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RESEARCH NOTES

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BI-MONTHLY

RESEARCH NOTES

A selection of notes on current research conducted by the Canadian Forestry Service, Department of Fisheries and Forestry

BIOLOGY

Effect of Partial Defoliation on Leader Growth.—This note concerns the inter-relationships of leader growth and growth in the rest of the tree in trembling aspen [*Populus tremuloides* Michx.]. The study was carried out in a nursery at Petawawa Forest Experiment Station. Mean annual temperature is 4.2C and annual precipitation averages 78.8 cm. Nursery plots lie on a well-drained sandy till.

One-year seedlings were transplanted in spring 1968 to a five-block layout with 24 x 24 inches (61 x 61 cm) spacing between plants. Each block contained 60 plants in each of three plots. On 26 May 1969, just before bud break, trees in two plots of each block were stripped of all branches (treatment 1). On 17 June 1969, after bud break, trees in one of these two plots in each block were treated by removal of all new (1969) branches (treatment 2). Trees in the remaining plot in each block were left untreated as controls. Thus, controls carried foliage on the new (1969) developing branches, and on branches originally formed in 1968; treatment 1 trees carried foliage on the 1969 leader and 1969 branches only; treatment 2 trees carried foliage only on the 1969 leader. Branches were not formed in the first year of seedling growth (1967). Five trees were lifted from each plot at five 3-week intervals during the summer; there were, therefore, five samples of 25 trees for each treatment and control. Plants were separated into leader foliage, other foliage if any, leader stem, wood, and other wood (stem, branches, and roots). Dry weights of these components were determined; plant height, area and number of leader leaves, and area of one subsample of 50 other leaves were measured for each plot sample of five trees. Only data from the last sample have been used in statistical analyses of results (Table 1). Where relevant, seasonal trends are illustrated (Fig. 1).

Analysis of variance (Table 1) indicates that neither treatment influenced height growth and weight of leaders (Fig. 1). Partial debudding of lower stems was similarly ineffective (Maini, Can. J. Bot. 44, 1581-90, 1966). Large differences in total plant increment (Fig. 1) resulted from the large differences in total leaf area.

The increase in size and number of leader leaves in treatments 1 and 2 may have been the result of a reduced transpiration load on the treated plants. This explanation is supported by the effects of pruning on fruit trees: pruning reduces total transpiration of the plant but increases transpiration in remaining leaves (Miller, Plant Physiology, p. 454; McGraw-Hill, 1938). Higher transpiration rates are associated with low internal moisture

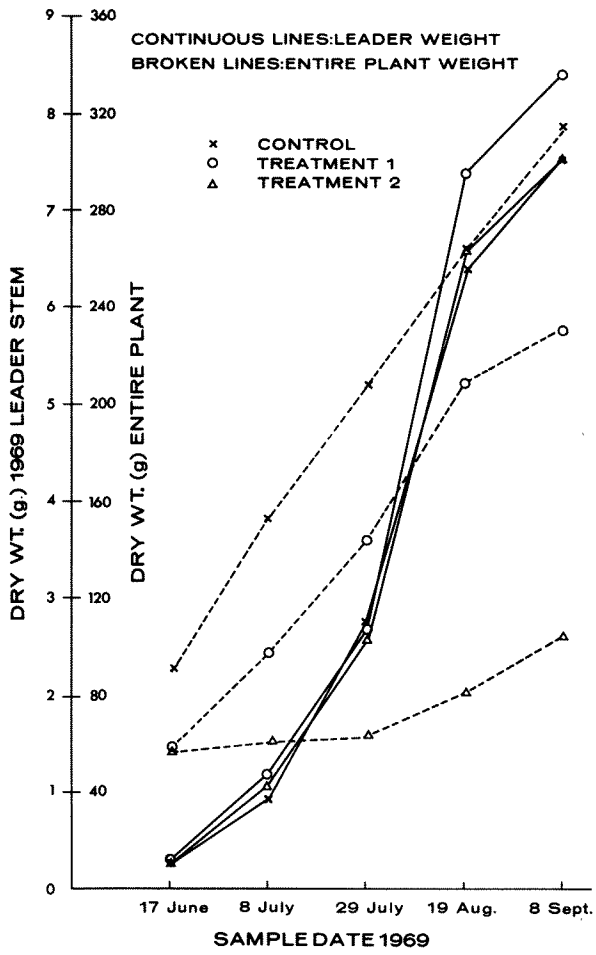
TABLE 1

Effects of defoliation treatments on growth of 3-year aspen seedlings and on characters of their current leaders.

	Treatment Mean			Variance Ratio
Variable	Control	1	2	Observed
Tree ht (cm)	174	174	171	0.20
Total tree wt (g)	314	232	105	16.9**
Leaf area (cm²)	7,063	5,479	1,268	14.5**
1969 leader:				
stem wt (g)*	7.6	8.2	7.7	0.22
leaf number	30.3	30.2	34.2	7.17**
leaf area (cm²)	787	967	1,268	7.40**
mean leaf area (cm²)	25.9	32.2	36.6	5.76**

*excluding leaves
**significant differences occur between means at P = 5%

FIGURE 1



stresses, and low stresses favor growth processes such as initiation, cell division and cell enlargement (Slatyer, Physiological aspects of crop yield, Crop Sci. Soc. Amer. 53-83, 1969).

All leaders were able to maintain usual growth, presumably because the leader has priority for its own produce. Independence of leader growth is not so evident in an evergreen conifer with determinate growth: although red pine debudded for 9 years did not show height growth different from that of controls (Berry, Forest. Chron. 38, 345-355, 1962), height growth of this species was retarded after removal of foliage below the leader (Kozlowski and Winget, Amer. J. Bot. 51, 522-29, 1964). Growth occurring in other organs in treatment 2 showed that the leader produced about five times more dry matter than was required for its own growth. It is consequently unlikely that leader growth resulted from relocation of assimilates from other parts of the tree.

Measurements of height growth are widely used in assessing results of tree breeding experiments; there is consequently good

reason for physiological studies being directed into leader extension growth. The design and interpretation of these studies would be easier if leader growth were more or less independent of growth in the rest of the plant; from data in this report, it is tentatively concluded that this is true for species showing indeterminate growth. The results suggest, so that some hardwood species could be managed to produce special purpose, knot-free boles without loss of height growth.—D. F. W. Pollard, Petawawa Forest Experiment Station, Chalk River, Ont.

Emergence Patterns of the Mountain Pine Beetle from Lodgepole Pine.—The effects of temperature and light on daily emergence and the effect of weather on the seasonal emergence of the mountain pine beetle [*Dendroctonus ponderosae* Hopk.] from lodgepole pine [*Pinus contorta* Dougl. var. *latifolia* Engelm.] have been studied by Reid (Can. Entomol., 94: 531-538, 1962) and Powell (Agr. Meteorol., 4: 189-201, 1967). Reid (*loc. cit.*) found that, in southeastern British Columbia, the pattern of daily emergence is more the result of temperature than light conditions. Emergence threshold is about 58F but most of the emergence occurs at temperature above 70F. Seasonal emergence is related to temperature since the beetles require about 8340 degree-hours above 10C in the subcortical zone of the stem to develop from egg to adult (Powell, *loc. cit.*). This paper relates the daily emergence patterns of the mountain pine beetle in southeastern British Columbia to aspect and height on the stem, tree diameter, heat units, and beetle size.

Beetles emerging from the northern and southern aspects of 6 trees in 1968, and 10 trees in 1969, were trapped at 2-foot intervals on the bottom 20 feet of the boles. The traps, consisting of ice-cream cartons 3 inches deep and 3⅞ inches in diameter with vials containing 75% alcohol attached to their lower sides to collect the beetles, were inserted into slits cut through the bark with a circular hole-saw when about 85% of the brood had matured. The traps were inspected every 2 to 3 days, between 8 and 9 AM, throughout the emergence period, and the number of emerging beetles was recorded by aspect, height, and date of emergence. Sex was determined by presence or absence of the stridulating teeth on the 7th abdominal tergite of the male (Hopkins, U.S.D.A. Bur. Entomol. Bull. 83 Part I, 1909). Pronotal width, measured on the dorsal aspect to the nearest 0.5 mm, was used as an index of beetle size. Heat units were expressed in degree-days above 58F.

Emergence in 1968 occurred between 14 July and 8 August, and in 1969 between 17 and 29 July. During these two emergence periods, 431 and 111 beetles respectively were collected in the traps; the corresponding male-to-female ratios were 1:1.9 and 1:3.3.

Emergence was directly proportional to degree-days above the 58F threshold during the emergence period in both years. The

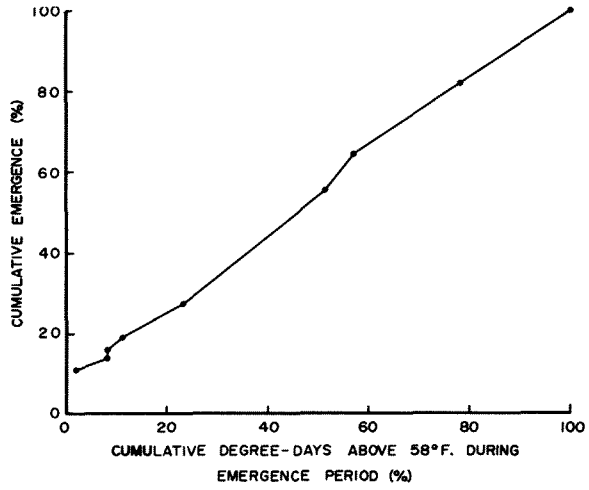


FIGURE 1. Cumulative emergence of male and female *Dendroctonus ponderosae* from the bottom 20 feet of the stem of lodgepole pine trees in relation to cumulative degree-days above 58F (1968 data).

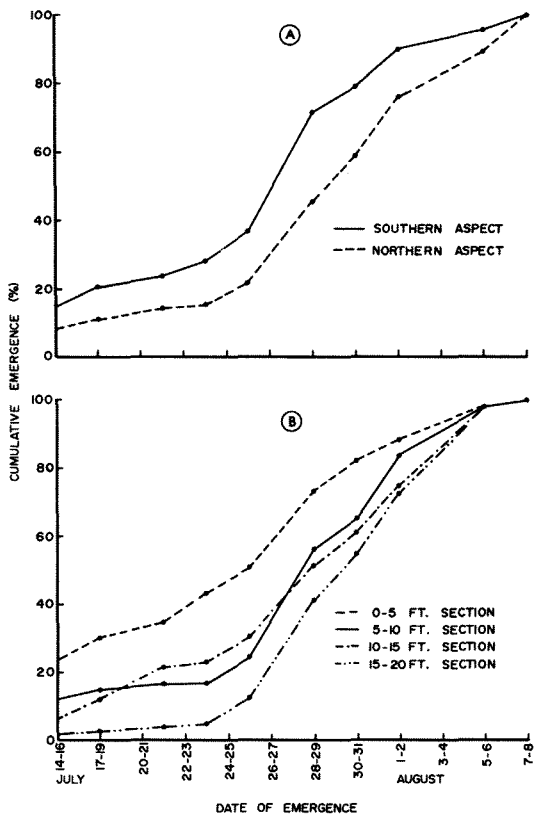


FIGURE 2. Cumulative emergence of male and female *Dendroctonus ponderosae* from the bottom 20 feet of the stems of lodgepole pine trees in relation to date of emergence in 1968. A, cumulative emergence by aspect; B, cumulative by level.

TABLE 1

Cumulative emergence of the mountain pine beetle from the bottom 20-ft section of lodgepole pine stems in relation to diameter in 1968[a].

Diameter at breast height (inches)	Cumulative emergence (%)	Date on which cum. emergence in column 2 was reached
12.2	25	July 18
	50	July 25
12.0	25	July 16
	50	July 25
11.5	25	July 26
	50	July 29
11.3	25	July 27
	50	July 29
11.1	25	July 27
	50	July 31
10.2	25	July 27
	50	July 31

[a] The 1969 data were excluded because, on the average, only 11 beetles per sample tree were trapped.

TABLE 2

Differences between average pronotal widths of mountain pine beetles emerging from the bottom 20-ft section of lodgepole pine stems during first and second halves of the emergence period.

	Average pronotal width of emerging beetles (mm)			
Year	Males		Females	
	First half of emergence period versus second half		First half of emergence period versus second half	
1968	1.92(74)[a]	1.86(73)	2.10(157)	2.04(127)*
1969	1.93(12)	1.85(14)	2.11(54)	1.99(31)*

[a] Numbers in brackets indicate sample size.
* Differences significant at the 5% probability level; entries without asterisks are not significant.

(*Continued on page 19*)

FOREST PRODUCTS

The Pyrolysis of Aspen and Black Spruce Lignins.—The search for more effective fire-retardant treatments for wood has resulted in the publication of a number of detailed studies on the pyrolysis of cellulose (MacKay, Wood Fire Behavior and Fire-Retardant Treatment. C.W.C. Nov. 1966). Relatively fewer investigations on the lignin component of wood have been made. However, because of its aromatic nature, lignin might be expected to be a major contributor to the development of the smoke associated with fire. A study was therefore initiated to investigate the basic processes involved in lignin pyrolysis and the mode of action, if any, of fire-retardants. Results of initial studies of the pyrolysis of two types of lignin are reported here.

Gas-chromatographic analysis of the flash-pyrolysis products of polymers has been used extensively to elucidate polymer structure and the mechanism of pyrolytic polymer degradation. This technique has been used by Kratzl *et al.* (Kratzl), Holz. Roh. *u.* Werkstoff 23(6):237, 1965) to characterize the pyrolysis products of Björkman spruce lignin, crude softwood sulfate lignin and crude hardwood sulfate lignin; also by Kitao and Watanabe (Kitao, J. Soc. Materials Sci. Japan 16(169):844, 1967) who studied the pyrolysis products of milled wood lignin (Björkman) from pine, beech, and rice straw.

In our studies, 0.5 mg samples of high-purity, fractionated ball-milled lignins (Brownell, Tappi 51(7):298-300, 1968) of aspen [*Populus tremuloides* Michx.] and black sprice [*Picea mariana* (Mill.) BSP.] were flash pyrolyzed at 425 C, in a stream of helium, using an F & M Model 80 Pyrolysis unit. The products were separated using an F & M Model 700 dual column, gas chromatograph, fitted with flame ionization detectors. With this arrangement the pyrolysis products were swept directly onto the column, thus minimizing secondary reactions. Copper columns, ¼ in. x 11 ft, packed with 5% Carbowax 20M on Chromosorb W (AW), operating at 177 C, afforded good resolution of the products as is shown in Fig. 1. Tentative identification of the phenolic products was made by comparing their retention times with those of expected reference model compounds (Table 1). A tentative qualification is noted since, in three instances, the retention times of single pyrolysis peaks (numbers 7, 9 and 10) correspond to those of two reference models. Improved resolution of lignin pyrolysis products was attained, as compared with earlier work.

TABLE 1

Retention times of aspen and black spruce lignin pyrolysis products

Pyrolysis product peak No.	Model reference compound	Relative retention time*
1	Guaiacol	1.00
2	4-Hydroxy-3-methoxytoluene	1.32
3	Phenol	1.48
4	4-Hydroxy-3-methoxyethylbenzene	1.67
5	*p*-Cresol	1.90
6	4-Hydroxy-3-methoxypropylbenzene	2.14
7	Eugenol 4-Ethylphenol	2.60
8	4-Hydroxy-3-methoxystyrene	2.87
9	*cis*-Isoeugenol 2,6-Dimethoxyphenol	3.61
10	*trans*-Isoeugenol 4-Hydroxy-3,5-dimethoxytoluene	4.72
11**	4-Hydroxy-3,5-dimethoxyethylbenzene	5.80
12**	4-Hydroxy-3,5-dimethoxypropylbenzene	7.35
13**	4-Hydroxy-3,5-dimethoxyallylbenzene	9.72
14	Vanillin	10.12
15	Acetovanillone	12.37

*relative to guaiacol (200 sec.).

**absent from black spruce lignin pyrogram.

Pyrolytic studies of aspen lignin or highly fractionated spruce lignin have not been reported previously. The use of high-purity lignins facilitates the characterization of the pyrolysis products by reducing the initial tailing of non-lignin products. In crude lignins, such tailing tends to swamp subsequent peaks. The presence of guaiacyl compounds among the pyrolysis products of spruce lignin and of both guaiacyl and syringyl compounds among those of aspen lignin is in agreement with the findings of others regarding the major difference in gross structure between gymnosperm and dicotyledonous-angiosperm lignins.

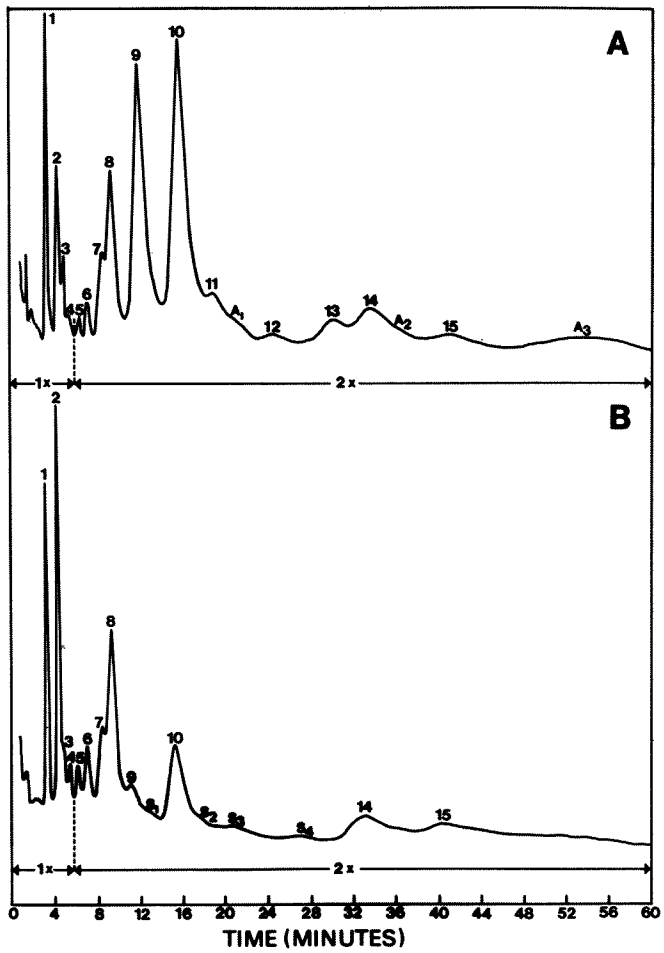


FIGURE 1. Wood lignin pyrogram: A. aspen [*Populus tremuloides* Michx.]; B. black spruce [*Picea mariana* (Mill.) BSP.].

Complete details of this work and recent findings on the effect of fire-retardants on the pyrolysis of these lignins are presently being prepared for publication.—D. P. Fung and R. A. Ripley, Forest Products Laboratory, Ottawa, Ont.

INSECT PATHOLOGY

Production of Resting Spores of Some *Entomophthora* Species on Artificial Media.—The periodic effectiveness of the genus *Entomophthora* in restricting or controlling natural populations of certain insects is well documented, but a major problem in inducing epizootics of these fungi is the development of a suitable method of introducing the fungus into the insect population. In nature, the fungus is in general propagated by conidia during the summer months and overwinters as thick-walled resting spores.

Conidia are readily produced on artificial media and germinate well, but they have a short life-span and are dependent upon high humidity for survival. Resting spores appear to offer the greatest potential for introduction of the fungus into an insect population as they are long-lived and resistant to a wide variety of weather conditions. Although they have proved difficult to germinate in the laboratory, this disadvantage may be offset by the fact that timing of applications is not as critical as it is for conidia.

Production of resting spores by *Entomophthora virulenta* was reported by Hall and Halfhill (J. Econ. Entomol. 52:30-35, 1959) when the fungus was grown on Sabouraud dextrose agar medium. These workers noted that 2-5% of these spores germinated readily when transferred to fresh medium. Gustafsson (Lantbrukshogskolans Ann. 31:103-212, 1965; *ibid.* 31: 405-457, 1965) confirmed the findings of Hall and Halfhill on *E. virulenta*, and noted the

production of resting spores in pure culture by *E. coronata*, *E. culicis* (Sabouraud dextrose medium), *E. sphaerospherma* (potato dextrose peptone medium), and *E. exitialis* (egg yolk medium).

This note concerns the production of resting spores by the following species of *Entomophthora*:

Species	Source of isolates	Obtained from
E. virulenta	*Peronea minuta*	Centraalbureau voor Schimmelcultures, Baarn.
E. tipula	Not known	Dr. J. Weiser, Prague.
E. conglomerata	Not known	Dr. J. Weiser, Prague.
E. pyriformis	*Rhopalosiphum insertum*	Mme G. Thoizon, Pasteur Institute, Paris.
E. thaxteriana	*Therioaphis maculata*	Agriculture Experiment, Station Berkeley, Calif.

These isolates grow rapidly and sporulate well on Sabouraud dextrose agar (Difco) supplemented with 0.2% yeast extract. For production of resting spores, Petri plates containing the medium were inoculated by spreading a washed mycelial suspension evenly over the surface of the medium. The mycelial suspension was obtained from a 2-3 day-old shake cultures grown in liquid medium of similar composition. The plates were incubated in an inverted position under continuous fluorescent light at room temperature (22-23 C). In all cases, conidial production generally began by the 2nd day, while resting spore formation was evident by the 4th or 5th day. The conidia were forcibly ejected from the surface of the medium by the conidiophores, and adhered to the lids of the Petri dishes.

Incubation of the plates was continued for approximately 2 weeks, by which time all growth and sporulation had ceased. The resting spores were readily obtained from the cultures by scraping the vegetative material from the agar surface with a glass microscope slide, followed by maceration a in VirTis homogenizer and repeated washing with distilled water. Very little contamination by conidia was noted.

To determine the effect of the various constituents of the medium on sporulation dextrose, peptone and yeast extract were incorporated singly and in pairs into media in amounts similar to those in the complete medium. The media were inoculated as described. Only media which included dextrose as one of the constituents supported substantial growth and the formation of conidia and resting spores. In all cases where sporulation occurred both conidia and resting spores were formed. Sporulation is therefore dependent upon the presence of a readily utilizable sugar in the growth medium. Experiments are now in progress to determine whether other sugars can replace dextrose in supporting sporulation of these isolates.

Our results are in accord with the findings of Hall and Halfhill, and Gustafsson, for *E. virulenta*, and further extend the number of *Entomophthora* species known to produce resting spores in culture. Work on the production of resting spores is now being extended to include other *Entomophthora* species available in pure culture.—David Tyrrell, Insect Pathology Research Institute, Sault Ste. Marie, Ont.

Preliminary Results of Radiation Induced Sterility of the Male Spruce Budworm.—The feasibility of employing the sterile-male technique in controlling the spruce budworm [*Choristoneura fumiferana* Clem.] is under investigation. This note presents preliminary results of the effects of gamma irriadiation on the male spruce budworm.

Male spruce budworms reared on a meridic diet (McMorran, Can. Entomol. 97: 58-62, 1965) after the method of Stehr (Can. Entomol. 86: 423-428, 1954) were irradiated with gamma rays from a Co^{60} source at the Atomic Energy of Canada laboratory in Chalk River, Ontario. The dose rate of the Co^{60} unit was 250 R/min at 49 cm from the source as determined by a dosimeter. Fourth-, fifth-, and sixth-instar larvae were each exposed to four levels of radiation, 0, 5, 10, and 30 kR. The pupae and adults were irradiated at 0, 10, 30, and 40 kR. The adults were mated at Chalk River after subjecting them to gamma rays, whereas the larvae and pupae were brought back to Sault Ste. Marie and mated after they had reached adulthood. Each male was placed in a suitable container with one virgin female and the mating success was determined by examining for the presence of sperms in the bursa copulatrix and seminal receptacle of the female. The eggs laid by the mated females and the larvae that hatched from these eggs were counted.

The irradiated larvae showed several pathological symptoms. Many of them had radiation burns (Fig. 1) and some of them had crumpled wings when they reached the adult stage. Pupation was considerably delayed and many died as pupae. Of the ones that reached the adult stage, only a few mated. Total sterilization, however, was never achieved.

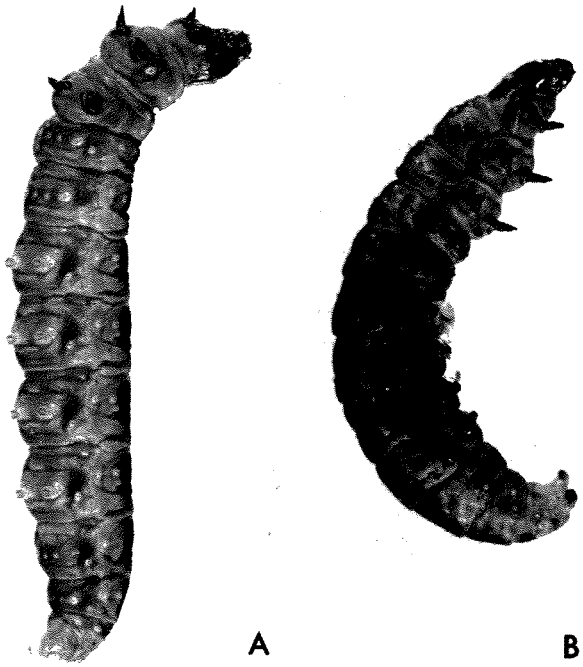


FIGURE 1. Effect of gamma radiation on the sixth-instar larva of the spruce budworm. A) Control B) Received 30 kR and shows radiation burns.

The minimum sterilizing dose for pupae was 30 kR/male (Table 1). Some of the irradiated pupae developed a pair of vesicles filled with fluid instead of the wing buds, and failed to develop into adults. As the dose was increased there was a progressive increase in mating failure.

TABLE 1

Radiation sterilization of male pupae of spruce budworm.

Treatment (kR/♂)	Sample size	% mating failure	% egg hatch from ♀ that mated with irradiated ♂
0	19	5	80
10	21	57	60
30	22	86	0
40	22	95	0

The minimum sterilizing dose for the adults was also 30 kR/male (Table 2). The high incidence of mating failure was probably due to the disturbance they were subjected to while being transported to Chalk River during winter, since the untreated controls behaved as poorly as all but the most heavily irradiated ones.

These preliminary results indicate that larvae and pupae are difficult to sterilize without producing any adverse side effects. Adult males, however, can be successfully sterilized by exposing them to 30 kR/insect. Work on mating competitiveness of irradiated adult males is currently in progress.

TABLE 2

Radiation sterilization of adult male spruce budworm.

Treatment (kR/♂)	Sample size	% mating failure	% egg hatch from ♀ that mated with irradiated ♂
0	17	35	76
10	16	31	59
30	20	20	0
40	20	50	0

The author wishes to thank Dr. W. F. Baldwin, Biology and Health Physics Division, Atomic Energy of Canada Limited, Chalk River, Ontario, for laboratory facilities and setting up the Co^{60} source for irradiation. The technical assistance of Mr. John French and Mr. Christopher Rose are greatefully acknowledged. —Arthur Retnakaran, Insect Pathology Research Institute, Sault Ste. Marie, Ont.

PATHOLOGY

Infection of Engelmann Spruce by Hemlock Dwarf Mistletoe.—Evidence from nature and from artificial inoculations indicate that hemlock dwarf mistletoe [*Arceuthobium campylopodum* Engelm. f. *tsugehsis* (Rosend.) Gill] will infect about 20 conifer species and varieties included in the genera *Tsuga*, *Abies*, *Pinus*, *Larix* and *Picea*. Extensive damage is generally restricted to the principal hosts, western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] and mountain hemlock [*T. mertensiana* (Bong.) Carr.], though pure stands of shore pine [*Pinus contorta* Dougl.] are occasionally severely attacked.

Species of spruce [*Picea*] are rarely attacked, and only when closely associated with infected western or mountain hemlock. Reports of natural infection exist for Brewer spruce [*P. breweriana* S. Wats.] in California (Hawksworth and Graham, Nthwst. Sci. 37:31-38, 1963) and Sitka spruce [*P. sitchensis* (Bong.) Carr.] in Alaska (Laurent, Plant Dis. Reptr. 50:921, 1966) and British Columbia [Molnar *et al.*, Can. Dep. For., 1967 Ann. Rpt. For. Insect Dis. Surv., 1968). Inoculation of white spruce [*P. glauca* (Moench) Voss] and Norway spruce [*P. abies* (L.) Karst.] showed these species were also susceptible to hemlock mistletoe (Smith, Can. Dep. For., Bi-m. Progr. Rpt. 21(6):3-4, 1965). In September 1969, F. G. Hawksworth (Rocky Mtn. For. and Range Exp. Sta., Ft. Collins, Colorado, Pers. comm. 1969), found a suppressed Engelmann spruce [*P. engelmannii* Parry] with several mistletoe-caused brooms near Santiam Pass, Oregon. No aerial shoots were visible but basal cups were present. Because the spruce occurred among western hemlock trees heavily infected by hemlock dwarf mistletoe, the mistletoe on it was assumed to be the same. This note presents information on the susceptibility of Engelmann spruce to hemlock dwarf mistletoe gained from artificial inoculations.

Inoculations were carried out near Victoria on plantation-grown Engelmann spruce from two provenances, Montana and southeastern British Columbia. The test trees were thrifty, growing almost 12 inches per year during the past 5 years. Seeds were collected and stored and inoculations effected, but only at the axils of needles, as previously described (Smith, Bi-Mon. Res. Notes, 2:—, 1970). Each year from 1963-1966, 10 mistletoe seeds from each original host were planted on each of four trees of the two provenances. A total of 640 seeds were used during the 4-year period.

Sixty-three infections were obtained; 28 swellings appeared within 1.5 years of inoculation, while a few were not apparent until after 3 years. Swellings were more globose (length: width = 2.7:1) than those resulting from normal parasitism of western hemlock trees (5.7:1) growing in the same plantation. Aerial shoots appeared irregularly, as early as 1.5 years after inoculation in a few infections, but more commonly not for 2 years or more. By August 1969 (3-6 years after inoculation) more than half of the infections still lacked shoots, contrasting with infections on western hemlock in which all swellings produced aerial shoots within 3 years of inoculation. After emergence, aerial shoots on Engelmann spruce developed normally; the longest measured was 79 mm. Flowers developed on 13 of the infections and anthesis proceeded regularly. A few female flowers were observed in 1968 but failed to develop into fruit in 1969. More female flowers appeared in 1969 and they seemed to be developing normally at the last examination.

Because of the earlier success with white and Norway spruce, infection of Engelmann spruce was not entirely unexpected. However, the high rate of infection was surprising. In particular, 44 infections developed from 160 seeds planted in 1965, an infection rate of 28%. This included 16 infections on southeastern British Columbia Engelmann spruce from 40 seeds collected from shore pine. Other than the latter particularly successful combination, there were no overall differences in the susceptibility of Montana and British Columbia spruce, or in the infectiveness of hemlock mistletoe from hemlock and shore pine.

Considering the relatively high frequency of infection produced in this study, natural infection of Engelmann spruce can be expected to occur wherever it is exposed to hemlock mistletoe. The Santiam Pass report noted earlier is the first observation of this in nature. In this case, the absence of living shoots prevented verification of the mistletoe species, but the presence of only hemlock mistletoe in the area and the demonstrated susceptibility of Engelmann spruce indicate that hemlock mistletoe was likely the casual agent. As range maps suggests that Engelmann spruce and hemlock mistletoe are probably sympatric in other areas of the Cascade Mountains in Oregon, Washington and British Columbia, other instances of this host-parasite combination undoubtedly exist. Hemlock mistletoe on Engelmann spruce may not be extensive or particularly damaging, but forest managers concerned with mistletoe control should be aware of this potential source of dwarf mistletoe inoculum.—R. B. Smith, Forest Research Laboratory, Victoria, B.C.

Development of Corky Root Disease in Douglas-fir Transplants.—Corky root, a stunting disease of Douglas-fir seedlings (Bloomberg, Can. Dep. For., Bi-Mon. Res. Notes 24:8, 1968), was probably introduced into the Duncan, B.C., forest nursery in fill-soil containing large populations of the nematode *Xiphinema bakeri* Williams 1961 (Sutherland and Dunn, Plant Dis. Reptr. In press). Consequently, the disease is present in well-defined areas.

In 1967, 1-0 Douglas-fir of a single seedlot from an uninfected nursery were transplanted into the area containing the nematode-infested soil and also into an area containing the original nursery soil. Two years later, the transplants in small patches of the imported soil area were severely stunted but elsewhere stunting was absent. For sampling purposes, the area was divided into "stunted" and "unstunted" plots. Five transplants were removed from each plot by carefully digging out as much of the root system as possible, together with surrounding soil. The plants and soil were placed immediately in polyethylene bags. For comparison, six transplants plus surrounding soil, in an adjoining area containing the original nursery soil, were dug from eight points about 20 feet apart.

Shoot and root growth of each seedling were measured. Lateral roots, and new root tips were counted. Disease severity in roots was rated by degree of swelling, lack of root hairs and clubbing of root tips.

The number of *X. bakeri* on seedling roots were determined by carefully removing the roots, with adhering rhizosphere soil, and quickly submerging them in a bucket half-filled with water. The roots were then washed with a stream of water, and the nematodes extracted by a modified (final screen of 325 mesh) Christie and Perry method (Proc. Helminthol. Soc. Wash. 18:106-108, 1951). To determine the populations of *X. bakeri* in the soil, each sample was thoroughly mixed and the nematodes extracted, by the same procedure from a 500 g (wet wt) aliquot. Nematode counts were expressed on an oven-dry weight of soil basis.

TABLE 1

Growth, disease severity, nematode populations and fungus infection in Douglas-fir transplants

Area	Plant Condition	Shoot growth after transplanting: 1st year % annual increase in length[c]	Shoot growth after transplanting: 2nd year % annual increase in length[c]	Shoot growth after transplanting: Total length (mm) at end of 2nd yr.	Root Growth: Tap root (mm)	Root Growth: % with >10 laterals	Root Growth: Disease severity[d]	Root Growth: No. new tips	No. *X. bakeri*: on roots	No. *X. bakeri*: in soil[e]	% Infection by *C. destructans*
Original soil distant[a]	Healthy	71	106	240	242	100	0.0	3.0	1.1	2.5	3
Original soil adjacent[b]	Healthy	58	131	244	273	100	0.4	5.5	22	61	7
Imported soil	Unstunted	61	85	186	253	100	1.1	8.7	411	433	15
Imported soil	Stunted	45	14	88	157	57	2.6	2.2	86	92	60

[a]Samples furthest from imported soil area. [b]Samples nearest to imported soil area. [c]% of shoot length at end of previous growing season. [d]0 = nil, 1 — light, 2 = moderate, 3 = severe. [e]Basis, 500 g O.D. soil.

Fungi were isolated from roots by submerging 10-mm root segments in an ultrasonic cleaner containing "Cavicide" (Mettler Electronics) for 10 minutes, rinsing with water and then aseptically transferring the central 5 mm of each segment to 2% malt extract agar containing 100 ppm steptomycin sulphate and 100 ppm penicillin G. Root segments were taken from swollen "corky" regions, if present; otherwise, they were taken from the mid-region of the taproot.

Table 1 presents a summary of our observations. During the first year after transplanting, there was little difference in the percentage of shoot-length increase between unstunted and adjacent plots. Therefore soil factors were not likely the cause of reduced shoot-length increase (45%) in the stunted plots. Also, the numbers of *X. bakeri* were much higher in soil and roots samples from the imported soil than from the original soil, and the root disease symptoms were characteristic of damage by *Xiphinema* spp. on other hosts (DiSanzo and Rhode, Phyto pathology 59:279-284, 1969; Davis, Phytopathology 49:523, 1959; Schindler and Braun, Nematologica 2:91-93, 1957). The symptoms and their localization in small patches of the imported soil were typical of corky root disease elsewhere (Bloomberg, *loc. cit.*).

Paradoxically, at the end of the second year after transplanting within the imported soil area, plots with the highest disease ratings had lower *X. bakeri* populations than plots with less disease. This may have resulted from initially high local populations damaging the roots so severely in the first year that height-growth was reduced but the available food became limited and the population declined. By the same reasoning, initially low populations may not have increased appreciably until the second year after transplanting when feeding had just begun to reduce height-growth but had not yet produced severe root disease symptoms.

Why the transplants growing in the unstunted plots of the imported soil and the adjacent plots of the original soil developed the most new root tips is not clear. These roots also had more nematodes than roots with fewer tips and it is possible that feeding stimulated the development of new tips.

The incidence of the fungus *Cylindrocarpon destructans* (Zinssm.) Scholten (= *C. radicicola* Wr.) increased with increased disease severity, adding to the evidence (Bloomberg, *loc. cit.*) that the fungus plays a role in the disease. However, the fungus is a very weak parasite of other tree hosts (Peace, Pathology of Trees and Shrubs, Clarendon Press, Oxford, 1962) so it may only infect roots that have already been damaged by the nematode. The fungus appears to persist in the roots but it is not known whether it prevents their recovery.

Corky foot disease had previously been observed only on Douglas-fir seedlings. The fact that it can also occur on transplants increases the importance of the disease. W. J. Bloomberg, Jack R. Sutherland, W. Lock and T. G. Dunn, Forest Research Laboratory, Victoria, B.C.

Seed Disease of Douglas Fir During Cone Storage. — An earlier report (Bloomberg, Forest Sci. 15: 176-181, 1969) dealt with the effects of cone characteristics, seed condition and fungus growth on disease and germinability of Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] seeds during 125-225 days of cone storage. In 1968, the importance of these factors was investigated immediately after the cones were picked and during 90 days subsequent storage.

Four to six sacks (ca. 6-10 bu) of cones were picked from each of three stands (lots) of Douglas fir, 20 to 100 miles apart, on southern Vancouver Island. Picking took place 1-12 Sept. Operational picking, storage and seed extraction methods of the British Columbia Forest Service were used. Sampling design and methods of cone, seed and fungus assessment were the same as in the previous study. An unheated garage served as a temporary collection depot, the cone sacks being placed upright on the concrete floor with 1-ft spaces between them. After 30 days, the sacks were transferred to the cone sheds at the British Columbia Forest Service Seed Centre, Duncan, B.C. Air temperatures and relative humidity in each location were as follows:

	Collection Depot	Storage Shed
Air Temp (C)		
Range	5.5–16.6	−3.2–27.1
Avg weekly min	7.7	0
Avg weekly max	13.3	20.0
Relative humidity %		
Range	66–97	32–100
Avg weekly min	74	39
Avg weekly max	93	100
Avg no. hr 90%	2	13

Samples of cones were drawn from three sacks of each lot immediately after picking, and again after 7, 30, 60 and 90 days in storage. In each sample, cone, seed and fungus characteristics (see Table 1) were microscopically examined in 20 dissected cones, and cone moisture content (per cent oven dry weight) was determined from 200 cones. Seeds were extracted (except at 7 days' storage) from about 500 cones, cleaned in a Dakota blower, stratified, then tested for germination in four replicates of 100 seeds by standard procedures (Baldwin, FAO Forest. Development Paper 4, 1955).

Cone Characteristics. The cones of the three lots varied greatly in moisture content and scale closure (Table 1). At picking, the cones in lot A were drier and almost completely open, where those in lot B were almost completely closed. Insects, mainly *Contarinia washingtoniensis*, occurred in 25 to 90% of the cones examined and did not vary greatly among lots or storage periods.

Fungus growth. Mycelial growth on the cone surface, inside the scales and around the seeds was sparse or absent at the time of picking. Thereafter growth increased rapidly, completely covering cones in lots B and C after 30 days. Mycelial growth inside the cones also increased but attained maximal development later than the external growth. Growth occurred earlier around empty seeds than around filled ones. Fungus genera most commonly found on the cones included: *Papulospora, Penicillium, Trichoderma, Phoma, Trichothecium* and *Gliocladium* in that order.

Seed Condition. Less than 1% of the seeds examined in the cone were diseased, i.e., had lesions, or were discolored or decayed, but in germination tests after extraction, up to 27% of the filled seeds became diseased, accounting for 85% of the germination failures. In lot B, disease incidence during germination decreased with cone storage and in lot C, incidence increased temporarily after

TABLE 1. Relationship of cone storage period, cone characteristics, mycelial growth and seed condition in Douglas fir.

Lot	Cone Characteristics				Mycelial Growth			Seed Condition	
					Mycelial Density[2]				
	Cone storage period	Moisture content % oven dry wt	Scale Closure[1]	Cone surface covered	On inner scale	Around empty seeds	Around filled seeds	Germinable[3]	Diseased[3]
	(days)		index	%	index	index	index	%	%
A	0	50	1.2	14				87	
	7	—	—	40				—	
	30	41	1.0	65				89	
	60	25	1.0	—				87	
	90	26	1.0	—				87	
B	0	140	4.9	0	0	0.2	0	66	27
	7	—	—	12	1.0	0.5	0	—	—
	30	126	2.2	99	2.7	2.6	2.6	74	19
	60	92	1.5	100	5.5	4.2	3.2	80	17
	90	62	1.3	100	6.3	5.5	4.1	80	13
C	0	134	3.7	2	0.7	0.6	0	82	12
	7	—	—	45	2.9	2.5	2.0	—	—
	30	118	2.5	90	3.3	2.9	2.7	72	21
	60	78	1.4	98	4.3	4.4	3.9	87	11
	90	46	1.1	100	6.2	4.9	3.3	86	11

Note: Within the same lot, means followed by a bar are not significantly different ($p < .05$) by Duncan's multiple range test.
[1] Rated from 1 = fully open to 5 = tightly closed.
[2] Rated from 0 = nil to 10 = very heavy.
[3] Per cent of filled seeds: Other categories of seed condition (not shown) account for the balance of 100%.

the first 30 days in storage, then decreased. Fungus genera associated with disease included: *Penicillium, Gliocladium, Papulospora* and *Cephalosporium.*

Germinability (per cent filled seeds germinating) in all lots exceeded 80% after 90 days in storage. In lots A and C, germinability after 90 days in storage was the same as at the time of picking, whereas germinability of lot B increased.

The above results support indications from the previous study that, under local operational conditions, cone storage for at least 90 days does not reduce the germinability of Douglas-fir seeds, but may increase it; also that fungi are non-injurious to seeds while in the cones but are associated with disease during germination. As in the previous investigation, and in partial disagreement with other reports (Rediske and Shea, Forest Sci. 11: 463-472, 1965; Shea, Weyerhaeuser Co. Forest Res. Note 31, 1960), no other factors examined had any relationship to disease or germinability. Nor did insect damage, negligible in the previous investigation but severe in the present one, bear any relationship to disease or germinability — W. J. Bloomberg, Forest Research Laboratory, Victoria, B.C.

Infection of Western Larch by Hemlock Dwarf Mistletoe.— Since it was first described (Rosendahl, Minn. Bot. Studies 3: 271-273, 1903), hemlock dwarf mistletoe [*Arceuthobium campylopodum* Engelm. forma *tsugensis* (Rosend.) Gill] has been considered distinct from larch dwarf mistletoe [*A. campylopodum* forma *laricis* (Piper) Gill] (Piper, Contr. U.S. Nat. Herb. 11: 222-223, 1906). In a monograph of the genus (Gill, Trans. Conn. Acad. Arts and Sci. 32:111-245, 1935), the two were differentiated as forms mainly on the basis of principal hosts, western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] for hemlock mistletoe and western larch [*Larix occidentalis* Nutt.] for larch mistletoe. The lack of evidence of cross-infection was considered justification for taxonomic separation even in the absence of demonstrated morphological differences. However, a report of natural infection of plantation-grown European larch [*Larix decidua* Mill.] by hemlock dwarf mistletoe on Vancouver Island (Kuijt, Madrono 17:254-256, 1964) suggested that physiological differences in the two forms were less pronounced than hitherto believed. The latter combination produced distinct swellings but no aerial shoots. Wicker (Ph.D thesis, Wash. State Univ., 1965) obtained a single infection of hemlock mistletoe on western larch by using an inoculation technique involving an artificial incision on the host branch.

To further the knowledge of host ranges, a series of inoculations employing several dwarf mistletoe and conifer species were conducted in a plantation near Victoria, B.C. Results pertinent to the taxonomy of larch and hemlock dwarf mistletoes are reported here.

Hemlock mistletoe seeds were collected in early October on Vancouver Island from western hemlock, the primary host, and from shore pine [*Pinus contorta* Dougl.], an occasional host. Larch mistletoe seeds were collected in September from western larch growing in southeastern British Columbia. All seeds were stored at 5C before inoculation in late October and early November. To effect adhesion to the branch surface, the seeds were briefly wetted and then placed mainly on 1- and 2-year-old branches at the axils of needles or at the bases of buds. Inoculations were repeated for 4 years from 1963 to 1966.

Twenty-nine of the 160 hemlock mistletoe seeds collected from shore pine and placed on western larch produced swellings, normally the first indication of infection; however, by 27 Aug. 1969, none bore aerial shoots even though swellings reached to 100 mm in length. Ten of the 160 seeds collected from western hemlock caused swellings on larch and one of these produced aerial shoots. The production of aerial shoots by this host-parasite combination is apparently rare. The inoculation was made in early November 1965, and a swelling with aerial shoots was first observed in October 1966. By 1968, five shoots were present. The largest (48 mm in length) bore staminate flowers in 1968. Anthesis occurred normally. Pollen recovered from the

flowers was examined by F. G. Hawksworth (U.S.F.S., Ft. Collins, Colorado) who classified it with the hemlock dwarf mistletoe type. By early 1969, all aerial shoots had died and no new shoots have appeared since.

It is instructive to compare the response of western larch to hemlock mistletoe with that of western larch to larch mistletoe. Of 144 larch mistletoe seeds planted on larch, 39 caused swellings. All swellings bore aerial shoots and new shoots are continually appearing. A comparison of the size of swellings caused by the two dwarf mistletoes indicates that the endophytic system of larch mistletoe is more vigorous than hemlock mistletoe when both are parasitizing western larch (Fig. 1).

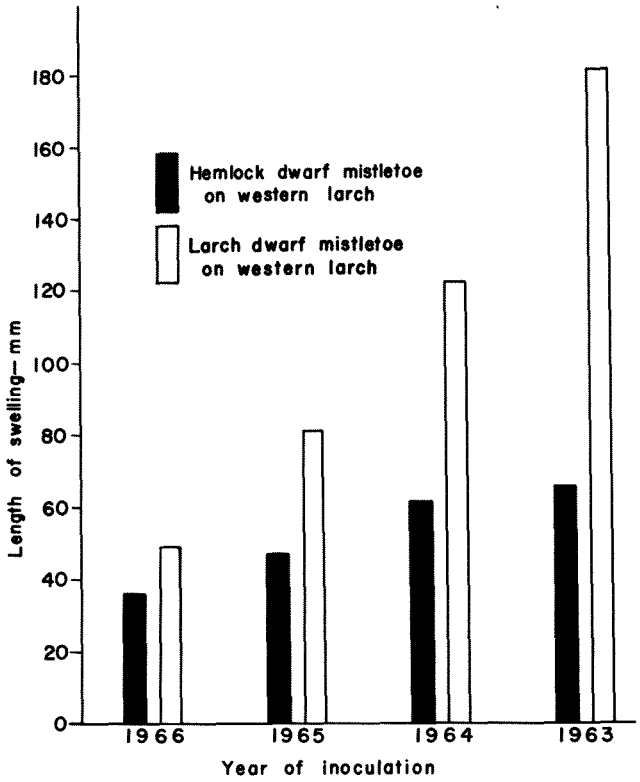


FIGURE 1. A comparison of the length of swellings on western larch caused by larch and hemlock dwarf mistletoes. Measurements were made 27 August 1969. Basis: 39 infections for each type.

No larch mistletoe infections were obtained on western hemlock.

Evidently, hemlock dwarf mistletoe can establish fairly readily on western larch. However, the slow growth it exhibits and the rarity of aerial shoot production shows that larch is a relatively incompatible host. Results also suggest that western hemlock is immune to larch mistletoe under artificial conditions, substantiating observations made in nature (Kuijt, Nat. Mus. Can. Bull. 186:134-148, 1963). These differences in the responses of western larch and western hemlock to larch and hemlock dwarf mistletoes, indicate that taxonomic separation of the two mistletoes, at least on a physiological basis, is justified.—R. B. Smith, Forest Research Laboratory, Victoria, B.C.

Butt Decay in Balsam Fir Defoliated by the Spruce Budworm.—The 1949-1959 outbreak of the spruce budworm [*Choristoneura fumiferana* (Clem.)] caused varying degrees of defoliation, top-killing, and tree mortality in dense stands of balsam fir [*Abies balsamea* (L.) Mill.] in northern New Brunswick (Baskerville, Forest. Chron. 36: 342-345, 1960). The surviving trees constitute the pulpwood forest of the future and the possibility of a high incidence of butt decay associated with the budworm stress is of vital interest. Rankin (Phytopathology 10: 314-315, 1920) and McCallum (Can. Dep. Agr. Bull. 104, 1928) reported no correlation between the amount of cull and previous budworm injury; however, Stillwell (Forest Sci. 2: 174-180, 1956) found a higher incidence of stem decay was commonly associated with buried leaders which had been killed by severe budworm defoliation. Similar information on the incidence of butt decay is lacking, although Redmond (Forest Sci. 4: 15-21, 1957) reported that the presence of butt decay could not be exclusively related to rootlet mortality resulting from budworm defoliation. However, existing infections may spread more quickly because of the reduction in tree growth and vigor.

In 1967, 368 trees greater than 4.5 inches dbh. were felled in two stands which had not been sprayed with insecticide during the 1949-1959 outbreak of spruce budworm: 191 trees were from the Kedgwick watershed in northwestern New Brunswick and 117 were from the Charlo watershed in north central New Brunswick. Both stands were released by the 1912-1920 outbreak and are predominantly balsam fir. The Kedgwick and Charlo stands were subjected to 9 and 7 years respectively of moderate to severe defoliation.

The volume of butt decay was determined for each tree. If no decay was visible in the stump, all main roots were cut about 1 foot from the root collar and examined. Decay fungi were cultured on 2% malt agar slants. A disk, marked on the north side, was taken from each tree about 2 feet from ground level and the dates and number of suppression rings were determined.

Of the isolation attempts on the two study areas, 54% yielded basidiomycetes. Six basidiomycetes were commonly isolated from both areas with nearly the same relative frequency (Table 1). Of the 122 basidiomycete isolates, 38% were *Scytinostroma galactina* which did not appear to be associated with any particular suppression group. *Armillaria mellea*, previously isolated with low frequency from balsam fir, constituted 30% of the isolates and was associated with trees of the higher suppression classes, conforming with the established pattern of *A. mellea* progressing rapidly in weakened trees (Boyce, Forest Pathology, McGraw Hill, 1961). *Coniophora puteana* comprised 22% of the isolates and was isolated with about equal frequency from all suppression classes.

TABLE 1

Frequency of isolation of basidiomycetes from butt decay in the Kedgwick and Charlo stands

Fungus	Kedgwick	Charlo
	Number of times isolated	
Scytinostroma galactina (Fr.) Donk	25	22
Armillaria mellea (Vahl ex Fr.) Kummer	21	15
Coniophora puteana (Schum. ex Fr.) Karst.	17	10
Odontia bicolor (Alb. & Schw. ex Fr.) Quel.	1	2
Polyporus balsameus Peck	2	2
Xeromphalina campanella (Batsch ex Fr.) Kuehn. & Maire	4	1
TOTAL	70	52
	122	

Radial growth of balsam fir is reduced 1 to 3 years after the first severe defoliation (Mott, Nairn, and Cook, Forest Sci. 3: 286-304, 1957). In the present study, all suppression rings initiated during the known period of the budworm infestation were assumed to be the result of defoliation. The few stems with more than seven suppression rings appeared to be suppressed by factors in addition to defoliation and were discarded.

The percentage of trees with butt decay in each suppression class is shown in Figure 1. Repression analysis of the data resulted in r^2 values of 0.67 and 0.79 for the Kedgwick and Charlo stands respectively, and the slopes of both regression lines were significant at the 5% level. Trees in the Charlo stand that suffered little or no suppression had an appreciably higher incidence of decay than trees of the same group in the Kedgwick stand. This suggests that factors in addition to budworm defoliation, such as site and stand history, are responsible for the overall higher incidence of decay in the Charlo stand.

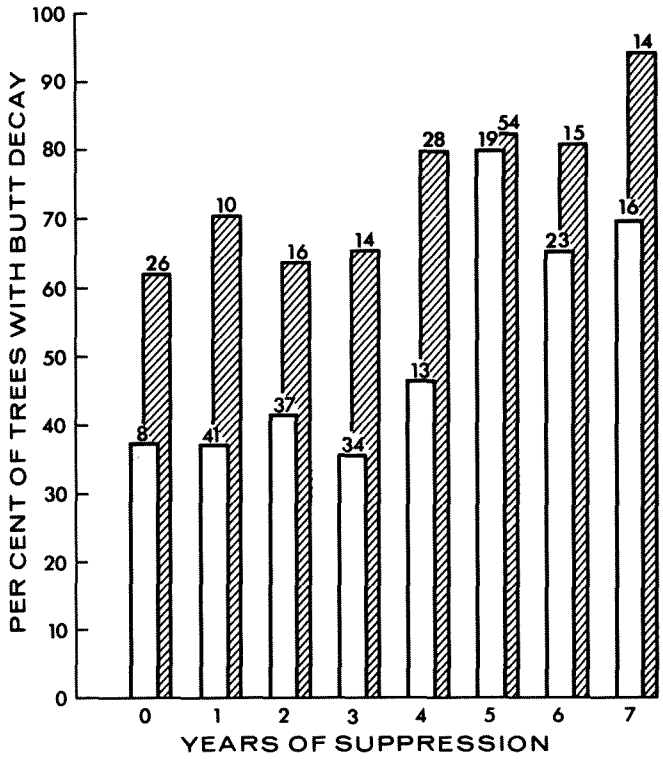


FIGURE 1. Percentage of trees containing butt decay in each suppression class. Numbers at top of bars indicate the total number of trees in each suppression class. Open – Kedgwick, hatched – Charlo.

The majority of the decay volumes were small and no relationship was apparent in either area between volume of decay and severity of suppression. Only 23% of the decayed trees from the Kedgwick stand had decay pockets more than 1 inch in diameter and only 27% of the decay pockets extended more than 6 inches above ground level. Decay volumes were somewhat higher in the Charlo stand where the values were 43 and 49%. As similarly defoliated trees age, however, they may contain higher volumes of butt decay which would tend to make them more susceptible to windthrow than trees that had not been defoliated. Consequently, this aspect of "budworm damage" should also be assessed so that a more precise prediction of the stands' future could be made.—T. E. Sterner, Forest Research Laboratory, Fredericton, N.B.

Pathogenicity of *Aleurodiscus amorphus*.—*Aleurodiscus amorphus* (Pers. ex Purt.) Schroet., a basidiomycete reported on Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco], true firs [*Abies* spp.], mountain hemlock [*Tsuga mertensiana* (Bong.) Carr.], Bishop pine [*Pinus muricata* D. Don], and spruces [*Picea* spp.] (Lemke, Can. J. Botany 42: 213-282, 1964), occurs in Quebec on balsam fir [*A. balsamea* (L.) Mill.]. In Quebec, the fungus is usually encountered on dead, lower branches of its host. Occasionally, it is also found on cankers of living branches of suppressed trees. *A. amorphus* has been associated with cankers of stems of lowland white fir [*A. grandis* Lindl.] and of branches of southern balsam fir [*A. fraseri* (Pursh) Poir.] in the United States by Hansbrough (Hansbrough, J. Forest. 32:452-458, 1934). Pathogenicity of the fungus, however, has not been demonstrated.

To investigate the pathogenicity of *A. amorphus*, a number of vigorously growing conifers were inoculated in 1968 in Quebec (Table 1). In addition, young, suppressed balsam fir in the understory of a coniferous stand in Laurentide Park were inoculated in 1966.

A total of 170 inoculations and 170 controls were made. An equal number of suppressed and vigorous balsam fir (20 trees each) were inoculated. All inoculations were done in the fall. The method of inoculation has previously been described (Smerlis, Can. J. Botany 47: 213-214, 1969). Two monospore isolates were used as inocula, one in 1966 and the other in 1968. Both isolates, grown on 3% malt agar at 15 C, originated from balsam fir. Inoculations on eastern white cedar, eastern hemlock, jack, lodgepole, red, Scots, and white pine, and Norway and red spruce were done on internodes of branches and stems ranging in age from 3 to 6 years. The other conifers were inoculated on leaders on 3-to-6-year-old internodes of branches or stems.

Results are presented in Table 1. *A. amorphus* was pathogenic on eastern hemlock, balsam fir, and the species of pines and spruces tested. Inoculations on eastern white cedar and the larches, trees on which *A. amorphus* has not been reported, were negative. The fungus was reisolated from all infected tree species although not from all infections. Controls were not infected. Infections on leaders of balsam fir caused either cankers or dying above the point of inoculation. Successful inoculations on internodes of branches and stems of balsam fir and the other tree species resulted in formation of cankers. The infections were more numerous and the cankers larger on vigorously growing balsam fir than on suppressed trees of the same species. The balsam fir, which were inoculated in 1968 but not sampled for the presence of *A. amorphus* in the spring of 1969 were reexamined in mid-July, 1969. Fruiting bodies of *A. amorphus* on the infections of these trees were not observed. The other tree species and also the balsam fir inoculated in 1966 were not reexamined after isolations had been made and presence or absence of fruiting bodies of *A. amorphus* was not established. E. Smerlis, Forest Research Laboratory, Ste. Foy, Quebec.

TABLE 1

Results of inoculations with *Aleurodiscus amorphus*.

Tree species	Inoculations				Controls	
	Total	Symptoms observed	Sampled	*A. amorphus* reisolated	Total	Symptoms observed
Abies balsamea (L.) Mill.[a,b] (balsam fir)	40	31	13	6	40	0
Larix decidua Mill.[c] (European larch)	10	0	0	0	10	0
L. laricina (Du Roi) K. Koch[a] (tamarack)	10	0	0	0	10	0
Picea abies (L.) Karst.[a] (Norway spruce)	10	7	3	1	10	0
P. glauca (Moench) Voss[a] (white spruce)	10	9	4	3	10	0
P. mariana (Mill.) BSP.[a] (black spruce)	10	7	3	2	10	0
P. rubens Sarg.[a] (red spruce)	10	8	3	1	10	0
Pinus banksiana Lamb.[a] (jack pine)	10	6	4	1	10	0
P. contorta Dougl.[a] (lodgepole pine)	10	4	3	1	10	0
P. resinosa Ait.[a] (red pine)	10	9	3	2	10	0
P. sylvestris L.[a] (Scots pine)	10	9	3	2	10	0
P. strobus L.[a] (white pine)	10	4	4	1	10	0
Thuja occidentalis L.[d] (eastern white cedar)	10	0	0	0	10	0
Tsuga canadensis (L.) Carr.[d] (eastern hemlock)	10	8	3	2	10	0

Locations: a = Valcartier; b = Laurentide Park; c = Saint-Etienne-de-Lauzon; d = Saint-Louis-de-Blandford.

SILVICULTURE

Effect of Scarification on a Non-regenerating Burn.—The ability of fire to create a suitable seedbed on upland black spruce [*Picea mariana* (Mill.) BSP.] sites is largely dependent upon moisture conditions at the time of burning. A dry-season fire will frequently consume most of the raw humus and leave only a thin layer of organic residue with some exposed mineral soil (Chrosciewicz, Forest. Br. Dep. Forest. Rural. Develop. Pub. No. 1181, 1967); this condition is favorable for the regeneration of spruce. A fire occurring during a period of low drought index often destroys only the surface litter leaving a thick layer of surface-charred humus which is detrimental to the establishment and survival of spruce seedlings. This latter condition results in poorer

seedbeds than before burning and accounts for some of the extensive areas of understocked spruce sites in Newfoundland.

An opportunity to test the effect of scarification to improve seedbed conditions on a non-regenerating burn was presented in August 1965 when a wildfire swept through a portion of 1964 cutover on the Gander watershed of central Newfoundland. The burn was located on moraine material, derived from fine granites, along the south side of the Northwest Gander River valley at an elevation of 300 ft A.M.S.L. The soil is a fresh sandy loam overlain by 3-5 inches of organic material which, prior to burning, supported a moss and ericaceous shrub vegetation. After cutting, in the absence of fire, this condition would not normally prohibit adequate spruce regeneration. However, the late season fire did not burn deeply and created a typical problem area.

Site treatment was applied in August 1966, 1 year after burning, using an SFI scarifier. This is a mechanical device, with scalping arms, which produce scalps at 6-ft. intervals (Wilton & Salter, Dep. Fish. Forest, Br. Info. Rep. N-X-32, 1969). These spaced scalps are patches, each about 2.5 square feet in size, on which the mineral and organic soils have been loosened and intermixed. The treatment was applied to an area of approximately 10 acres. Seeding to Sitka spruce [*Picea sitchensis* (Bong.) Carr.] was conducted on a portion of the area in November 1967; the remainder of the scarified section was left unseeded. Seeding consisted of depositing, by hand, 10 viable seeeds on or near a scarrified patch. The design permitted testing of all combinations of scarification and seeding treatments; in addition an adjoining unburned cutover block was used as a control.

The area was examined in the fall of 1969, approximately 2 years after establishment. Assessment was based upon examination of contiguous milacre quadrats in each of the treatment categories. It is obvious (Table 1) that the area would have regenerated adequately, after clearfelling, in the absence of fire. However, the table also indicates that scarification and seeding is required for successful regeneration of lightly burned cutovers.

Table 2 shows an analysis of seedling occurrence, on the scarified area, classified according to seedbed categories. This is based upon the detailed mapping of individual milacre quadrats. Relative seedbed receptivity, in Table 2, refers to the seedling numbers per unit area.

TABLE 1

Regeneration Results from Combinations of Treatments

Treatment	Samples (Milacre Quadrats)	Percent Quadrats Stocked	Average Seedlings Per Stocked Quad.
Burned, scarified, seeded	100	89	6.9
Burned, scarified, unseeded	100	14	1.1
Burned, unscarified, unseeded	50	16	1.2
Burned, unscarified, seeded	50	8	1.0
Unburned, unscarified, unseeded	50	52	6.0

TABLE 2

Seedling Frequency for Various Seedbed Media Occurring on a One-Acre Scarified and Seeded Block

Seedbed Type	Percent of Total Area	Number of Seedlings			Relative Seedbed Receptivity (Sitka Spruce)
		Sitka Spruce	Black Spruce	White Birch	
Mineral Soil	7.3	3010	—	1010	37
Mixed mineral and organic soil	4.1	2550	10	400	56
Charred organic material	85.7	530	—	480	1
Live mosses	1.1	10	—	80	1
Other	1.8	100	—	100	5

It is noteworthy that natural seedlings occur on these seedbeds in approximately the same ratio as seeded specimens. The study has demonstrated that a surface-charred thick organic layer does not constitute a good spruce seedbed and, in the absence of additional site treatments, such areas are likely to degenerate to open stands of hardwood species.—W. C. Wilton and E. Salter, Forest Research Laboratory, St. John's, Newfoundland.

(*Continued from page 11*)

relationship between cumulative percentage emergence and cumulative percentage degree-days for the 1968 data is shown in Fig. 1. Males and females emerged at the same relative rate in both years. Beetles emerged at a greater relative rate from the southern aspect of trees than from the northern aspect (Fig. 2A) possibly because subcortical temperatures are usually higher on the southern aspect (Powell, *loc. cit.*). Furthermore, the relative rate of emergence from the stem generally decreased with height from the ground (Fig. 2B). The rates of emergence in relation to aspect and height on the stem were about the same in both years. Beetles generally emerged at a faster rate from trees with large diameters than from trees with small diameters (Table 1).

The average pronotal width of females emerging in the first half of the emergence period was significantly greater (at the 5% level) than that of females emerging in the second half in 1968 and 1969 (Table 2). Although the average size of the males was also greater in the first half of the emergence period than in the other half in both years, the differences in these averages were not statistically significant.

These results suggest that the emergence pattern of the mountain pine beetle from lodgepole pine is related to host characteristics associated with height on the stem and tree diameter, in addition to subcortical temperatures before emergence.—L. Safranyik and R. Jahren, Forest Research Laboratory, Calgary, Alta.

(*Continued from back cover*)

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