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ENTOMOLOGY

Flight Ability of Spruce Beetles Emerging After Attacking Frontalin-Baited Trees.—Aggregation of spruce beetle [*Dendroctonus rufipennis* (Kirby)] attack into frontalin-baited trees (Dyer and Chapman, Bi-mon. Res. Notes, Can. Dep. Fish. and Forest. 27:10-11, 1971) has potential use as a practical tool in directing beetle attacks on trees unsuitable for brood development. However, some beetles emerge from such trees before or subsequent to brood establishment, depending on the severity of pitching (Dyer, Can. J. For. Res. 3:486-494, 1973). Knowledge of flight capability of these emerging parent beetles would determine whether or not they have been eliminated from the attacking population for that year and thus would have a direct bearing on the effectiveness of using frontalin for trapping beetles in preselected trees.

Twelve spruce trees, baited with frontalin in June 1972, were later attacked by beetles at White Rocks Mountain, west of Kelowna (5000 ft a.s.l.), in the Okanagan area of British Columbia. These trees were caged 14 July, after the main flight and attack period, and fitted with catch bottles containing formal saline (0.7% NaCl in 10% formalin and 5% glycerine). Emerging beetles caught in bottles were collected at various intervals from 21 July to 19 September and stored in formal saline for later dissection.

Flight muscle size can be used to judge flight capability (Gray and Dyer, J. Ent. Soc. Brit. Columbia 69:41-43, 1972). The indirect flight muscles, lateralis medius, were chosen because they are easily recognized and show a greater change in size than other flight muscles. They were removed from 152 male and 110 female beetles randomly chosen from each collection date. The muscles were placed on individual slides with a small drop of formal saline and the width of each was measured at ¼, ½ and ¾ of the length with an ocular micrometer. A median size index, calculated by dividing the mean of the three widths by the width of the beetle's pronotum and averaging the values for the left and right muscles (McCambridge and Mata, Can. Entomol. 101:507-512, 1969) was used to compensate for the effect of body size on muscle size.

The females had consistently larger muscles ($P<.01$) throughout the collection period (Fig. 1). However, pronotal width of all adults measured showed no significant difference ($P>.8$) between the sexes. The average female muscle size index for the period 24

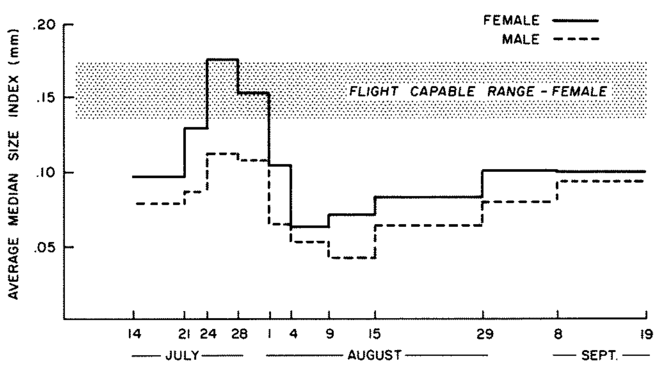

Figure 1. Average median size index of the lateralis medius of male and female spruce beetles emerging from frontalin-baited trees, which they attacked in late June and early July.

TABLE 1
Average indirect flight muscle size index of beetles emerging during four periods of the summer following attacks on host trees baited with frontalin.

Emergence Period	% of Beetles Emerged[1]	Male			Female		
		N	Mean	S.D.	N	Mean	S.D.
July 14 — July 24	16.3	29	0.080	.032	29	0.115	.038
July 24 — Aug. 1	18.3	35	0.110	.045	21	0.164	.039
Aug. 1 — Aug. 15	14.3	46	0.052	.022	16	0.071	.037
Aug. 15 — Sept. 19	51.1	42	0.079	.029	44	0.092	.028

[1]497 beetles emerged, of which 262 were measured.

July to 1 August was 0.164 (Table 1) which, according to Gray and Dyer (*op. cit.*), is within the flight capable range. The average male muscle size index for this period was 0.110, but it is not known whether this is adequate for male flight.

The muscles of female beetles collected during the first period 14 July to 25 July were below the flight capability range (Table 1). They may have been forced out by resin flow before they could regenerate their flight muscles, whereas those in the second period late in July were able to remain in the tree until they attained the flight capable level. A small second flight occurred in the area during the latter period, about 3 weeks after the main flight (Dyer, field data). The muscle size index in the last two periods during August and September remained below the flight ability level, indicating that these emerging beetles would crawl or drop to the base of host trees to hibernate.

This study has shown that most (82%) of the beetles that emerged after attack on frontalin-baited trees were unable to fly and re-attack new hosts. Only those females that emerged during a short period in late July were capable of flight.—Carol M. Lawko and E. D. A. Dyer, Pacific Forest Research Centre, Victoria, B.C.

FOREST PRODUCTS

Fiber Saturation Point and Strength of Heated Green Wood.—Maximum crushing strength (MCS) of heat-treated green 2 x 2 x 8-cm specimens of white spruce [*Picea glauca* (Moench) Voss] was determined at room temperature at a crosshead loading rate of 0.3 mm/min. End-matched specimens, approximately 1 x 1 x 2 cm and heat-treated simultaneously, were used for determining the fiber saturation point (FSP).

Since the samples consisted of never-dried sapwood (stored under water in a laboratory refrigerator), they retained the natural permeability of sapwood. For this reason, centrifuging was chosen to create the condition of fiber saturation, i.e., to centrifuge free water from the cell cavities without affecting the water absorbed in the cell walls (Perem, J. For. Prod. Res. Soc. 4:77-81, 1954).

Five samples for each temperature level were heated for 24 hours in a closed container of water, approximately 10 times the volume of the wood.

The test results in Tables 1 and 2 show that with increasing treatment temperature the FSP value increased and the MCS of green wood was reduced. The decrease in MCS was approximately linear (about 0.4% per degree of heat treatment temperature). The higher temperatures brought about changes in FSP at a progressively increasing rate. An exceptional, but slight reduction in the FSP value occurred at 50 C (compared with unheated wood). This discrepancy was not necessarily accidental, but no explanation is offered here.

Increases in FSP of wood after treatment at moderately high temperatures were accompanied by swelling (Table 2). During the period of cooling, additional swelling occurred apparently due to a reduction in the mobility of water molecules and increased absorption of water by the cell walls. (When determining FSP values for normal temperature conditions, the heat generated by the centrifuge was offset by operating the centrifuge refrigeration mechanism.)

Expansion of the heat-treated samples occurred mainly in the tangential direction; very little radio or longitudinal change oc-

TABLE 1
Fiber saturation point (FSP) and maximum crushing strength (MCS) of green heat-treated white spruce wood.

Treatment Temperature (°C)	Moisture Content at FSP (%)		MCS			
	Mean	Standard deviation	Mean		Standard deviation	
			k Pa	psi	k Pa	psi
Control	30.9	0.2	18926	2745	896	130
50	30.6	0.2	17526	2542	331	48
70	32.1	0.2	16313	2366	1648	239
90	35.5	0.6	15024	2179	1034	150
150	51.0	0.6	9660	1401	338	49

TABLE 2
Dimensional changes in green wood due to heat treatment in water.

Dimension	Sample Condition	Dimensional Change (% of original) Treated at 70°C	Treated at 90°C
Volumetric	hot	+0.10	+0.44
	cooled	+0.23	+0.77
Longitudinal	hot	0.00	+0.01
	cooled	+0.01	−0.01
Radial	hot	0.00	−0.15
	cooled	+0.02	0.00
Tangential	hot	+0.10	+0.58
	cooled	+0.24	+0.75

curred. At the highest temperature (150 C) an average volumetric contraction of 2.4% was recorded for the samples, although no collapse was apparent.

The pH value of the water used for heating the wood samples decreased markedly with increasing temperature of treatment. Thus, it fell to 5.9 at 70 C, 4.8 at 90 C and 3.3 at 150 C. This reduction in pH is due to the hydrolysis of acetyl groups to form acetic acid, which in turn causes hydrolytic degradation of hemicelluloses to soluble substances that migrate from the cell wall, leaving voids. It is these voids that are responsible for the increase in fiber saturation point (Stone and Scallan, TAPPI 50:496-501, 1967).

Hydrolytic degradation is unavoidable under certain wood service conditions (for example, in water-cooling towers, in certain wooden conduits and tanks). The extent of degradation and the accompanying deterioration in strength depends mainly on the temperature, the duration of exposure, and the rate at which the products of hydrolysis are removed from the wood. In assessing the residual strength of wood under these and similar conditions, the FSP-value should serve as a useful indicator.—E. Perem, Eastern Forest Products Laboratory, Ottawa, Ont.

PATHOLOGY

Effect of Soil pH on Rhizomorph Growth of ***Armillarie mellea*****.—** In Britain, forest sites with a hardwood history are frequently infested with *Armillaria mellea* (Vahl ex Fr.) Kummer. There, as in other temperate countries, rhizomorphs are regularly associated with disease caused by *A. mellea* (Redfern, Ann. Bot. 32:293-300, 1968) and are considered to be the principal means whereby the fungus spreads. Armillaria root disease has been observed on sites differing widely in soil moisture, texture and pH. Although certain soil conditions are reported to favor disease development (Twarowski and Twarowska, Prace Inst. Bad. Lesn. No. 192, 1959), factors affecting rhizomorph growth in soil have received relatively little study. Exceptions are some work on soil moisture (Garrett, Ann. Bot. 20:193-209, 1956) and soil temperature (Rishbeth, Trans. Br. mycol. Soc. 51:575-586, 1968); Bliss (Phytopathology 31:859, 1941) observed that rhizomorphs developed in soils differing in type and reaction, such as peat moss (pH 4) and sand (pH 8). In Thetford Chase forest, East Anglia, soil pH ranges from strongly alkaline, where a few centimeters of sand overlie chalk, to quite acid, where leaching has occurred in deep sand. The effect of soil pH on rhizomorph growth was studied at locations in the forest and under controlled conditions in the laboratory.

Fresh, unsterilized stem segments of oak [*Quercus robur* L.], about 2.5 cm in diameter and 6 cm long, were inoculated at one end with starter-disks colonized on a malt agar culture of *A. mellea* (Rishbeth, Eur. J. For. Path. 2:193-205, 1972). When thoroughly colonized, segments were buried 30 cm deep at locations where the pH values at that depth were 6.2 and 4.8. Soil moisture content (expressed as per cent saturation) at the two locations differed by not more than 3% each month during the experiment. After 7 months (May to November, inclusive), rhizomorphs were harvested by sifting the soil and their dry weights were measured.

At the two locations, the isolates responded differently; that is, isolate 2 produced a greater dry weight of rhizomorphs in alkaline soil, whereas isolate Bg produced more in acidic soil (Table 1). Similar results were obtained in the laboratory when inoculum segments were placed in jars of soil (moistened to 50% saturation) from 30 cm depth at the two locations and incubated for 16 weeks at 20 C (Table 1). Except for isolate 2 in the field, where there was a great deal of variation among replicates, differences in rhizomorph growth between soils were highly significant.

In a further laboratory experiment, rhizomorph growth of 13 isolates was assessed in soils having pH 4.4 and 7.6. Inoculum segments were incubated at 20 C for 16 weeks. Table 2 shows the number of segments producing rhizomorphs, rhizomorph dry weights, results of "t" tests and rhizomorph growth habits of isolates. Two isolates responded better to alkaline conditions, seven to acidic conditions, and four were indifferent. Three of the four isolates failed to produce rhizomorphs from a large proportion of segments in both soil types; such failures usually resulted from poor colonization of inoculum segments. Isolates 2 and Bg behaved as they had in the earlier field and laboratory experiments. In the soil type which was less favorable for rhizomorph growth, the number of inoculum segments producing rhizomorphs and the number of initials formed on a segment were frequently lower than in the more favorable soil. All isolates but one produced rhizomorphs in both soils and, as the field experiment showed, rhizomorph growth was only retarded, not prevented, in unfavorable soil.

TABLE 1
Dry weights of rhizomorphs produced by two isolates of *A. mellea* in soils with pH 4.8 and 6.2.

Expt.	Soil pH	Rhizomorph dry weight (mg)+ Isolate 2	Isolate Bg
field	6.2	670	63
	4.8	445^{ns}	152**
lab	6.2	296	40
	4.8	186**	96**

+ mean of 10 replicates.
^{ns} means not significantly different.
** means significantly different at P=.01.

TABLE 2
Number of segments producing rhizomorphs, rhizomorph dry weights and growth habits for isolates of *A. mellea* incubated in acidic (pH 4.4) and alkaline (pH 7.6) soils.

Isolate	Growth habit	Number of segments producing rhizomorphs Acidic	Alkaline	Rhizomorph dry weight (mg) Acidic	Alkaline
2	I	4/10	8/10	26 **	113
Df_1	I	6/10	9/10	93^{ns}	87
Df_2	I	6/10	10/10	39 **	130
O_2	I	3/9	6/9	40 ^{ns}	27
R_1	I	3/8	2/8	85 ^{ns}	101
D	II	10/10	10/10	180 **	71
V	II	9/9	10/10	142 **	69
8	II	10/10	10/10	158 **	74
Bg	II	10/10	10/10	57 *	21
Sp_3	II	10/10	8/10	51 **	9
Sp_6	II	8/8	1/8	107 **	1
BC_2	II	3/7	2/7	21 ^{ns}	28
BC_6	II	8/8	0/8	88 **	0

^{ns} means not significantly different.
* means significantly different, at P=.05.
** means significantly different, at P=.01.

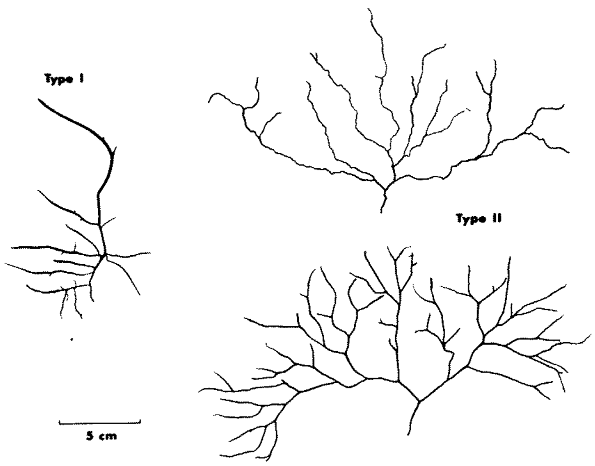

Figure 1. Type I and Type II rhizomorph growth habits.

Among isolates used in the study, two rhizomorph growth habits were observed; rhizomorphs produced by inoculum segments in soil branched either monopodially (Type I) or dichotomously (Type II, Fig. 1). Rhizomorphs of isolates that grew well in alkaline soil had Type I growth habits, whereas Type II isolates preferred acidic soil. This suggests that each type has a different pH optimum for rhizomorph growth.

This work formed part of a thesis submitted to the University of Cambridge for the degree of Ph.D. I express my gratitude to Dr. J. Rishbeth for his advice and encouragement.—D. J. Morrison, Pacific Forest Research Centre, Victoria, B.C.

Effect of Soil Extracts on Ecologically Different Fungi.—Sensitivity to effects of soil extracts seems to vary between fungi (Vaartaja and Agnihotri, Phytopath. Zeits. 60:63-72, 1967) and *Pythium ultimum* Trow, one of the most important seedling pathogens, has been found to be strongly inhibited (Vaartaja, Bi-Mo. Res. Notes 23:14, 1967a; 25:25-26, 1969). In the 1967a study, one extract was tested by placing it in agar at a colony edge of each of 27 fungi. In the 1969 study each of 22 extracts were incorporated in agar medium and one fungus studied. Further exploration of the varying sensitivity of fungi is reported here. In particular, this study was to determine whether the large variation found between fungal species in the 1967 study could be confirmed with the methods used in 1969, where only *P. ultimum* was used.

Samples were collected in May 1968, at Maple, Ont. from two sandy soils: one under mature pines; the other one from a nearby grassy pasture. The soils were extracted with distilled water, and the extracts passed through (0.2μ) filters, incorporated in agar and tested in petri dish cultures as reported in 1969. Cultures of the following pathogens were used as inocula: (1) *Ceratobasidium cornigerum* (Bourd.) Rog. (isolate No. 5651B; low virulence to conifer seedlings, Vaartaja, Phytopathology 57:765-768, 1967b), (2) *Pythium* sp. (probably a new species related to *P. splendens* Braun (9336), (3) *P. coloratum* Vaartaja (6030B; low virulence to conifer seedlings, Vaartaja, Mycologia 57:417-430, 1965), (7) *P. salpingophorum* Drechsler (9167A), (8) *P. ultimum* (9248) and (9 and 10) *Waitea circinata* Warcup & Talbot (7101 and 7745B; medium virulence to conifer seedlings (Vaartaja, 1967b). For comparison, a common mycorrhiza-forming fungus (11) *Cenococcum graniforme* (Sow.) Ferd & Winge (8902C), and a common antagonist of various fungi (12) *Gliocladium fimbriatum* Gilman & Abbott (7047) were also included. After 4 days of incubation at 15 C radial growth of these fungi was measured and expressed as a percentage of that in distilled water controls. The two replicates gave nearly identical results (mostly within 5%).

TABLE 1
Effects of two soil extracts on growth of fungi.

Species	Virulence[1] on conifer seedlings	Pine Soil	Pasture Soil	Avg
		(avg radial growth, control = 100)		
I. STIMULATION				
P. salpingophorum	low	141	127	134
C. cornigerum	low	133	113	123
II. NO EFFECT				
C. graniforme	(symbiotic)	90	95	93
G. fimbriatum	low	93	93	93
III. INHIBITION				
P. debaryanum I	high	80	68	74
P. debaryanum II	high	61	85	73
Pythium sp.	high	57	65	61
P. pyrilobum	high	45	62	53
P. ultimum	high	38	64	51
W. circinata (avg)[2]	medium	25	60	42
IV. STIMULATION OR INHIBITION				
P. coloratum	low	118	91	104
AVERAGE		76	82	79

[1] As determined from studies cited or unpublished results.
[2] Results for two isolates were similar.

Table 1 shows the main results. Microscopic observations indicated that the density of colonies and hyphal diameters were affected in the same way as radial extension growth. Thus the differences in the amount of growth were greater than those shown in Table 1. Furthermore, inhibited growth was accompanied by early lysis. Two morphologically different isolates of *P. debaryanum* responded differently while two identical isolates of *W. circinata* responded identically.

Data in Table 1 confirm the findings of the earlier study (Vaartaja and Agnihotri, *loc. cit.*), that different fungi have greatly different responses to soil extracts. Three of the fungi of Table 1 (*C. cornigerum*, *C. graniforme* and *W. circinata*) were tested earlier with similar results. In the tests employed here, the soil solution was in a uniform 1-1 dilution. In soil, however, the inhibitors likely occur in greater concentrations in certain micro-environments than in others, particularly when the soil is not saturated. Furthermore the degree of inhibition has been shown to vary greatly when the extracts are obtained at different times from the same soil (Vaartaja, 1969). Those *Pythium* species that are known to be virulent pathogens of tree seedlings were consistently inhibited. These data indicate that the sensitivity of *P. ultimum*, isolate 9248, represents a response common among virulent *Pythium* isolates. Therefore this isolate is being used extensively in further assays of soil mycostasis.

Prevailing ecological theories suggest that virulent soil-borne pathogens have evolved from saprophytes and usually have not retained their high tolerance of mycostatic factors. These fungi are saprophytic prior to contacting the living host. This is the stage in which mycostasis operates and which could be utilized for disease control. The antagonist *G. fimbriatum* and the mycorrhiza fungus *C. graniforme* may exert biological disease control. Since these fungi seem tolerant of at least some mycostatic factors, attempts should be made to utilize them in disease control.—O. Vaartaja, Forest Ecology Research Institute, Ottawa, Ont.

SILVICULTURE

Effect of Four Site Treatments on Survival and Growth of White Spruce and Lodgepole Pine Seedlings.—The usual machine for mechanical site preparation of moist white spruce/alpine fir [*Picea glauca* (Moench) Voss/*Abies lasiocarpa* (Hook.) Nutt.] sites in the Prince George Forest District of British Columbia is a bulldozer. Whether the machine is equipped with a standard or a toothed, land-clearing blade, the sites are commonly scalped. Duff and uppermost mineral soil is thereby pushed out of reach of the newly planted seedling. This drastic treatment has been adopted because seedling survival may be greatly reduced by competing vegetation. Scalping must be deep enough to eliminate the roots of competing vegetation if regrowth is to be adequately controlled. This depth of scalping may reduce soil fertility and increase susceptibility to frost heaving, especially in clay soils. Observations (e.g. Prochnau, B.C. For. Serv., Res. Note 37, 1960; Gagnon, Bi-mon. Res. Notes 25:7, 1969) suggest that incorporation of the duff with the underlying mineral soil may improve seedling growth. Excessive regrowth of competing vegetation can, however, offset the advantage of retaining the uppermost horizons within the outplanting spot. If adequate control of competing vegetation could be achieved by the process used to incorporate surface horizons, soil mixing would merit consideration as an alternative to scalping for mechanical site preparation.

A field trial was initiated in 1972 to evaluate the effect of various site preparation alternatives on survival and growth of outplanned tree seedlings. The following treatments were investigated: 1. removal of competing vegetation without disturbing the duff (clipped treatment); 2. removal of competing vegetation together with the duff (scalped treatment); 3. incorporation of competing vegetation and duff with the underlying mineral soil (mixed treatment); 4. no disturbance of either competing vegetation or duff (no treatment). The test area, which covered approximately 8 ha, was located in a clear-cut about 80 km northeast of Prince George on Tree Farm License No. 30 (Northwood Pulp and Timber Ltd.). Before cutting, which was done during the winter of 1970-71, the site supported an overmature white spruce/alpine fir stand. Lesser vegetation was characteristic of the Oplopanax Site Type (Illingworth and Arlidge, B.C. Forest Service, Res. Note No. 35, 1960). The soil was a Bisequa Gray Luvisol. The duff layer, which averaged 4 cm deep, was generally undisturbed because the area had been logged in winter.

The four treatments were prepared as follows:

Clipped Treatment. All vegetation was clipped to ground line in early June 1972. Regrowth was clipped twice during the remainder of the 1972 growing season and three times during the 1973 growing season. The duff was left undisturbed.

Scalped Treatment. A D8H Caterpillar tractor equipped with a standard bulldozer blade removed the vegetation, duff and uppermost 5 cm of mineral soil in the usual manner to prepare exposed mineral soil strips which had an average width of 4 m.

Mixed Treatment. All vegetation and surface organic materials were mixed into the underlying mineral soil using a 9 hp, hand-operated, Mang rotovator. Removal of logs and large branches that would have impeded operation of the rotovator was the only disturbance to the site before rotovation. The new surface horizon was a homogeneous, organic-enriched, mineral layer about 7 cm deep after settling.

No Treatment. Both vegetation and duff were left undisturbed.

The effect of these treatments on survival and growth of 2 + 0, bare-root, white spruce and lodgepole pine [*Pinus contorta* Dougl. var. *latifolia* Engelm.] seedlings was assessed in a semi-randomized block experiment. Clipped, mixed and no-treatment plots, each approximately 100 m^2 in area, were randomly located in each of the eight blocks into which the test area was divided. A scalped strip, constituting the fourth treatment plot, was located on one side of each block. Thirty seedlings of each species were mattock planted in each of the eight replicates of each treatment during early June 1972. Their survival and height growth were measured at the end of the second growing season, in September 1973. Data were analysed by Duncan's new multiple range test. Percent survival data were transformed to the square root of the ARCSINE before analysis, but original values are reported in Table 1.

Survival was highest in the plots where both vegetation and duff had been disturbed (scalped and mixed treatments). Differences, however, were not statistically significant for spruce (Table 1). These results suggest that on such sites, increases in survival resulting from site preparation may only be modest when ~~ap~~propriate outplanting stock is used.

TABLE 1

Survival, total height and height increment during the second growing season following outplanting of 2 + 0, bare-root, white spruce and lodgepole pine seedlings planted in variously prepared sites.

Treatment	Survival %	Total height (cm)	2nd year incr (cm)
White spruce			
No treatment	81 a[1]	22 a	7 a
Scalped	91 a	23 a	8 ab
Clipped	84 a	25 a	9 b
Mixed	90 a	29	12
Lodgepole pine			
No treatment	87 a	23 a	11 a
Clipped	92 ab	27 a	13 ab
Scalped	98 b	27 a	14 b
Mixed	98 b	33	20

[1] Means followed by a letter in common do not differ significantly ($p = .01$).

Total height was greatest for both species in the mixed treatment plots (Table 1). Since increments during the year of outplanting were small and differed insignificantly among treatments, most of this improvement resulted from increments during the second growing season. Average 1973 increments for the mixed treatment surpassed those for the other treatments by 30 to 80%. These results suggest that considerable gains in height growth may be realized by incorporating the surface organic materials of white spruce/alpine fir clear-cuts into the underlying mineral soil during site preparation. Although vegetation regrowth did occur, its effects did not offset the advantage of retaining duff and uppermost mineral soil. Rotovation, the soil mixing process used in this experiment, apparently provided adequate control of competing vegetation.

The limited response of seedlings to vegetation removal without duff disturbance (clipped treatment) suggests that the presence of competing vegetation is only one factor affecting seedling performance when planting sites are not prepared. The low soil temperatures prevailing beneath the duff of undisturbed sites (Dobbs and McMinn, Bi-mon. Res. Notes 29:6-7, 1973) are possibly suboptimal for seedling growth. Consequently, these results suggest that a similarly modest response might be realized following herbicide treatment, since herbicides, like clipping, do not remove the duff. Survival and growth in the untreated plots were probably similarly affected by low soil temperature as well as competing vegetation.

The reduction of soil fertility inherent in duff removal by scalping may be offset not only by the control of competing vegetation afforded by this site treatment but also by the enhancement of soil temperature which follows exposure of mineral soil. Mixing, like scalping, probably provides the favorable soil temperature regime associated with exposure of mineral soil in this forest region. However, mixing, unlike scalping, preserves the fertility inherent in the duff and uppermost soil horizons. If the improved growth evident so far is maintained, the operational feasibility of soil mixing as a method of mechanical site preparation warrants further investigation.—R. G. McMinn, Pacific Forest Research Centre, Victoria, B.C.

Phytotoxicity of Four Insecticides to Germinants.—The collembolan, *Bourletiella hortensis* (Fitch), is a pest of young pine, spruce and hemlock seedlings in the nurseries of coastal British Columbia, and effective non-phytotoxic insecticides are needed for its control.

Observations in the United Kingdom (Bevan, XIIth Int. Congr. Ent., Lond. pp. 666-668, 1965) and preliminary work in British Columbia (Marshall, unpub.) indicated that conifer seedlings were attacked just before and at the "drumstick" stage, i.e., when the hypocotyl had straightened out but before the seed coat was shed. Certain insecticides were suggested for collembolan control (Spencer, 1968. Guide to the chemicals used in crop protection. Can. Dep. Agric. Publ. 1093), but the phytotoxic effects of these chemicals on germinating conifers were unknown. A greenhouse experiment was therefore carried out to determine the effect of four selected insecticides on three conifer species: Sitka spruce [*Picea sitchensis* (Bong.) Carr.], white spruce [*P. glauca* (Moench) Voss] and western hemlock [*Tsuga heterophylla* (Raf.) Sarg.], with the British Columbia Forest Service seedlot numbers 951 (Kingcome River 50N, 126W), 1522 (Ptarmigan Creek, 53N, 120W) and 1832 (Kitimat area, 54N, 129W), respectively.

In March 1972, plastic pots (10.2 x 10.2 cm) were filled with an unsterilized 1:1 sand:peat mixture and thoroughly soaked before seeding. Seeds were hand sown and covered with coarse sand to the depth of the seed, to permit observation of the development of seedlings. Enough seeds were sown to give approximately 100 germinants per pot. The insecticides were applied when 50% of the germinants in each pot reached the following stages: (1) seed stage (½ day following sowing when the seed coat began to split), (2) radicle stage (tip of the radicle exposed), (3) root stage (radicle penetrating the soil), (4) cotyledon stage (hypocotyl perpendicular with the seed coat enclosing the cotyledons), and (5) cotyledon stage (seed coat had dropped from the cotyledons). The insecticides and their equivalent application rates of active ingredients (a.i.) were: (1) Diazinon® [0,0-diethyl 0-(2 isopropyl-4-methyl-6-pyrimidyl) phosphorothioate] at 0.56 and 2.24 kg/ha, (2) Dyfonate® [0-ethyl s-phenyl ethylphos = phono-dithioate] at 2.24 and 6.72 kg/ha, (3) Malathion® [diethyl mercaptosuccinate, s-ester with 0,0-dimethyl phosphorodithioate] at 4.48 and 8.96 kg/ha, and (4) Vydate® [methyl N′, N′-dimethyl-N- [(methylcarbamoyl) oxy] -1-thiooxamimidate] at 1.1 and 3.4 kg/ha. They were applied as a water base emulsion at the rate of 9350 *l*/ha by an air sprayer with a nozzle delivering 1.4 kg/cm^2 in a solid cone-shaped spray pattern. Each treatment was replicated five times in a completely random design.

Pots were watered twice for the first 2 days following sowing, then once daily until the trial ended. Greenhouse temperatures were controlled at 20 C during the first 93 days of germination, but thereafter ranged from 15 to 41 C.

Ninety-three to 113 days after seeding, the seedlings were washed from the soil and data were obtained on: total number of seedlings; stem and tap root length of 25 randomly selected plants per treatment, and oven-dry (75 C) stem and root weight of 50 randomly selected plants from each treament. Treament means were compared using Dunnett's tables for multiple comparisons (Dunnett, Biometrics 20:482-491, 1964).

Table 1 shows the parameters that were significantly reduced or increased from controls. Each species behaved differently at each germination stage and with each insecticide concentration. Generally, the insecticide did not significantly (P = 0.05) affect germinants, as indicated by the large number of blanks in the table. Insecticide application at the seed stage had no adverse effect on white spruce and little on Sitka spruce; application at the cotyledon stage had the least adverse effect on Sitka spruce and western hemlock. In the absence of a pest, a positive or negative response in plant growth depends on complex interactions between phytotoxicity and the stimulatory effects of insecticides. Increased plant growth may result when phytotoxicity is outweighed by stimulation, which can occur at low or high dosages depending on the insecticide, plant species (Kabir and Khan, J. Econ. Entomol. 65:1179-1972) and stage of development (Table 1). A negative or positive response at a higher application rate for a particular germination stage was expected, but a negative response at a lower rate not accompanied by a similar response at a higher rate (e.g. Dyfonate on Sitka spruce at the radicle stage) was surprising. Such responses probably resulted from phytotoxicity at the higher rate being outweighed by the stimulatory effect of the insecticide. However, further work is required in such seemingly contradictory areas to determine the cause-effect relationship.

For Sitka spruce, Dyfonate and high concentration of Vydate depressed stem growth, but only the high concentration of Malathion, when applied at the seed stage, reduced numbers of germinants by 23%.

White spruce appeared to be insensitive to Dyfonate, but its germinants were reduced about 15% by Diazinon, Malathion and Vydate when applied at the radicle, root or hypocotyl stages. At the higher concentration, Vydate killed 39 and 32% of western hemlock germinants when applied at the seed and radicle stage, respectively. Even at the lower concentration there was at least a 20% reduction in root and shoot growth. The phytotoxic symptoms of Vydate on western hemlock were: twisted and chloritic primary needles, necrotic cotyledons, and completely aborted plants (Fig. 1).

TABLE 1
Effect of insecticides on seedling growth.

Dosage (Kg a.i./ha) Insecticide		Seedling species	Application Stage, Parameter and Response[a]																		
			Seed					Radicle					Root			Hypocotyl				Cotyledon	
			NS	SW	SL	RW	RL	NS	SW	SL	RW	RL	SW	SL	RW	NS	SW	SL	RW	SW	RW
Diazinon	10.56																				
		White spruce				112															
		Western hemlock														87					
	2.24																				112
		White spruce				112															
		Western hemlock	111					85													
Dyfonate	2.24																				
		Sitka spruce									79			78							
	6.72																				
		Sitka spruce					111							74							
		Western hemlock																			113
Malathion	4.48																				
		Sitka spruce													113						
		Western hemlock				81													84		
	8.96																				
		Sitka spruce	77							113								112			
		White spruce	112					84													70
		Western hemlock				84														112	
Vydate	1.10																				
		Sitka spruce								112								112			
		White spruce						86													83
		Western hemlock		65	36	64			78		79										
	3.40																				
		Sitka spruce									85										
		White spruce												115		88					83
		Western hemlock	61	41	44	40	65	68	45	50	51	68	74		79		77				

[a] Parameters and seedling species for which there was no response are not shown; parameters measured include: NS = number of seedlings; SW = stem weight; SL = stem length; RW = root length. Only statistically significant (P = 0.05) decreases (underlined) and increases are given.

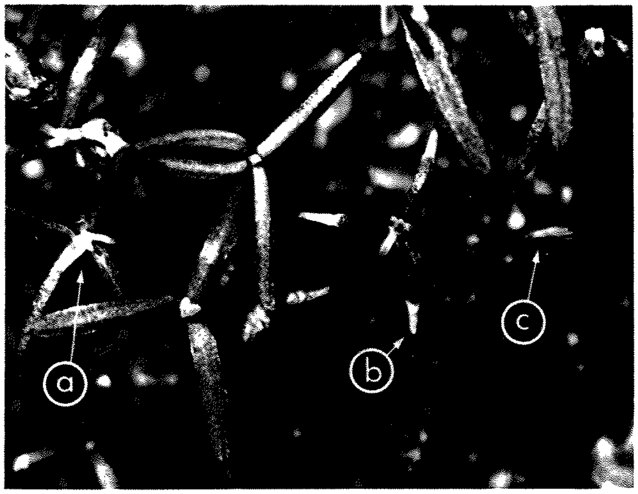

Figure 1. Some phytotoxic symptoms of Vydate on western hemlock seedlings:
a) twisted chlorotic primaries;
b) necrotic cotyledons, and
c) aborted seedling.

Chlorosis occurred mainly in primary needles, but the seedling became green again after 2 to 3 weeks.

For a seedlot under field conditions, a trade-off between collembolan control and phytotoxicity is expected, and the least phytotoxic chemical may not produce the best balance. Also, the less severely damaged seedlings should recover. Apart from high concentrations of Malathion on white spruce and Vydate on western hemlock, the average recommended dosages — intermediate between those tested here — should not seriously affect germination of Sitka spruce, white spruce and western hemlock seedlings.—S. Ilnytzky and V. G. Marshall, Pacific Forest Research Centre, Victoria, B.C.

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