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ENTOMOLOGY

Effects of Late Spring Frosts in 1980 on Spruce Budworm and its Host Trees in the Laurentian Park Region of Quebec.—Late spring frosts occasionally kill new shoots on balsam fir (*Abies balsamea* [L.] Mill.) and white spruce (*Picea glauca* [Moench] Voss), and can affect spruce budworm (*Choristoneura fumiferana* [Clem.]) populations (Blais, For. Chron. 33:364-372, 1957). In the spring of 1980, frost damage to new shoots on fir and white spruce was very extensive in various forest regions of Quebec. Observations of effects on the trees and on budworm populations (then at outbreak levels) were made in the spring and summer of 1980 in connection with this phenomenon in Laurentian Park, a mountainous region covering 15 000 km^2 north of Quebec City. Since 1972, this region has been under budworm attack; at elevations below 700 m, insect populations have remained high, whereas at elevations above 700 m (about 40% of the study area), populations declined in 1978 and have remained at a low level since then. By the end of 1979, impact of the budworm on the forest was considerable; an average of 12% of the balsam fir of merchantable size in 37 study plots in the region were dead, whereas 35% of the living trees had lost more than 75% of their foliage (Blais, Laurentian Forest Res. Cent. Inf. Rep. LAU-X-43, 1980).

Temperatures in May 1980 at the Quebec airport (about 40 km south of Laurentian Park) were close to normal; mean for the month was 11.5° C, whereas mean for the normal is 10.6° C. Temperatures in Laurentian Park are lower because of the higher elevation, but temperatures in May for that region were presumably close to normal because budworm emergence from hibernacula, early larval development, bud bursting, and shoot elongation on spruce and fir occurred about the same time as in previous years. During the 1st wk in June at elevations below 700 m, shoots on fir and spruce measured about 1.5–2 cm, and budworm larvae were mostly in the third instar; populations varied somewhat among localities but averaged about 18 larvae per 45-cm branch. Loss of current foliage resulting from such population levels ranged from 25 to 70%. At elevations above 700 m, larvae were in the second instar, and buds on fir and white spruce were starting to open; budworm populations were scarce and averaged about two larvae per 45 cm branch.

Meteorological records at the Montmorency Experimental Forest Station in the park at an elevation of 620 m reveal that frosts are not uncommon at this locality in late May and early June. However, in 1980, some unseasonably low temperatures were recorded for that time of year. Minima of -2.5° C, -5.5° C, and -2.5° C were registered for 24, 29, and 30 May respectively, and of -2.0° C and -3.0° C for 6 and 9 June respectively. The very low minimum temperatures on 29 May, and especially on 9 June, when vegetation and insect development was more advanced, were probably mainly responsible for the frost damage observed later.

TABLE 1
Average number of shoots, percentage of frozen shoots, average number of larvae, and percentage of dead larvae for five 45 cm balsam fir branches by observation point.

Observation Point	Average no. of shoots per 45-cm branch	Percentage of frozen shoots	Average no. of larvae/45 cm branch	Percentage of dead larvae
1	105	91	19	20
2	123	55	13	16
3	101	32	13	8
4	140	19	11	0
5	118	22	20	20
6	129	18	24	7
7	102	99	29	48
8	127	41	19	15
Average	118	46	18	17

On 12 and 13 June, observations were made in eight localities 1–5 km apart, in and around the Montmorency Experimental Forest. One 45 cm branch tip was obtained with pole pruners from the mid-crown of each of five balsam fir trees (approximately 12 m in height) from each locality. All new shoots were counted on these branches and classified as frozen or intact; all budworm larvae were counted and classified as living or dead. At the time of sampling, insect development was at peak L_3 with a few L_2 and L_4; average shoot length measured 1.6 cm (Table 1). Percentages of frozen shoots varied considerably among localities and ranged from 19 to 99, with an average of 46 for the eight localities. Percentages of dead larvae varied among localities with a range of 0–48 and an average of 17. It is noteworthy that relatively few larvae were killed by the freezing temperatures.

Observations made in August and September 1980 indicate that frost damage to fir and spruce was most pronounced in the western half of the park. Moderate to severe frost damage occurred in an area of 8 200 km^2 west of highway 175, linking Quebec City to Chicoutimi. East of this highway and south of the park, frost damage was light to nil.

Fir and spruce can sustain the loss of much or all of the foliage growth produced in one season without any serious consequence to the trees. However, a very large proportion of the fir, especially at elevations below 700 m, was in a greatly weakened condition because of repeated defoliation by budworm. The complete loss of the current year's foliage, through the combined action of frost and feeding by the insect, will hasten tree mortality in those sectors where the infestation persists and where defoliation by budworm would only have been moderate (25–70%) in 1980. In sectors where little defoliation would have occurred because of greatly reduced insect populations, the loss of the 1980 foliage growth through frost will cause some trees to die that otherwise would have recovered.

The egg-mass survey conducted by employees of the Quebec Department of Energy and Resources reveals that budworm populations will be sufficiently high to cause severe defoliation in 1981 in most sectors where the budworm infestation has been persisting in Laurentian Park. This indicates that late spring frosts in 1980, although they caused considerable damage to foliage and may hasten the mortality of weakened trees, did not seriously affect budworm populations. — J.R. Blais, Laurentian Forest Research Centre, Ste. Foy, Que.

The Potential for Selection for Freezing-Tolerance in an Ontario Population of *Scolytus multistriatus* (Coleoptera: Scolytidae).—In Ontario there are two main insect vectors of Dutch elm disease: the native elm bark beetle, *Hylurgopinus rufipes* (Eichh.), and the smaller European elm bark beetle, *Scolytus multistriatus* (Marsh.). The latter was first reported near Windsor in 1948 (Watson, Can. Dep. Agric., Div. Entomol., Bi-mon. Prog. Rep. 4(5):2, 1948).

By 1957 the northern limit of *S. multistriatus* corresponded to a line drawn between Sarnia and Hamilton, and by 1974 its range extended from Midland on Georgian Bay, north of Lake Simcoe and east to the Ontario-Quebec border in a narrow strip along the St. Lawrence Seaway. Also in 1974, successful establishment of *S. multistriatus* was recorded in Ottawa, 40–50 km north of its previously known range.

In 1970, *S. multistriatus* was found for the first time in Sault Ste. Marie where it was breeding in a single elm (Thomas, Bi-mon. Res. Notes 27:1, 1971), and by 1971 two additional sites were reported (Sippell et al., Annu. Rep. Forest Insect and Dis. Surv., Can. For. Serv., p. 61, 1971). Since these finds were 250 km north and west of the known distribution in Ontario, and 190 km north of any known infestation in Michigan, it was assumed that they were accidental and that the beetle would not become established.

Cold-hardiness tests conducted at the Great Lakes Forest Research Centre in the late 1960s and early 1970s indicated that *S. multistriatus* would be restricted in its northward spread by its inability to survive at temperatures of -30° C or lower (Sullivan, Great Lakes Forest Res. Cent., pers. comm.). Sault Ste. Marie is located just south of the -30° C isotherm and occasionally experiences temperatures of -35° C. Consequently, Sullivan felt that, although small pockets of *S. multistriatus* might be found because of the protection afforded by snow cover, the population would frequently experience stress temperatures that would limit its potential as a vector in northern areas.

However, in 1978 and again in 1979, large numbers of *S. multistriatus* were caught in Sault Ste. Marie on multilure-pheromone traps (Euale et al., Great Lakes Forest Res. Cent. Rep. 0-X-307, 1980). Furthermore, a random sample of 38 diseased trees taken in January 1980 to determine the number of overwintering elm bark beetle galleries/m^2 in brood elms revealed substantially more overwintering *S. multistriatus* than *H. rufipes* larvae (Table 1). Although this does not mean that there are more *S. multistriatus* than *H. rufipes* in Sault Ste. Marie, it does suggest that the *S. multistriatus* population is increasing. Hence, a study was begun to determine if the cold hardiness of *S. multistriatus* has increased by natural selection through exposure to low temperatures.

TABLE 1

Bark beetle galleries/m^2 in brood elms

No. of trees sampled	Total area sampled (m^2)	Unsuccessful galleries		Successful galleries	
		S. multistriatus /m^2	*H. rufipes* /m^2	*S. multistriatus* /m^2	*H. rufipes* /m^2
38	21.9	0.18	0	0.82	0.09

Trap logs baited with pheromones were set out in Sault Ste. Marie in August to attract *S. multistriatus* adults. The progeny of these adults in the trap logs were brought into the laboratory in early March and held at -2° C until required for testing.

Larvae were removed, as required, from the trap logs and then warmed sufficiently to determine that they were alive. Live larvae were placed on filter paper in a petri-plate that was then refrigerated on a bed of crushed ice in an insulated container until the supercooling point of the larvae could be determined.

The cooling rate for tests ranged from 0.5°C to 2.0°C per minute in an alcohol-dry ice bath (Sullivan, Can. Entmol. 97:978-993, 1965), in accordance with the standard proposed by Salt (Can. J. Zool. 44:655-659, 1966) for determining biological supercooling points. The temperature at which freezing occurred was determined by the rebound in the cooling curve caused by the release of latent heat as the insect tissue froze and was recorded on a potentiometer. Tested specimens were incubated at 20°C and 50% RH for 24 h to determine if they had been susceptible to freezing. Those specimens that showed no adverse effects of freezing were selected for further incubation in elm bark.

Elm bark, which would have been acceptable for infestation by adult beetles, was removed from diseased and dying trees. Holes were drilled from the phloem side into the bark to accommodate the supercooled larvae. Care was taken to ensure that the holes drilled were not too large, but would accommodate the test specimens without injury. After drilling, the shredded phloem remained attached to the area surrounding the drill hole and provided excellent material for packing and sealing the implanted larvae in the bark. The bark was then incubated at 20°C and 50% RH for 6 wk and the incubated samples were checked regularly for adult emergence.

The mean supercooling point for the 49 *S. multistriatus* tested was -27.58 ± 1.61°C (range -24.0 to -32.2°C), which was similar to the mean -28.9 ± 0.24°C reported by Sullivan (pers. comm.) for a sample of 1970-1971 overwintering larvae. In Sullivan's experiment 5.2% of the supercooled specimens recovered some body movement. Six pupated but were unable to shed their larval skin and none developed to the adult stage. Consequently, Sullivan considered the species susceptible to freezing.

In the tests reported here, 31 of the 49 larvae, or 63%, recovered some body movement. Twenty-nine were selected for incubation in elm bark and of these, 18 became desiccated and died, one could not be found, and 10 became adults. However, only one of the 10 adults appeared to be normal; the remainder exhibited varying degrees of abnormality. Of 29 control larvae (i.e., larvae that were not supercooled) similarly incubated in elm bark, 11 became desiccated and died, three were missing, and 15 became adults. Eleven of the 15 adults emerged. The four adults that did not emerge showed malformations similar to those of the adults that developed from supercooled larvae. It is clear that the experimental technique caused larval desiccation and malformations.

Past experience in rearing *S. multistriatus* has shown that healthy individuals normally develop to emerging adults in rearing material with relatively low moisture content. However, in this experiment it was clear that the technique was causing larval desiccation. Initially the elm bark was moistened with an atomizer, but this practice was abandoned because of fungus contamination. It therefore appears that the supercooled larvae are more susceptible to dehydration than normal larvae. Work is under way to devise a method that will allow supercooled larvae to develop normally in moist elm bark and it is expected that under such conditions healthy adults will emerge from supercooled larvae.

The greater survival of the 1979-1980 supercooled larval population (63%) than that of the 1970-1971 population (5.2%), even though the mean supercooling points for the two populations were about the same, represents an increase of 57.8% in larvae recovering some body movement. The fact that 34% of these larvae pupated and became adults suggests that, under natural, favorable brood conditions, healthy adults may develop from supercooled larvae. The implication of this work is that *S. multistriatus* may, through natural selection as a result of continual stress from a cold climate, be developing tolerance to freezing. If so, *S. multistriatus* may become established throughout the range of elm in Canada. Because supercooling is a product of both temperature and time (Salt, Can. J. Res., D., 28:285-291, 1950), time also must be considered if laboratory-determined supercooling points are to be related to field conditions. Further work is under way to determine the effect of prolonged supercooling on survival and development.—D.B. Roden, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

Effect of Additives on the Persistence of Aminocarb in Conifer Foliage.—Aminocarb (Matacil®), 4-dimethylaminon-tolyl N-methylcarbamate has been used operationally since 1973 for the control of spruce budworm (*Choristoneura fumiferana* [Clem.]) in Canada with few adverse environmental effects (Buckner et al., Chem. Cont. Res. Inst. Inf. Rep. CC-X-91, 1975). Usually the chemical is used as an oil formulation at an operational dosage of 0.070 kg A.I./ha. Under the present conditions of forest spraying, only a small portion of the released aminocarb penetrates the forest canopy and reaches the foliage. The deposited chemical can dissipate from the foliage by various physical and biological processes yielding a low residual half-life (Sundaram et al., Chem. Cont. Res. Inst. Inf. Rep. CC-X-116, 1976). The effectiveness of the sprayed insecticide is dependent upon the appropriate residual activity and hence is related to foliar half-life. While the active ingredient is responsible for insecticidal activity, the additives in the formulation can play a significant role in maintaining a desirable half-life in the forest environment. At present, little factual information exists in correlating foliar stability and efficacy of an insecticide. Our present understanding of the efficacy of the additives is superficial. Consequently, there is a need to investigate the usefulness of some solvents and diluent oils in