.5a	R39.3a
Germination value	H	R26.17a	R28.66a	R27.48a	R21.36b	R26.44a	R27.48a
	I	S12.51a	S12.59a	S10.88a	S11.09a	S11.50a	S13.30a
	P	T2.99a	T3.58a	T2.90a	T2.45a	T3.27a	T3.00a
R_{50}	H	R12.0a	R11.0a	R11.5a	R14.2a	R11.8a	R11.6a
	I	S18.3a	S19.9a	S20.6a	S21.3a	S20.1a	S18.6a
	P	S18.6a	S18.6a	S18.6a	S18.6a	S18.6a	S18.6a

1/ Values are means of 10 observations; reading across means followed by the same letter are not significantly (P=.05) different; reading down means preceded by the same letter (within each grouping of seed qualities for each response measured) are not significantly (P=.05) different. Data for the bird and insect losses were minimal and are not shown,

2/ The first four responses are for data accumulated over the entire growing season; shoot growth was measured *at* the end of the growing season; the last *two* responses were calculated from data obtained over the first three counts *(see* Appendix III); for brevity the *peak* value data are not shown.

3/ H=high, I-intermediate, and P=poor quality seeds.

Table 2. Effects of seed treatments on germination, damping-off incidence and growth of different quality Douglas-fir seeds at Surrey nursery,

Response measured [2]	Seed quality [3]	Seed treatments [1]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Emergence, %	H	R59.5a	R71.7a	R78.8a	R74.9a	R70.1a	R75.5a
	I	S40.1a	S44.6a	S46.1a	S48.0a	S41.2a	S43.4a
	P	T12.0a	T16.8a	T17.2a	T22.8a	T19.5a	T16.9a
Early damping-off, %	H	R11.2a	R14.0a	R15.8a	R13.6a	R13.3a	R13.1a
	I	R22.6a	R27.8a	S33.3a	R27.4a	RS22.6a	S29.7a
	P	R15.3a	R25.0a	R20.3a	R19.4a	R31.9a	S27.8a
Late damping-off, %	H	R5.3a	R6.1a	R6.3a	R6.9a	R6.1a	R5.6a
	I	R15.0a	R11.7a	R9.9a	R7.3a	S18.0a	R13.08
	P	R10.5a	R11.6a	R4.5a	R6.2a	RS11.9a	R4.02a
Survival as percentage	H	R43.7a	R50.3a	R59.9a	R54.5a	R49.4a	R53.8a
	I	S23.4a	S25.4a	S24.4a	S29.1a	S23.7a	S24.3a
	P	T7.6a	T8.2a	T10.1a	T14.4a	T9.8a	T9.8a
Shoot length, mm	H	R119.3a	R112.6a	R108.1a	R104.2a	R110.5a	R111.8a
	I	S101.4a	R101.4a	R99.3a	R101.1a	S94.4a	R101.0a
	P	T80.3a	S77.1a	S80.8a	S77.4a	S89.9a	S83.9a
Germination value	H	R10.91a	R29.31a	R28.56a	R24.63a	R30.00a	R31.36a
	I	R13.49a	S13.09a	S11.93a	S11.37a	S10.75a	S10.48a
	P	S3.83a	T3.11a	T1.11a	T1.50a	T2.34a	T1.82a
R_{50}	H	R9.1a	R9.9b	R10.7b	R11.0b	R10.2b	R9.6b
	1	S15.0a	S16.9a	S16.7a	S17.0a	S15.7a	S18.3a
	P	S18.3a	S18.3a	S18.3a	S18.3a	S18.3a	S18.3a

[1] Values are means of 10 observations; reading across means followed by the same letter are not significantly (P=.05) different; reading down means preceded by the same letter (within each grouping of seed qualities for each response measured) are not significantly (P=.05) different, Data for the bird and insect losses were minimal and are *not* shown.

[2] The first four responses are for data accumulated over the entire growing season; shoot growth was measured at the end of the growing season; the last two responses were calculated from data obtained over the first three counts *(see* Appendix III); for brevity the peak value data are not shown.

[3] H=high, I=intermediate, and P=poor quality seeds.

Table 3. Effects of seed treatments on growth room germination of different quality Douglas fir seeds.

Response measured[2]	Seed quality[3]	Seed treatments[1]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Germination capacity, %	H	R90.8a	R90.Oa	R91.0a	R87.5b	R65.5c	R71.0bc
	I	S62.3a	S54.5a	S67.0a	S68.0a	S52.0a	S64.5a
	P	T30.2a	T41.5a	T32.0a	T37.5a	T31.0a	S36.0a
Germination value	H	R15.57a	R19.29a	R21.69a	R18.57a	R6.97b	R8.53b
	I	S6.02ab	S4.70a	S9.44b	S8.45ab	RS4.54a	R7.19ab
	P	T1.40a	S2.78a	T1.88a	T2.11a	S1.62a	S1.80a
Peak value	H	R4.8a	R6,Oa	R6.7a	R5.9a	R3.0b	R3.4b
	I	S2.7a	S2.4a	S3.9b	S3.4ab	R2.4a	R3.Oab
	P	T1.3a	S1.9a	T1.5a	T1.5a	S1.4a	S1.4a
R_{50}	H	R12.Oa	R10.0a	R9.la	R10.Oa	R15.9a	R14.6a
	I	R19.4a	R13.9a	R14.2a	R16.8a	R16.0a	R17.9a
	P[4]	-	7.0	-	7.0	-	-
Percentage of ungerminated seeds which were mouldy	H	R86.7a	R56.7a	R65.8a	R47.Oa	R74.7a	R58.4a
	I	R100.Oa	S94.5a	R96.9a	S98.8a	R95.2a	R91.7a
	P	S21.2a	R47.9ab	R62.4b	R60.8b	R63.6b	R82.6b

[1] Values are means of four replicates; reading across means followed by the same letter are not significantly (P=.05) different; reading down means preceded by the same letter (within each grouping of seed qualities for each response measured) are *not* significantly different.

[2] The first four responses apply to data collected over the 28 day germination period; the data on mouldy weeds were from the cutting test at the end of the germination period, the firm seed data are not given as they are the corollary of the mouldy seed data; the empty and insect-filled seed data were negligible and are omitted.

[3] H= high, I=intermediate, and P=poor.

[4] The dash indicates that germination had not reached 50% at the end of the test.

Table 4. Effects of seed treatments on germination, damping-off incidence and growth of different quality Sitka spruce seeds at Koksilah nursery.

Response[2] measured	Seed[3] quality	Seed treatments[1]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Emergence, %	H	R55.5a	R48.1a	R47.6a	R47.7a	R49.3a	R57.5a
	I	R65.6a	S68.3a	R55.9a	R52.4a	R60.3a	R67.7a
	P	S41.5a	T30.0a	S27.6a	S33.3a	S30.3a	S32.6a
Early damping-off, %	H	R28.8a	R28.6a	R28.7a	R30.9a	R26.3a	R19.9a
	I	R21.5a	R17.6a	R23.9a	R23.3a	R24.7a	R14.5a
	P	R23.2a	R25.8a	R28.3a	R22.3a	R24.Sa	R26.5a
Late damping-off, %	H	R3.9a	R2.9a	R3.9a	R5.5a	R3.8a	R4.2a
	I	R1.5a	R2.5a	R6.7a	R4.3a	R2.4a	R1.3a
	P	R2.8a	R3.7a	R8.2a	R2.3a	R6.9a	R2.8a
Survival as percentage of seeds sown	H	RS41.1a	R36.6a	R36.0a	R33.Oa	R37.6a	R44.5a
	I	R50.9ab	S56.4a	R42.6ab	R38.8b	R45.5ab	S57.6a
	P	S33.0a	T21.4a	S19.0a	R25.0a	S21.8a	T26.5a
Shoot length, mm	H	R12.3a	R14.5a	R15.3a	R12.3a	R15.2a	R14.0a
	I	R15.5a	R16.1a	R17.9a	R17.2a	R17.5a	R14.0a
	P	R11.2a	R12.3a	R12.3a	R11.1a	R11.4a	R9.9a
Germination value	H	R13.21a	R12.99a	R12.27a	R11.81a	R13.97a	R16.57a
	I	R12.87a	R12.65a	R13.29a	R8.85a	R12.62a	R14.18a
	P	R7.81a	S5.42a	S5.72a	R6.29a	S6.44a	S7.10a
R_{50}	H	R18.1a	R17.3a	R17.1a	R18.7a	R15.2a	R15.2a
	I	R20.1a	R20.4a	R19.8a	S23.1a	S20.3a	S20.5a
	P	R19.1a	R18.3a	R18.6a	R19.4a	S19.7a	S18.3a

1/ Values are means of 10 observations; reading across means followed by the same letter are not significantly (P=.05) different; reading; down means preceded by the same letter (within each grouping of seed qualities for each response measured) are not significantly (P=.05) different. Data for the bird and insect losses were minimal and are not shown,

2/ The first four responses are for data accumulated over the entire growing season; shoot growth was measured at the end of the growing season; the last two responses were calculated from data obtained over the first three counts (see Appendix 111); for brevity the peak value data are not shown.

3/ H=high, I=intermediate, and P=poor quality seeds.

3/ ... for brevity the peak value data are not shown, ... the first
H=high, I=intermediate, and P=poor quality seeds.

Table 5. Effects *of* seed treatments on germination, damping-off incidence, and growth of different quality Sitka spruce seeds at Surrey nursery,

Response measured[2/]	Seed quality[3/]	Seed treatment[1/]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Emergence, %	H	R58.8a	RS59.3a	R61.6a	R61.8a	R64.2a	R63.5a
	I	R54.6a	R63.9a	R63.4a	R59.7a	RS56.6a	RS52.7a
	P	R52.5a	S48.5a	R54.0a	R50.9a	S46.8a	S48.1a
Early damping-off, %	H	R54.2a	R56.5a	R52.5a	R45.0a	R55.8a	R50.4a
	I	R38.0a	R37.3a	R30.7a	R31.8a	R40.8a	R47.1a
	P	R59.6ab	R59.9ab	R56.8ab	R42.9a	R55.2ab	R64.3b
Late damping-off, %	H	R4.8a	R6.4a	R8.9a	R5.3a	R2.8a	R4.3a
	I	R5.3a	R6.9a	R2.1a	R4.5a	R4.3a	R4.7a
	P	R4.2a	R3.9a	R1.4a	R1.9a	R0.7a	R8.2a
Survival as percentage *of* seeds sown	H	RS27.4a	RS26.8a	R29.4a	R33.9a	R28.2a	R31.4a
	I	R35.0a	R37.1a	S42.4a	R38.9a	R33.2a	RS27.9a
	P	S21.1a	S19.8a	R24.1a	R30.1a	R21.7a	S18.3a
Shoot length	H	R25.5a	R27.2a	R27.6a	R23.2a	R24.4a	RS26.7a
	I	S34.3a	S35.0a	S32.9a	S35.5a	S34.4a	R30.9a
	P	R21.7a	R23.0a	R20.5a	R21.7a	R19.5a	S22.2a
Germination value	H	R18.71a	R21.22a	R22.48a	R19.91a	R25.71a	R23.19a
	1	S8.39a	S14.15b	S13.83b	S10.77ab	S14.21b	S12.98b
	P	R18.21ab	RS17.61ab	R21.52a	S13.61b	S15.82ab	S16.33ab
R_{50}	H	R18.5a	R18.4a	R18.3a	R18.8a	R17.3a	R18.2a
	1	S21.4a	S20.8a	S20.5a	S22.0a	S20.9a	S21.8a
	P	R19.4a	R18.8a	R18.7a	R19.0a	R18.9a	R18.8a

1/ Values are means of 10 observations; reading across means followed by the same letter are not significantly (P=.05) different; reading down means preceded by the same letter (within each grouping of seed qualities for each response measured) are not significantly (P=.05) different. Data for the bird and insect losses were minimal and are not shown.

2/ The first four responses are for data accumulated over the entire growing season; shoot growth was measured *at* the end *of the* growing season; the last two responses were calculated from data obtained over the first three counts (see Appendix III); for brevity the peak *value* data are not shown.

3/ H=high, I=intermediate, and P=poor quality seeds.

Table 6. **Effects of seed treatments on growth room germination of different quality Sitka spruce seeds.**

Response measured[2]	Seed quality[3]	Seed treatments[1]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Germination capacity, %	H	R88.5a	R93.5a	R88.5a	R90.0a	R87.5a	RS84.5a
	I	R90.0a	R88.0a	R89.0a	R95.0a	R93.0a	R92.0a
	P	S70.5a	S73.0a	S68.5a	S72.5a	S71.5a	S77.5a
Germination value	H	R25.59a	R29.63a	R24.96a	R26.00a	R27.45a	R22.87a
	I	R23.75a	S21.66a	R22.50a	S21.01a	R25.56a	R23.28a
	P	S13.55a	S17.42ab	S13.90	S18.58ab	S15.30ab	R20.14b
Peak value	H	R8.2a	R8.9a	R7.9a	R8.1a	R8.8a	R7.6a
	I	R7.4a	S6.9a	R7.1a	S6.2a	R7.7a	R7.1a
	P	S5.4ab	S6.7ab	S5.7ab	RS7.2b	S6.0ab	R7.3b
R_{50}	H	R8.1a	R7.3a	R7.7a	R8.0a	R7.3a	R7.8a
	I	R8.6a	S8.6a	RS8.5a	R9.0a	S8.5a	R8.7a
	P	R8.9a	RS8.1a	S8.9a	R8.0a	S8.7a	R8.0a
Percentage of ungerminated seeds which were mouldy	H	R77.8a	R70.8a	R87.5a	R83.8a	R96.4a	R85.4a
	I	R83.9a	R88.7a	R79.8a	R70.0a	R75.0a	R65.0a
	P	R49.4a	R80.4a	R87.0a	R89.7a	R96.8a	R92.7a

[1] Values are mans of four replicates; reading across means followed by the same letter are *not* significantly (P=.05) different; reading down means preceded by the same letter (within each grouping of seed qualities for each response measured) are not significantly different,

[2] The first four responses apply to *data* collected over the 28 day germination period; the data on mouldy seeds were from the cutting test at the end *of* the germination period, the firm seed data are not given as they are the corollary *of* the mouldy seed data; the empty and insect-filled seed data were negligible and are *omitted*.

[3] H=high, I=intermediate, and P=poor.

Table 7. *Effects* of *seed* treatments on germination, damping-off incidence and growth of different quality white (interior) spruce seeds at Surrey nursery.

Response measured[2]	Seed quality[3]	Seed treatments[1]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Emergence, %	H	R70.6a	*R64.0a*	R67.2a	R72.7a	R68.3a	R71.2a
	I	S58.2a	R61.7a	R59.9b	S62.3b	S47.8a	S57.3ab
	P	T32.2a	S29.4a	S33.6a	T32.1a	T31.8a	T31.8a
Early damping-off, %	H	R31.4a	R38.7a	R31.1a	R33.7a	*R34.0a*	R29.*4a*
	I	*R42.6a*	R36.2a	R47.3a	R40.7a	R50.*4a*	R51.2a
	P	R34.9a	R39.7a	*R42.6a*	R50.9a	*R48.1a*	*R44.1a*
Late damping-off	H	R2.2a	R2.*4a*	RO.3a	R1.*4a*	R1.7a	R1.6a
	I	R0.9a	R2.3a	R1.4a	R1.7a	R1.9a	R1.9a
	P	RO.8a	R2.2a	R2.5a	R1.3a	R1.3a	R3.*5a*
Survival as percentage of seeds sown	H	*R47.0a*	R39.8a	R46.1a	*R47.0a*	*R44.6a*	R50.3a
	I	S33.2ab	R38.4a	S30.3ab	S36.7ab	*S24.8b*	S28.9ab
	P	T20.2a	S16.7a	T19.8a	T15.8a	S17.0a	T17.1a
Shoot length, mm	H	R17.9a	R19.3a	R17.9a	R19.1a	R19.1a	R20.0a
	1	R21.2a	RS17.*3a*	R17.9a	RS16.3a	R19.0a	R19.3a
	P	S13.5a	S14.7a	S13.5a	S14.3a	S15.7a	S14.9a
Germination value.	H	R27.67a	R25.52a	R24.49a	R31.92a	R31.09a	T29.22a
	I	S21.*44a*	R24.41a	R24.07a	S22.61a	S17.05a	S21.82a
	P	T6.93a	S6.13a	S7.83a	T8.83a	T7.20a	T6.92a
R_{50}	H	R13.1ab	R14.0a	R13.5ab	R12.0ab	R10.8b	R11.6ab
	I	S16.0a	*R14.6a*	R15.2a	S15.8a	S16.2a	S15.8a
	P	S17.9a	S19.1a	S19.7a	T21.0b	T20.1a	T20.1a

1/ Values are means of 10 observations; reading across means followed by the *same* letter are not significantly (P=.05) different; reading down means preceded by the same letter (within each grouping of seed qualities for each response measured) are not significantly (P=.05) different. Data for the bird and insect losses were minimal and are not shown.

2/ The first four responses are for data accumulated over the entire growing season; shoot growth was measured *at* the end *of* the growing season; the last two responses were calculated from *data* obtained over the first three counts *(see* Appendix III); for brevity the peak value data are not show.

3/ H=high, I=intermediate, and P=poor quality seeds.

Table 8. **Effects of seed treatments on growth** room **germination of different quality white** (interior) **spruce seeds.**

Response measured[2]	Seed quality[3]	Seed treatments[1]					
		Captan	Benlate	Benlate T	MBC-P	Talc	Control
Germination capacity, %	H	R93.5a	R88.5a	R87.5a	R90.5a	R87.5a	R91.0a
	I	S77.0ab	S68.5a	S66.5a	S81.5a	S70.0a	S75.0ab
	P	T46.5ab	T41.5a	T35.5c	T50.5b	T36.0c	T43.5a
Germination valve	H	R32.24a	R33.18a	R31.82a	R33.91a	R29.32a	R32.82a
	I	S20.35a	S16.83a	S13.98a	S25.02a	S22.00a	S20.55a
	P	T4.45a	T5.47a	T3.52a	T9.18b	T3.84a	T5.42a
Peak value	H	R9.6a	R10.5a	R10.2a	R10.5a	R9.4a	R10.1a
	I	S7.4a	S6.9a	S5.9a	S8.6a	S8.8a	S7.7a
	P	T2.8a	T3.7ab	T2.8a	T5.1b	T3.0a	T3.5a
R_{50}	H	R6.9a	R6.3a	R6.3a	R6.5a	R6.5a	R6.4a
	I	R7.4a	R7.6a	R9.9a	R6.9b	R8.3a	R7.3a
	P[4]	5.8	-	-	-	-	-
Percentage of ungerminated seeds which were mouldy	H	R87.5a	R76.8a	R74.4a	R77.6a	R79.2a	R79.2a
	I	R75.5a	R92.1a	R88.5a	R95.5a	R89.9a	R92.5a
	P	R96.1a	R88.8a	R94.6a	R97.5a	R97.6a	R99.2a

[1] Values awe means of four replicates; reading across mans followed by the same letter are not significantly (P=.05) different; reading down means preceded by the same letter (within each grouping of seed qualities for each response measured) are not significantly different.

[2] The ffrst four responses apply to data collected over the 28 day germination period; the data on mouldy seeds were from the cutting *test* at the end of the germination period, the firm seed data are not given as they are the corollary of the mouldy seed data; the empty and insect-filled seed data were negligible and are omitted.

[3] H=high, I=intermediate, and P=poor.

[4] The dash indicates that germination had not reached 50% at the end of the *test.*

Appendix I

Formulas used to calculate germination and pest-loss parameters from field data **which were collected** and **cumulated** over the **entire** growing **season:**

(1) Germination **capacity** (growth room **experiments)** = $\frac{\text{No. of germinants}}{\text{No. of seeds sown}} \times 100$

(2) Emergence, **% (field experiments)** = $\frac{(FC + TDO + B + I)}{\text{No. of seeds sown}}$

(3) **% early damping-off** = $\frac{\text{No. EDO}}{FC-(\text{No. LDO} + \text{No. bird} + \text{No. insect})} \times 100$

(4) **% late damping-off** = $\frac{\text{No. LDO}}{FC-(\text{No. EDO} + \text{No. bird} + \text{No, insect})} \times 100$

(5) % insect **losses** = $\frac{\text{No. insect losses}}{FC-(TDO + \text{No.' bird})} \times 100$

(6) **% bird losses** = $\frac{\text{No. bird losses}}{FC-(TDO + \text{No. insect})}$

(7) % survival **as percent of seeds sown** = $\frac{FC}{\text{No, seeds sown}} \times 100$

where :

FC = **final count of healthy seedlings.**

EDO = total **seedlings killed by early damping-off.**

LDO = total **seedlings killed by late damping-off.**

TDO = **total damped-off (early** and **late) seedlings.**

insect = total seedlings killed by insects.

bird = **total seedlings killed by** birds.

seeds sown = number of seeds sown.

Formulas used to calculate germination **parameters from field** and **growth room data which were collected in the 28 days following sowing:**

(8) R_{50} = **days *to* reach 50% germination, For our field data, counting times 1 to 3 were substituted for days (see Appendix III).**

(9) Germination capacity **or germination percentage = germination capacity after 28 days.**

(10) **Germination value** = MDG X PV, **For our field experiments** the **germination values were calculated** from **the data obtained** at counting **times 1 to 3 *(see* Appendix III).**

Appendix I (Cont'd)

(11) *Peak* value (PV) = peak value of germination and is the maximum quotient obtained by dividing daily the accumulated number of germinants by the corresponding number of days,

where:

MDG = mean daily germination and *is* the quotient obtained by dividing the accumulated total number of germinants by the number of days of the test (28 days in our experiments).

PV = *as* defined in 10 above.

Note: *See* Allen (1) for parameter 7, and Czabator *(4)* for 8 to 10. Lower R_{50} values indicate faster gemination; higher values of the other parameters denote better quality seeds,

Appendix If

Table A. Seed species, qualities, seedlots and germination parameters of seeds used in the field and growth room studies

Seed species and quality	Seedlot no.[b/]	Germination parameters[a/] Germination capacity	Germination value	R_{50}
Douglas-Eir				
High	315(1959)	71.5	9.47	14.20
Intermediate	1255	51.0	4.51	21.5
Poor	JO	23.5	1.10	-
Sitka spruce				
High	1504	77.0	15.03	10.53
Intermediate	951	68.0	7.65	17.11
Poor	1826	45.5	4.64	23.00
White (interior) spruce				
High	2211	79.5	16.46	9.81
Intermediate	1848	65.0	9.27	13.08
Poor	1863	36.0	3.77	-

[a/] See Appendix I; values are means of four replicates; the dash indicates that an R_{50} value was not reached.

[b/] B.C. Forest Service seedlot numbers.

Appendix III

Sowing and counting dates at Koksflah and Surrey nurseries

Counting Time	Nurseries and dates (1974)	
	Koksilah	Surrey
0 (sowing)	29 May	22 May
1	17 June	11 June
2	21 June	37 June
3	28 June	24 June
4	5 July	2 July
5	12 July	a July
6	19 July	15 July
7	26 July	22 July
8	2 August	29 July
9	13 August	6 August
10	29 August	26 August
11	23 September	30 September
12	28 October	29 October