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bi-monthly research notes

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PATHOLOGY

Lodgepole Pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) Shoot Abnormalities from Frost Injury.—Frost damage to phloem and buds can affect growth characteristics of new bud primordia (Zalasky, Bi-mon. Res. Notes 34:26-27, 1978) and subsequent development of shoots in lodgepole pine. The damage normally occurs when ground-level diurnal temperatures fluctuate drastically during prolonged dormancy, during May-June flushing, or during the ensuing development of new terminal buds. Undesirable phenophase shifts and adverse somatogenic changes follow. This paper describes new-dwarf-shoot abnormalities that arise from somatogenic damage to the phloem and buds of lodgepole pine seedlings.

Two groups of lodgepole pine seedlings were studied: one group was container-grown and field-outplanted in 1976; the other was container-grown and either field-outplanted or overwintered outside in 1977. The 1976 seedlings were reared in the greenhouse at 20° C and 20-h photoperiod for 16 wk and were then outplanted in Mayon lodgepole pine clear-cuts near Grande Prairie, Alta. The 1977 seedlings were reared under the same greenhouse conditions for 10 wk and in a growth chamber at 20° C and a 15-h photoperiod for 4 wk before being hardened for 2 wk at 6° C and 1 wk at 1.6° C without change in photoperiod. Some were then outplanted at the time on clear-cuts at Grande Prairie. Others were overwintered outside the greenhouse for various storage periods from September to April. After being moved to standard conditions in the greenhouse, the seedlings were transplanted and tested for frost damage and shoot rejuvenation. No comparisons were made between treatments, because the shoot abnormalities were similar for both groups.

Observations on microscopic deviations of new shoots in field-planted and overwintered seedlings were made over two or three growing seasons and one growing season, respectively. Similar observations were made on natural seedlings regenerated on the same clear-cuts in which the experimental seedlings were planted. Microscopic examination of the internal anatomical features was performed on macerated wood of new shoots obtained after growth had ceased (Zalasky, Bi-mon. Res. Notes 34:13-15, 1978).

Two types of abnormal short shoots were observed in the outplanted and overwintered containerized stock: clustered short shoots (Fig. 1) and sprouting short shoots (Figs. 2 and 3).

The clustered short shoots, with two to five fascicles (Fig. 1), developed on the stems of seedlings with frost-damaged phloem. Frost damage to the phloem during September-May triggered development of clustered short shoots from basal cluster primordia in the phloem. Each short shoot contained two needles (A in Fig. 1). Cluster primordia occurred after the spring flush either in axils of primary needles, where short shoots normally develop, or as outgrowths of needle internodes (A in Fig. 1). Each seedling had one to several outgrowths of clustered short shoots. In general, the seedlings were in good condition, and their terminal buds flushed to form normal leaders. Clustered short shoots usually increased the foliage density but did not form buds, unlike sprouting short shoots.

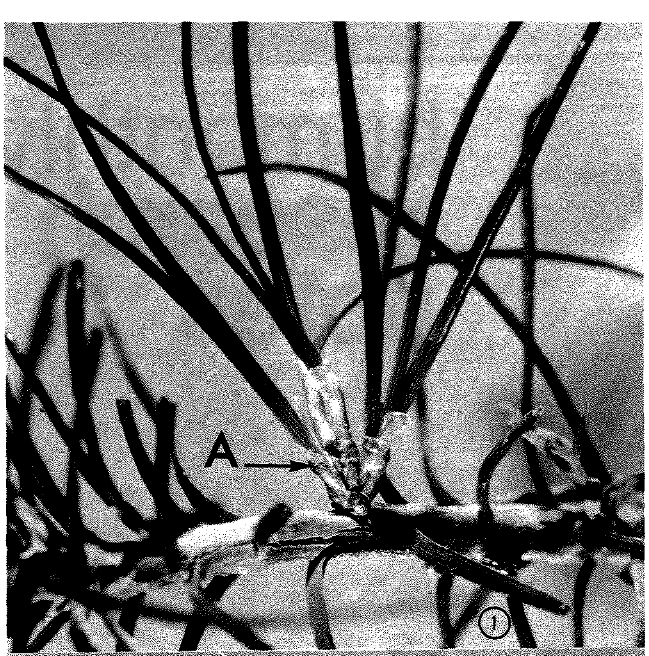

Figure 1. A seedling shows a cluster of five intercalary short shoots (A) developed from clustered primordia in the frost-injured phloem of a lodgepole pine overwintered in a container.

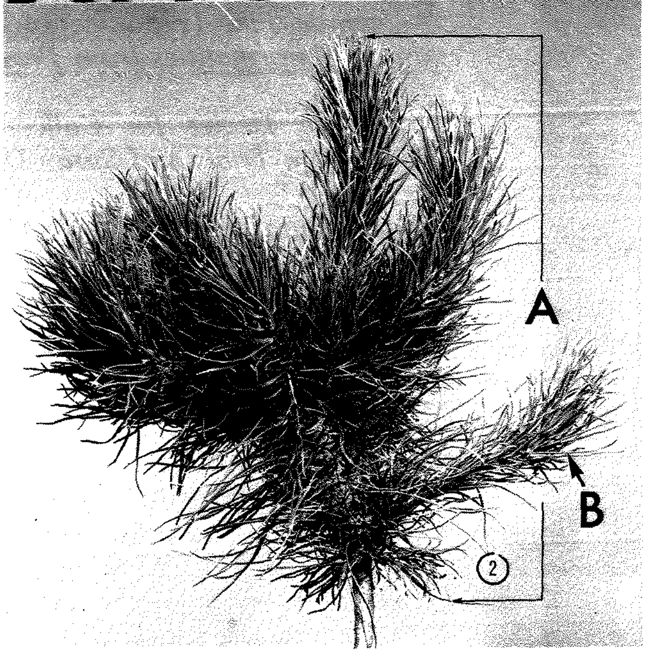

Figure 2. An outplanted lodgepole pine tree shows a bushy-growth habit (A) after all sprouting short shoots have either partly or fully developed into interfoliaceous shoots. A normal branch (B) developed before the seedling was frost injured.

The sprouting short shoots developed terminally from latent buds in the center of needle fascicles and resulted in interfoliaceous shoots (Figs. 2 and 3), which have been described by Morohin (For. Abstr. 17:194, 1956) as long shoots on short shoots. Such abnormal short shoots are recognized by their broad, flat, tapered needles in fascicles of two or three (A in Fig. 3) and by buds in various stages of dormancy. Smaller-than-normal interfoliaceous buds flushed either in the year of their production or in the following year. The abnormal shoots that developed from them resulted in two variations in crown form: the bushy (round) type and the flat-top type.

The bushy (round) crown form occurred in seedlings with a terminal bud killed entirely or partially during the winter months. The killing resulted in the production of a small number (mostly 1 to 12) of sprouting short shoots with interfoliaceous buds. These seedlings showed the most erratic shoot development, because frost damage to root and shoot tips resulted in delays in root and shoot regeneration. Such seedlings foliated sparely by producing new secondary needles developed in the axils of dead primary needles. Frost-damaged seedlings with only one or two living primordia and no living foliage from the previous year were weakest in development and survival. Very few interfoliaceous buds flushed in 1977: the majority overwintered anf flushed in 1978. Interfoliaceous buds on upper short shoots developed earlier than those on lower short shoots and produced candles (competing shoots) with primary and secondary needles or with secondary needles only. The affected seedling lost its natural symmetry and became bushy and multiwhorled from an overabundance of short horizontal lateral shoots, 65 of them counted on one stem measuring 8.5 cm (A in Fig. 2). Shoots were spindly, and only a few developed mature wood in basal parts (B in Fig. 3). Immature shoots were killed by frost in September.

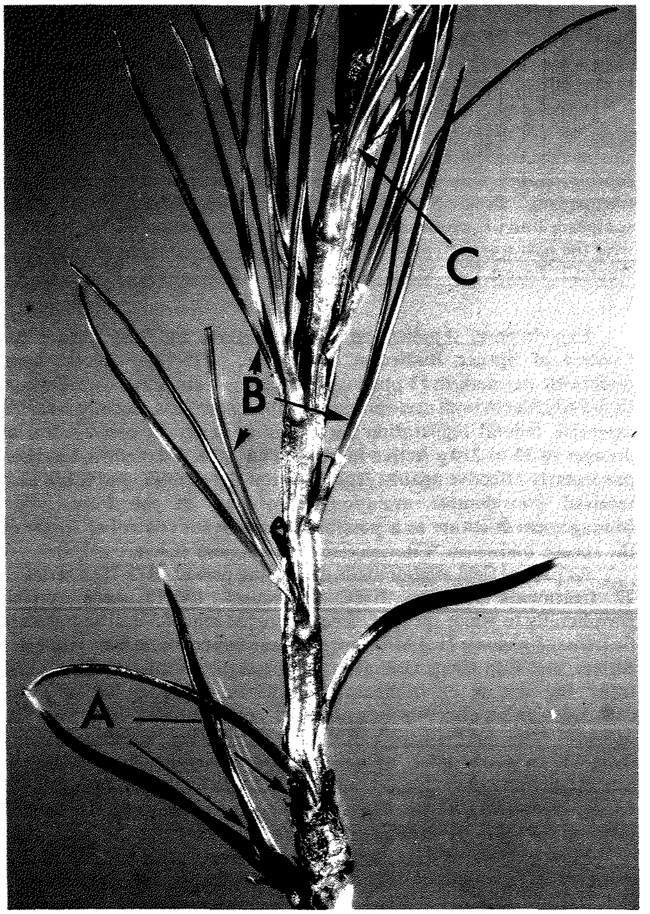

Figure 3. Two sprouting short shoots: (A) one has a bud and one has develope into a two-cycle interfoliaceous shoot; (B) the first-cycle portion shows two- and three-needle short shoots: (C) the second-cycle shoot starts with needles only half as long as those in B, the first-cycle portion.

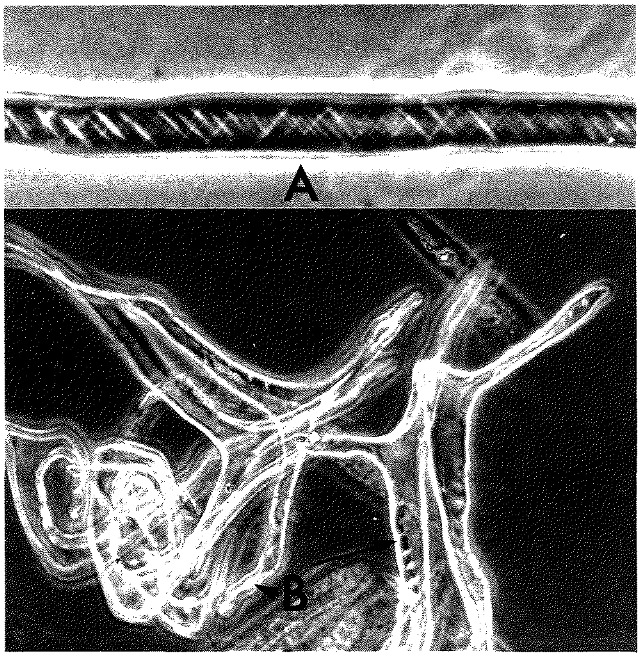

Figure 4. Summerwood tracheids from one of the interfoliaceous short shoots with (A) spiral thickenings in the tracheid and (B) branched, curvate tracheids.

In the second variation, a limby, flat-topped seedling with basket-whorled branches was produced. Occasionally healthy, undamaged seedlings flushed normally in the spring and produced vigorous first-cycle leading shoots. Low June temperatures often triggered primordia of new leading shoots to flush and produce up to 25 sprouting short shoots with active interfoliaceous primordia and broad, thick secondary needles. These active interfoliaceous primordia developed into buds that flushed immediately or throughout the season until September. Buds enlarged about to the size of a normal bud flushed and produced mostly two-cycle shoots during July-August; a few buds showed even a third partial flush in September-October. Some buds remained dormant (A in Fig. 3)and flushed throughout the next season. Normally buds flush only during May and June in the second season of development. Two changes occurred during abnormal flushing: an additional internode appeared between the unflushed bud and the short shoot, and the interfascicular internodes that followed flushing were abnormally elongated, measuring up to 2 cm.

Interfoliaceous shoots had an immature green periderm, well-spaced scales, and short shoots with two- and three-needle fascicles in their basal parts (first flush) as in B of Fig. 3. The late second flush formed short, tufted shoots with needles half as long as those in the first flush (B and C in Fig. 3). The longest shoots terminating with a bud in August were spindly to vigorous, often needleless in the lower half, and measured 20 cm. Affected seedlings with basket-whorled branches were limby and flat-topped, but height growth was not retarded as it was in the bushy variation.

The tracheids of spindly interfoliaceous shoots were immature; summerwood tracheids were long, slender, and straight, with or without spiral thickenings (A in Fig. 4). A few tracheids from brashy (short-grained) wood were curvate and branched (B in Fig. 4). Tracheid anomalies of frost-affected seedlings are similar to those in frost-affected juvenile trees and in mature timber (Zalasky, Can. J. Bot. 53:1888-1898, 1975) where trees have been affected by frost throughout the life of the stand.

Frost-damaged trees have an abnormal phenology of shoot development (Zalasky, Can. J. Bot. 34(4):26-27, 1978), slower height increment and crown closure, and increased risk of mortality from subsequent frost injury to late-maturing shoots (Ruden, For. Abstr. 23:227, 1962). The total fiber and timber yield are reduced because of a brashy wood and a greater number of large limbs. Because of growth retardation, which persists for 5 to 6 yr, bushy trees are subject to culls (Kienholtz, J. For. 31:392-399, 1933). Interfoliaceous shoots from flat-topped trees should not be used for scions, because tissues of this wood tend to grow into cone-shaped nodules and do not serve effectively as vascular tissues in graft unions (Zalasky, Can. J. Plant Sci. 56:501-504, 1976).—H. Zalasky, Northern Forest Research Centre, Edmonton, Alta.

ENTOMOLOGY

A Simple Device for Collecting Aerial-spray Deposits from Calibration Trials and Spray Operations. — The reliability of a field sampling system for the collection and retention of aerial spray droplets depends to a large extent upon the efficiency and ease of handling of the collecting units under a variety of field conditions as well as the choice of the site and surface for the units. The classical collection surface for spray deposits is a flat plate or card placed on a horizontal surface at ground level that is devoid of vegetation and open to all quadrants of the sky. The efficiency of the unit is directly related to the terminal velocity of the spray droplets, the horizontal air movement over the card surface, the vertical profile of the plate, and the total time of exposure.

Since 1949, many types of samplers have been used in detecting the larger spray droplets on small aerial-spray projects, but most of these units proved to be too cumbersome, too time-consuming, and too inaccurate as the droplets became smaller and the spray projects became larger (Stewart, Ont. Dep. Lands Forests Biol. Bull. 2, 1949; Hurtig et al, DRB Suffield Rep. 176, 1953).

The introduction of the converted DC-7b spray aircraft (Randall and Zylstra, Forest Pest Manage. Inst. Inf. Rep. CC-X-23, 1972) and the appearance of large-scale operational spruce budworm *Choristoneura fumiferana* (Clem.) control programs in Quebec necessitated the need for a simple, efficient, yet reliable collecting unit for spray deposit detetection and assessment. To meet these requirements a lightweight unit consisting of two 10.5 cm x 10.5 cm aluminum plates 0.83 mm (22-gauge RSM) thick, hinged together with bookbinding tape, was developed. On one inner surface a 10 cm x 10 cm Kromekote® card (Kruger Paper Co., Montreal) is held in place by means of two no. 32 elastic bands placed 1 cm in along opposite edges of the plate. The Kromekote® card is used to determine spray deposit density and drop size.

On the inner surface of the opposite plate are two 50 mm x 75 mm glass microscope slides hinged together with Sellotape (Dickenson/Robinson Co. Ltd., Toronto) so that the unit can be closed after spray application to protect the deposit. The tape can also be used to code-mark the sample.

Each microscope slide has three small drops of silicone sealer placed along one edge so that, when the hinged slides are closed, the drops act as separators to prevent contact of the surfaces.

The slides are fastened to the aluminum unit near the outer edge of the plate by means of a 0.5 cm x 0.5 cm piece of double-sided carpet tape; the top slide is thus allowed to open freely towards the hinged center of the unit. The glass slide can be quickly closed by a light flip, and the complete unit folded as a book to provide a compact 10.5 cm x 10.5 cm package approximately 0.5 cm thick (Fig. 1).

For the calibration of aerial-spray equipment these units can be placed directly on the flat surface of paved roads or airport runways, where vegetation cannot interrupt the flow of the spray cloud across the sampling layout. For field use, however, a horizontal platform mounted on an aluminum stake has been designed to elevate the unit above the ground surface.

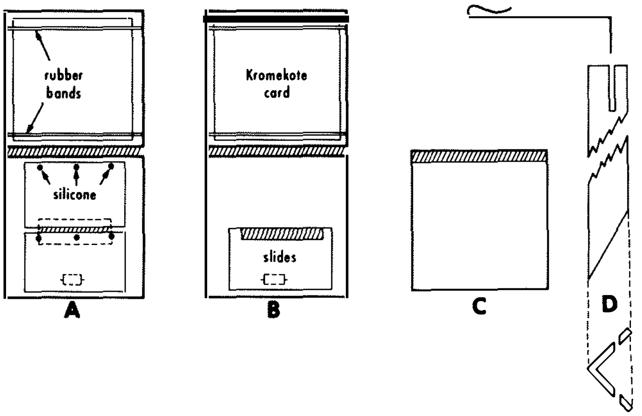

Figure 1. Spray-deposit sampling unit: (A) unit fully open; (B) unit open with glass slides closed; (C) unit closed for storage; (D) horizontal platform and stake.

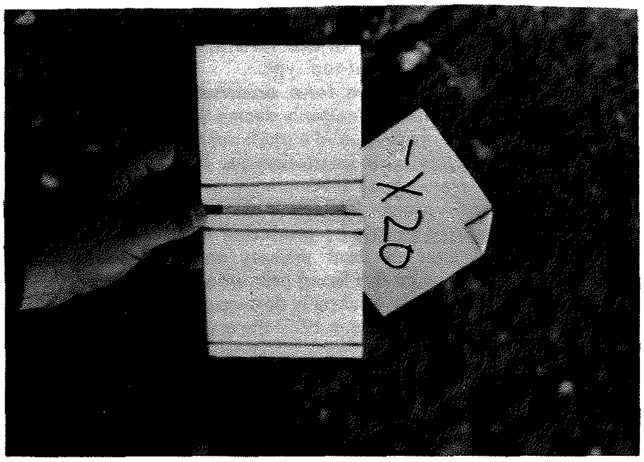

Figure 2. Field use of the sampling unit. In this case the unit is holding two Kromekote® cards.

The stake is a 30cm length of 2.5cm aluminum angle stock sharpened at one end to a 45° angle. The top flat end has a 1 mm slot cut across the corner to accept the platform attachment (Fig. 1).

The platform is a 10.5 cm x 10.5 cm x 0.82 mm (22-gauge ASM) aluminum plate with 2 cm of the opposite corners bent in opposite directions at 90° and 180° respectively to the flat surface. The 90° corner is inserted in the slot on the stake while the 180° corner acts as a spring clip to hold the open collecting unit in place (Fig. 2).

Experimental assessment of the reliability of various horizontal units such as aluminum pie plates, petri dishes, and the new units have shown that the flat plate design of the new units provides the highest reproducibility with the lowest variation between adjacent samples (Armstrong, Proc. 5th IAAC Warwickshire, Engl., 1975). These sampling units have been accepted and used successfully in the field over the past 6 yr at a considerable saving in cost and manpower.—A.P. Randall, Forest Pest Management Institute, Sault Ste. Marie, Ont.

Experimental Applications of Permethrin by Mist Blower for Control of Spruce Budworm in Quebec, 1975-78.—The synthetic insecticide permethrin [3-phenoxybenzyl (+) — cis, trans — 2, 2-dimethyl-3-(dichlorovinyl) cyclopropane carboxylate] has recently received extensive federal registration for use in agricultural pest control at dosages of 35 to 210 g Active Ingredient (AI)/ha. Permethrin has been particularly effective against lepidopterous defoliators, and it has also received considerable attention from staff of the Forest Pest Management Institute as a possible treatment for control of larvae of the spruce budworm, *Choristoneura fumiferana* (Clem.)

As part of field studies made during the period 1975-78, a series of 27 treatments with an FMC Rotomist® 100HT were applied peripherally to white spruce (*Picea glauca* [Moench] Voss) and balsam fir (*Abies balsamea* [L.] Mill.) forests near Grand'Mère, Ste. Anne des Monts, and Cap Chat, Que. (Fig. 1). Access was along roadways and trails, the size of experimental blocks ranging from 0.4 to 2.5 ha calculated on an effective spray-droplet penetration of 20 m from the nozzles. After preliminary calibration with water, volumes varying from 130 to nearly 200 L/ha were applied to target trees according to tree height and crown density. Selected dosages evaluated were 7, 9, 12, 18, 24, 35, and 70 g AI/ha. Chevron® spray sticker was mixed with each batch at 0.0125% by volume as the only adjuvant.

Most treatments were applied when larvae were mainly third (L_3) and fourth (L_4) instars at that part of the feeding period when defoliation was still minimal and larvae were somewhat exposed. Population densities on both hosts prior to treatment varied considerably but usually ranged from 20 to 60 larvae per 45 cm midcrown branch-tip sample. Applications were made systematically under wind speeds of less than 10 km/h to permit optimum vertical spray coverage and

TABLE I
Summary of results of applications of permethrin by mist blower for control of L_3-L_5 larvae of the spruce budworm on white spruce and balsam fir in Quebec, 1975-78

Treatment formulation	Dosage (g AI/ha)	Number replicates	Host species	Average number larvae/ 45 cm branch Pre-spray	1-5 days post-spray	6-15 days post-spray	Corrected percent population reduction[1]	Percent defoliation[2]
NRDC 143	7	3	wS	44	10	15	59	35
NRDC 143	9	2	wS	9	8	4	43	12
FMC 33297	12	2	wS	46	12	7	82	7
NRDC 143	18	5	wS	27	10	11	57	24
FMC 33297	18	1	wS	13	1	1	89	—
Average	18	—	wS	21	6	6	65	24
FMC 33297	24	1	wS	58	8	2	96	10
NRDC 143	35	7	wS	29	5	1	97	7
NDRC 143	35	1	bF	58	10	6	84	21
FMC 33297	35	1	wS	15	3	3	80	—
Average	35	—	wS, bF	31	8	3	91	11
NRDC 143	70	2	wS	56	3	2	95	7
NRDC 143	70	1	bF	56	6	5	85	14
FMC 33297	70	1	wS	7	1	1	87	—
Average	70	—	wS, bF	55	5	3	92	10
Untreated check	—	3	wS	29	31	26	—	63
Untreated check	—	1	bF	63	43	38	—	85
Average	—	—	wS, bF	37	35	30	—	71

[1] Corrected by Abbot's formula (1925); based on the number of living prespray larvae vs. final postspray.

[2] After Fettes (1951).

Figure 1. Application of permethrin by FMC Rotomist® 100HT for the control of spruce budworm on white spruce near Grand'Mère, Que.

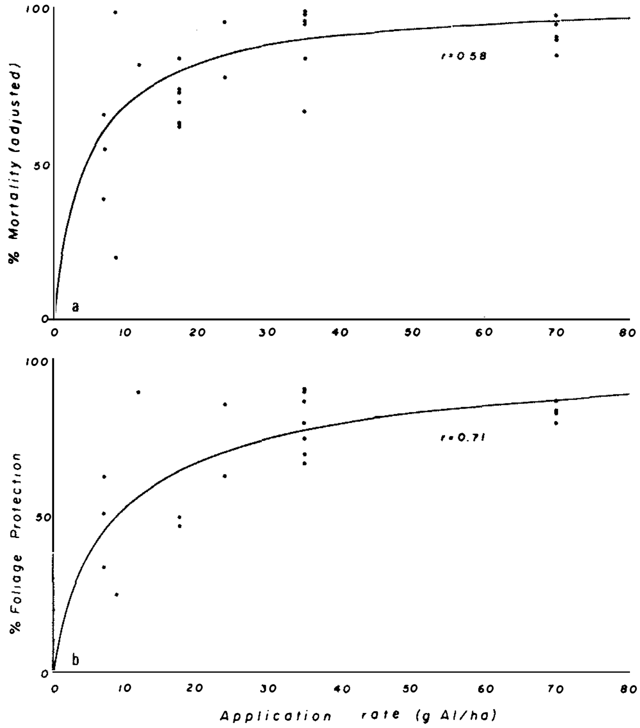

Figure 2. Trends in larval mortality(a) and foliage protection(b) after mist-blower applications of permethrin to white spruce and balsam fir in Quebec in 1975-78, timed at or near peak occurrence of L_4 larvae. (The curves were derived by fitting linear regression to probit transformation of percentages vs. logarithmic transformation of dosages. Credit: Aubrey Moore, FPMI.)

penetration. Larval populations were sampled once before each treatment and twice afterwards; averages were obtained from a minimum of 20 midcrown branch samples per collection per spray block. Abbott's formula (Abbott, J. Econ. Entomol. 18:265-267, 1925) was used to determine the effects of treatments on population density; defoliation estimates were based on the Fettes method (Ph.D. Thesis, Univ. Toronto, 1951), and 20 randomly selected but representative branch samples were used per treatment block.

Assessment of results indicated that very low dosages of permethrin, applied as dilute emulsions by mist blower, were extremely effective in reducing population densities of L_3-L_5 larvae of the spruce budworm (Table 1). As well, the carefully timed and applied treatments of from 18 to 35 g AI/ha provided excellent levels of foliage protection. On-site observations in several of the sprayed blocks indicated that most surviving larvae were on trees or portions of trees screened from spray penetration and contact. A partial second application, accompanied by special attention to trees harboring significant residual populations (e.g. 10 or more L_4/branch sample) and timed to within a few days after the first, would have provided better results in these few instances.

In summary, the results of the experimental mist-blower applications for control of L_3-L_5 larvae of the spruce budworm indicated (1) that compared with a variety of other insecticides similarly applied (DeBoo and Campbell, Can. For. Serv. Rep. CC-X-21, 1972; CC-X-59, 1974; CC-X-88, 1974) and equivalent dosages of AI, permethrin was one of the most effective insecticides evaluated to date; (2) that assessments of larval mortality and foliage protection led to the conclusion that not more than 35 g AI/ha would be required for effective control of serious infestations of the spruce budworm (Fig. 2); (3) that under conditions of inadequate coverage occasionally experienced during this study, and possibly also in situations of extreme hazard (i.e. with a very low shoot-to-larva ratio and/or late timing of sprays), applications to 70 g AI/ha may be required to give acceptable levels of foliage protection.—R.F. DeBoo, Forest Pest Management Institute, Sault Ste. Marie, Ont.

Mating of Caged Spruce Budworm Moths in Forests Treated with a Conrel® Hollow-fiber Pheromone Formulation.—Before the 1978 flight season of the spruce budworm, *Choristoneura fumiferana* (Clem.), four 100 ha blocks of fir-spruce forest near St. Quentin, N.B., and another four near Amherst, N.S., were treated with a Contrel® hollow-fiber pheromone formulation consisting of 24-31 mg of 94:6 (trans:cis) 11-tetradecanals and 10 mg of the antioxidant di-*tert*-butycresol per gram of fiber in hexane. The formulation was applied by aircraft, at four rates, during 16-22 June (i.e. about 9 days before first female emergence) at St. Quentin and between 24 June and 3 July (i.e. about 5 days before first female emergence) at Amherst. Different concentrations of fibers were applied to the 100 ha blocks to give expected pheromone release rates of 0.1, 1.0, 10, 13, and 20 mg/ha per h.

Virgin male and virgin female moths, collected as pupae from an earlier phenological zone, placed in 61 x 61 cm cylindrical screened cages containing balsam fir foliage, *Abies balsamea* (L.) Mill., and elevated to the midcrown level of the forest, were used to determine if the pheromone formulation would affect mating. Mating status was determined by removing females from the cages and dissecting them for the presence or absence of spermatophores in the bursa copulatrix. Three experiments were conducted.

In the first experiment, conducted at St. Quentin and Amherst, one female and three males were combined in cages for 48 h, except that during 21-26 June at St. Quentin the moths were removed from the cages after 24 h. The percent mating and the mating reduction relative to the control are shown in Table 1 for both the early season and the entire season. With the exception of the block in each area that released pheromone at the highest rate, none of the blocks consistently reduced mating in relation to the control either in the early season or over the whole season. Moreeover, the reduction in mating in the highest release blocks was not statistically different from that of the control.

In the second experiment, conducted at St. Quentin, 10 males were placed in each cage on day 1 and 10 females were added on day 2. All moths were removed from the cages 72 h later. The results are shown in Table 2. Mating was slightly reduced at a release rate of 10 mg/ha per h and greatly reduced during the initial part of the season in the 20 mg/ha per h block.

TABLE 1
Percent mating reduction in 48 h: 1 female + 3 males per cage

St. Quentin

Projected pheromone emission rate (mg/ha per h)	% females mated (n) 21-29 June	% mating reduction^{a}	% females mated (n) 21 June - 18 July	% mating reduction^{a}
Control	59 (29)	—	51 (74)	—
0.1	58 (19)	2	44 (45)	14
1	86 (14)	- 46	68 (37)	-33
10	83 (12)	- 41	61 (38)	-20
20	42 (12)	29	46 (35)	10

Amherst

Projected pheromone emission rate (mg/ha per h)	% females mated (n) 1-7 July	% mating reduction^{a}	% females mated (n) 1-19 July	% mating reduction^{a}
Control	67 (30)	—	63 (95)	—
0.1	67 (18)	0	67 (54)	- 6
1	67 (18)	0	74 (53)	-17
10	56 (18)	16	55 (49)	13
13	47 (17)	30	51 (45)	19

n = sample size, or number of females examined.

$^{a}\%\ \text{reduction} = \frac{\%\ \text{control} - \%\ \text{treatment}}{\%\ \text{control}} \times 100$; no reduction significant at the 0.05 level on the basis of the X^2 test.

TABLE 2
Percent mating reduction in 72 h: 10 females + 10 males per cage

St. Quentin

Projected pheromone emission rate (mg/ha per h)	% females mated (n) 20-26 June	% mating reduction^{a}	% females mated (n) 20 June - 2 July	% mating reduction^{a}
Control	73 (37)	—	69 (125)	—
0.1	58 (40)	21	73 (127)	-6
1	82 (38)	-12	76 (127)	-10
10	56 (39)	23	54 (126)	22*
20	29 (38)	60**	56 (124)	19

n = sample size, or number of females examined.

$^{a}\%\ \text{reduction} = \frac{\%\ \text{control} - \%\ \text{treatment}}{\%\ \text{control}} \times 100$.

*Significant at the 0.05 level.
**Significant at the 0.01 level on the basis of the X^2 test.

TABLE 3
Percent mating reduction of caged females in 72 h: effect of moth density on mating (St. Quentin)

Moths/cage	% females mated (n) Control	% females mated (n) 20 mg/ha per h	% mating reduction^{a}
1 pair	67 (27)	48 (25)	28
3 pairs	67 (58)	54 (57)	19
10 pairs	69 (125)	56 (124)	19
30 males + 10 females	96 (49)	77 (49)	20*

n = sample size, or number of females mated.

$^{a}\%\ \text{reduction} = \frac{\%\ \text{control} - \%\ \text{treatment}}{\%\ \text{control}} \times 100$.

*Significant at the 0.05 level on the basis of the X^2 test.

In the third experiment, the effect of four moth densities (1 pair, 3 pairs, 10 pairs, and 30 males + 10 females/cage) on mating was tested in the 20 mg/ha per h block in St. Quentin. From the results (Table 3) it is apparent that a reduction in mating occurred, but the reduction was small at all densities.

We wish to emphasize that these experiments tested only one pheromone formulation and thus cannot be used to test the broader question of whether or not the pheromone can reduce mating. The formulation apparently behaved aberrantly and released most of the pheromone before the main period of the flight season (C. Wiesner and P. Silk, pers. comm., and R. Turle and B. Lynch, pers. comm.). The unusual release rate of pheromone from the formulation appears to be reflected in the data: only at the highest release rates, and especially during the early part of the flight season, was a consistent reduction in mating observed.

In summary, the particular hollow-fiber formulation applied to the forest produced only a minor reduction in mating at the highest dosages and appeared to reduce mating slightly, but about equally, over a range of population densities. We conclude that, until problems with release rates from pheromone formulations are eliminated, tests of the efficacy of pheromone in reducing the mating of spruce budworms in the forest situation should not take place.—J.O. Schmidt, Entomology Department, University of Georgia, Athens, Ga.; A.W. Thomas, Maritimes Forest Research Centre, Fredericton, N.B.; and W.D. Seabrook, Biology Department, University of New Brunswick, Fredericton, N.B.

ERRATUM

On page 15, column 2, line 7, of vol. 36, no. 4 (July-August 1980), 15-yr should read 5-yr.

RECENT PUBLICATIONS— SEPTEMBER-OCTOBER 1980

7 **Bloomberg, W.J., R.B. Smith, and A. Van Der Wereld. 1980.** A model of spread and intensification of dwarf mistletoe infection in young western hemlock stands. Can. J. Forest Res. 10:42-52.

7 **Funk, A. 1980.** A description of *Verrucaria plumbaria* on Douglas-fir. Mycologia 72(2):422-425.

6 **Golding, Douglas L. 1980.** Research results from Marmot Creek experimental watershed, Alberta, Canada. Pages 397-404 *in* Proc., Symposium on the results of research on representative and experimental basins. Wellington (N.Z.), Dec. 1970. Ceutrick Printers, Louvain, Belg.

9 **Krywienczyk, Janina, Shozo Takai, and Barbara A. Mathieson. 1979.** Cerato-ulmin, a wilting toxin of *Ceratocystis ulmi*: development of antiserum against the toxin. Ann. Phytopathol. Soc. Jap. 45:745-747.

1 **Mukammal, E.I. 1971.** Some aspects of radiant energy in a pine forest. Arch. Meteorol. Geophys. Bioklimatol., Ser. B, 19:29-52.

4 **Ouellete, G.B. 1980.** Occurrence of tyloses and their ultrastructural differentiation from similarly configured structures in American elm infected by *Ceratocystis ulmi.* Can. J. Bot. 58:1056-1073.

2 **Robertson, Alexander. 1980.** A new species of Carex § Extensae. Rhodora 82(830):369-374.

2 **Sidhu, S.S. 1980.** Patterns of fluoride accumulation in boreal forest species under perennial exposure to emissions from a phosphorus plant. Atmos. Pollut. 8:425-432.

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