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Incidence of Nosema fumiferanae *in spruce budworm,* Choristoneura fumiferana *in the year following application*

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PATHOLOGY

Progression of Fluoride Damage to Vegetation from 1973 to 1975 in the Vicinity of a Phosphorus Plant.—Since the initial assessment of the fluoride damage to forest vegetation in Long Harbour, Newfoundland by Sidhu and Roberts (Can. For. Ser. Bi-mon. Res. Notes, 31:41-42, 1975), there have been significant changes in both the extent and intensity of damage. This research note presents an account of the changes in area having visible damage symptoms to the dominant tree canopy, and changes in both total fluoride concentrations in foliage and available fluoride in the soil humus since 1973.

Ground surveys were made during the fall of 1974 and 1975 to check the limits of the damage area and damage zones as identified in 1973 (Sidhu and Roberts 1975). Twenty transects were established so that each transect traversed all the damage zones. Percent mortality and fluoride damage symptoms in tree species were recorded beyond 1973 boundaries until no change in the damage class was detected for 500 metres along the transect. The existing boundaries of the zones were then established based on the dominant damage class within the damage area (Fig. 1), e.g., damage in Zone I is of class-1 predominantly, in Zone II of class-2, in Zone III of class-3 and in Zone IV of damage class-4.

The criteria for establishing the limits of damage classes are described in Table 1. Ten trees at each sample location were checked for percent tree mortality, percent defoliation and fluoride damage symptoms using procedures established in the 1973 survey (Sidhu and Roberts 1975). The revised limits of the damage zones were plotted on 1:50,000 topographic maps and the area within each damage zone was determined using a dot-grid.

The foliage and soil-humus samples were collected and analysed using 1973 techniques (Sidhu and Roberts 1975). Total

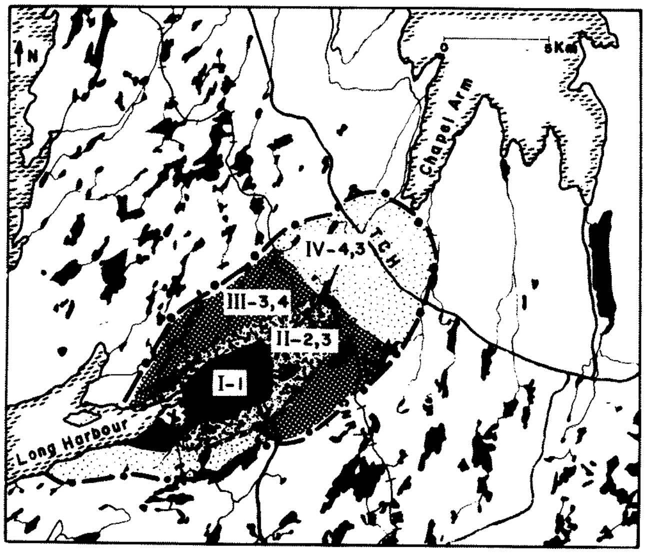

Figure 1. Fluoride damage zones in the Long Harbour area. The (X) indicates the location of the source. Roman numerals are the damage zones and Arabic numerals indicate the damage classes in order of their dominance. Black areas outside of Zone I are fresh water.

fluoride in foliage and available fluoride in soil-humus were determined. The results are given in Table 1.

Since the fall of 1973, there has been a significant increase in both the extent and intensity of the damage in the Long Harbour area. The post-1973 damage occurred during 1974 with an increase of 48% in the total damage area, from 7 721 ha to 11 434 ha (Table 1, Fig. 1). Most of the new damage area was added onto the 1973 southern limits of the damage Zone IV. However, due to increase in the degree of damage, the revised boundaries of the zones of intense damage were extended into the 1973 zones of lighter damage. Approximately 2 104 ha previously (1973) included in Zone IV are now classified as damage Zone III, 1 236 ha of Zone III as Zone II and 1 131 ha of Zone II were reclassified as Zone I. The damage classes which form the basis of the delineation of the damage area into damage zones, is based on the percent mortality of the dominant trees and the fluoride damage symptoms on the foliage of balsam fir, black spruce and larch.

The 1974 increase in the extent of the damage area was related to the 75% increase in total plant emissions over 1973 and by a 25% increase in the number of emergency stack openings in 1974 (ERCO, personal communication). The exact figures on fluoride emissions for 1973 and 1974 are confidential to the industry. However, estimated values for 1972 (146 tons/yr) were published by the Air Pollution Control Directorate (Environ. Can., EPS, Air Poll. Dir., Intern. Rep. APCD 75-7, Jan. 1976). The emergency stack opening usually results in temporary exposure of vegetation in the vicinity of the plant to high concentrations of fluoride in the air.

The total fluoride concentrations in 1974 foliage samples of balsam fir were similar to 1973 levels (Table 1). The differences were not significant ($P > 0.10$). Except for samples from Zone IV and control plots, the available fluoride in soil-humus were significantly ($P < 0.01$) lower in 1974 than in 1973. Data analysis revealed that the same intensity of damage to foliage occurred in 1974 as in 1973, yet the 1974 foliage had only about one-third the

TABLE I

Fluoride in foliage of balsam fir and soil humus and area affected from 1973 to 1975 in four damage zones near a phosphorus plant, Long Harbour.

Damage zone	Predominant damage class and observed damage age to dominant trees	Total fluoride concentration in foliage (F, ppm/dry wt.) 1973[a] Growth average (± S)	1974[b] Growth average (± S)	1975[c] Growth average (± S)	Available fluoride in soil humus (F, ppm/dry wt.) 1973[a] average (± S)	1974[b] average (± S)	1975[c] average (± S)	Total area affected (ha) 1973	1974	1975
I	1. 80-95% trees dead; severe to complete defoliation	281 ± 219.8	237 ± 75.5	9.9 ± 2.1	58.0 ± 9.4	24.2 ± 8.3	8.1 ± 4.6	610	1 741	1 741
II	2. 40-60% trees dead; severe to complete defoliation on windward side, tip burn all through the crown	141 ± 44.2	149 ± 68.5	6.1 ± 0.4	27.0 ± 27.5	10.5 ± 5.2	7.8 ± 4.9	2 175	2 380	2 380
III	3. 20-30% trees dead; partial defoliation on windward side; severe tip burn on windward side, light or no tip burn on leeward side or sheltered windward side	91 ± 34.0	75 ± 22.5	5.7 ± 0.3	15.0 ± 6.1	5.6 ± 2.0	3.6 ± 1.3	2 802	3 570	3 570
IV	4. No dead trees; little or no defoliation; light tip burn on the needles in the top crown, mostly on windward side	44 ± 15.6	36 ± 14.0	5.7 ± 1.3	3.8 ± 1.6	2.8 ± 1.1	2.1 ± 0.5	2 134	3 743	3 743
Control	5. No damage	7 ± 2.5	6.1 ± 2.0	6.0 ± 1.3	2.4 ± 0.4	2.1 ± 0.2	2.0 ± 0.5	-	-	-

[a]Sidhu and Roberts (1975) [b]June 1975 sample [c]September 1975 sample

accumulated levels of fluoride found in 1973. For example, 100% of balsam fir needles showed browning to 50% of their length at an accumulation level of 100 ppm in 1974 whereas in 1973 this degree of damage first occurred at accumulation levels of 280 ppm. As a result, the 1974 leaf litter contributed significantly lower levels of fluoride to the humus in 1974 and possibly a greater quantity of available fluorides were leached than that added through leaf litter to the soil-humus.

No adverse effects of emissions were recorded during the 1975 growing season (Sidhu, Can. For. Ser., Bi-mon. Res. Notes 32:16-17, 1976). In fact, there was improved growth in all the damage zones due to the absence of fluoride emission from June to November 1975 (Sidhu 1976). Correspondingly, fluoride concentrations in foliage and humus samples from damage areas did not differ significantly from controls ($P > 0.10$).

The fluoride levels in all (except controls) 1975 foliage samples were significantly ($P < 0.01$) lower than in 1973 and 1974 samples. All 1975 soil humus samples (except from Zone II and controls) had significantly ($P < 0.05$) lower fluoride concentrations than in 1973 samples but such differences (except Zone I) were not significant (> 0.10) between 1975 and 1974 humus samples. The data in Table 1 indicates that 66% of the available fluorides in 1974 humus samples from Zone I was leached during 1975. This percentage was 26, 38, 25 and 5 for Zone II, III, IV and controls respectively.

The surveys during 1973-75 indicate that for every 3% increase in fluoride emissions in 1974 over 1973 resulted in 2% increase in the extent of the damage area. The boundaries of the damage area may show little increase in future if emission levels remain below the 1974 levels. The possibility of accelerating the damage through emergency stack openings is reduced because the industry has already modified their system to minimize direct release of hot gases to the atmosphere during emergency shutdowns.

We express our thanks to Messrs. R. J. Howlett and E. R. Dawe of the NFRC for analysing the foliage and humus for fluorides.—S. S. Sidhu and B. A. Roberts, Newfoundland Forest Research Centre, St. John's, Newfoundland.

ENTOMOLOGY

Chemical Response Behavior of Scolytids in West Germany and Western Canada.—Ethanol combined with α-pinene was highly attractive to field populations of *Trypodendron lineatum* (Oliv.) (Coleoptera: Scolytidae) in experiments carried out in the Black Forest in West Germany (Bauer and Vité, Naturwissenschaften 62:539, 1975). However, the scant information available in North American literature was not in agreement with the foregoing (Werner and Graham, Can. Dep. Agric., For. Biol. Div., Bi-Mon. Prog. Rep. 13(4):3, 1957; Rudinsky, Science 152: 218-219, 1966; Moeck, Can. Entomol. 108:985-995, 1970) which indicated possible behavioral and perhaps morphological differences between the field populations of the two continents.

A cooperative study of the chemical response behavior of *T. lineatum* was therefore undertaken to establish whether or not a difference could be demonstrated, using the response of the ethanol-α-pinene combination as a criterion. A naturally occurring aggregating pheromone, 3-hydroxy-3-methylbutan-2-one (HMB) from *Trypodendron* spp. (Francke *et al.*, Z. Naturforsch. 29c:243-245, 1974) was also tested in the field.

In West Germany, the experiment was carried out in the Foehrental (Black Forest) at an altitude of 650 m. In Canada, the locations were at Port Renfrew, B.C., near a dry-land log storage area at about sea-level, and in three areas near Cowichan Lake, B.C. (approx. 165 m).

Ethanol, 94.8%, α-pinene, 98% pure, and HMB were used as test chemicals in the following combinations: 1. Water (Control); 2. α-Pinene; 3. Ethanol; 4. Ethanol + α-Pinene; 5. Ethanol + α-Pinene + HMB. Both α-pinene and HMB used in both countries were obtained from the same source.

In West Germany, two types of traps were used: a glass barrier trap (Nijholt and Chapman, Can. Entomol. 100:1151-1153, 1968) with a rectangular base, and a sticky trap of the same size and silhouette as the glass barrier trap. In the latter case, plastic sheeting coated with 'Stikem Special' (Michel and Pelton Co., Oakland, California) replaced the glass. In Canada, the window trap with water trough (Chapman and Kinghorn, Can. Entomol. 87:46-47, 1955) was used. In all cases, the traps were fastened at a height of 1 m to stakes driven into the ground. They were arranged in five treatment groups of four traps each. In West Germany, each treatment group consisted of two glass barriers and two sticky traps placed diagonally from each other. In all, the distance between traps was 5 m and between groups was 20 m. The treatments were rotated each day to exclude positional effects. The test chemicals placed in open glass vials, fastened to the support stakes, were replenished on a daily basis.

The results confirmed the synergistic effect of the ethanol-α-pinene combination, as found by Bauer and Vité (lit. cit.), and indicated similar response behavior by *T. lineatum* in both areas (Table 1). Ethanol was attractive to both *T. lineatum* and *Trypodendron domesticum* L., in agreement with Moeck (Dep. Fish. For. Bi-Mon. Res. Notes 27(2):11-12, 1971) and Kerck (Naturwissenschaften 59:423, 1972). α-Pinene was attractive to *T. lineatum*, but it had a repellent or masking effect on *T. domesticum*, as can be deduced from the response to the ethanol-α-pinene combination. This behavior is understandable as *T. domesticum* attacks broadleaf trees (e.g., *Quercus*) that do not contain α-pinene. The addition of the ketol HMB did not increase the attractiveness of the ethanol-α-pinene combination to *T. lineatum* or *T. domesticum* in West Germany. In Canada, the results even

TABLE 1

Numbers of *T. lineatum* and *T. domesticum* caught in traps baited with ethanol, α-pinene and a combination of both as well as HMB during the spring 1976 flight period.

Test materials	*T. lineatum*			*T. domesticum*	
	West Germany		Western Canada (Port Renfrew)	West Germany	
	Plastic sticky traps[1]	Glass barrier live traps[1]	Glass barrier wet traps[2]	Plastic sticky traps[1]	Glass barrier live traps[1]
Water (Control)	106	72	128	2	3
α-Pinene	362	153	297	8	7
Ethanol	993	414	351	134	88
Ethanol + α-pinene	2111	735	1297	9	12
Ethanol + α-pinene + HMB	1893	718	223	10	11

[1] Two traps per treatment
[2] Four traps per treatment

suggested a repelling or masking effect.

Due to inclement weather in the coastal area of western Canada, the flight activity of *T. lineatum* was sporadic and intermittent, leaving only a few days with good flight conditions. On the sites near Cowichan Lake, where normally good flight populations were observed, *T. lineatum* activity was negligible. However, *Pseudohylesinus nebulosus* (Leconte) responded strongly, as did *Hylastes nigrinus* (Man.) to a lesser extent (Table 2). Ethanol and α-pinene were both attractive, while an additive effect was also prominent. Surprisingly, *P. nebulosus* responded in large numbers to the addition of HMB and *H. nigrinus* showed a similar trend. The ketol was tested in combination with ethanol and α-pinene in the absence of other components of susceptible hosts. Whether the same ketol can be extracted from *P. nebulosus* and *H. nigrinus* would have to be determined by further tests.

No apparent behavioral differences between the European and North American populations of *T. lineatum* were evident in this field-bioassay, based on the response of the ethanol-α-pinene combination. However, proportionately fewer beetles responded to the three-way combination in Western Canada than in West Germany; therefore, this aspect of the response behavior of *T. lineatum* should be further investigated.—W. W. Nijholt, Pacific Forest Research Centre, Victoria, B.C. and J. Shönherr, Inst. of Forest Zoology, University of Freiburg i. Br., West Germany. (Part of this study was supported by the "Deutsche Forschunggemeinschaft").

TABLE 2

Numbers of *P. nebulosus* and *H. nigrinus* caught in glass barrier wet traps baited with ethanol, α-pinene and a combination of both as well as HMB during the spring 1976 flight period near Cowichan Lake, B.C.

Test materials	*P. nebulosus*				*H. nigrinus*
	Area [1]				
	1	2	3	Total	Total
Water (Control)	157	3	56	216	0
α-pinene	194	116	143	453	14
Ethanol	172	159	70	401	16
Ethanol + α-pinene	368	359	29	756	42
Ethanol + α-pinene + HMB	752	774	200	1726	69

[1] Four traps per treatment, per area.

Incidence of *Nosema fumiferanae* in Spruce Budworm, *Choristoneura fumiferana* in the Year Following Application.— During the summer of 1975 a microsporidian, *Nosema fumiferanae*, was tested against the spruce budworm, *Choristoneura fumiferana* on Manitoulin Island, Ontario. Experimental details have been reported previously. (Wilson and Kaupp, Bi-Mon. Res. Notes 32:2-3, 1976; Wilson and Kaupp, Can. For. Serv. Inf. Rep. IP-X-11, 1975). In June 1976, samples of spruce budworm larvae were taken from the same trees that had been sprayed in 1975. Smears of larvae from these samples were examined microscopically to determine the level of *N. fumiferanae* infection and the results are shown in Table 1.

The incidence of microsporidia in budworm larvae collected from trees sprayed in 1975 when the larvae were in the IV and V instar remained virtually the same for 1975 and 1976. This value was significantly higher than the check area. However, those trees sprayed in 1975 when the larvae were predominantly in the VI instar showed a significant increase in the level of *N. fumiferanae* in 1976. These values indicate that an artificial introduction of *Nosema fumiferanae* spores into a population of VI instar budworm increases the level of infection of this parasite in the year following application. In both treatments, the level of infection was not decreased as perhaps one might expect, due to immigration of healthy adults into the area. There was also an increase in the level of infection in larvae collected from the check area. This phenomenon has been observed before (Wilson, Bi-Mon. Res. Notes 29:35-36, 1973) and indicates that levels of microsporidian infection increases with the age of the infestation.—G. G. Wilson and W. J. Kaupp, Insect Pathology Research Institute, Sault Ste. Marie, Ontario.

TABLE 1

Incidence of the microsporidian parasite *Nosema fumiferanae* in living spruce budworm larvae collected one year after application

Trees	Date sprayed	Budworm instar sprayed	Date sampled	No. insects examined	Incidence of *N. fumiferanae* %
M1-10[a]	June 2, 1975	IV & V	June 27, 1975	568	53.0
M11-12[a]	June 13, 1975	VI	June 27, 1975	135	33.7
Check[a]	-		June 27, 1975	174	23.0
M1-10	-		June 6, 1976	311	52.4*
M11-12	-		June 6, 1976	150	50.6*
Check	-		June 6, 1976	141	39.0

[a] Date taken from last sample collected in 1975.

* This value is significantly different from the check at the 5% level (1976 data only); T-test applied to percentages.

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