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ENTOMOLOGY

Effects of Temperature and Relative Humidity on Egg Hatch, Survival of First-instar, and Establishment of Second-instar Spruce Budworm Larvae.—Overwintering mortality of spruce budworm (*Choristoneura fumiferana* Clem.) has been separated into fall "dispersal" loss and spring "dispersal" loss (Miller, Can. J. Zool. 36:409-22, 1958). The failure of first-instar larvae (L_1) to spin hibernacula was classed as a fall "dispersal" mortality factor whereas failure of second-instar larvae (L_2) to establish a feeding site was classed as a "spring" dispersal mortality factor. This paper describes the effects of temperature and relative humidity on these mortality factors.

In the first experiment (egg hatch and survival of L_1), three egg masses from our laboratory stock, which was heavily parasitized with microsporidia, were placed in each of 120 plastic dishes (4.3 cm diam x 1.1 cm deep) containing a piece of gauze for larval spin-up (Stehr, Can. Entomol. 86:423-428, 1954). Temperatures were maintained by positioning the dishes in a temperature gradient, and relative humidities were maintained by using saturated salt solutions (Winston and Bates, Ecology 41:232-237, 1960). The photoperiod was 16 h. The dishes were not disturbed until sufficient time had elapsed for the eggs to hatch and the larvae to spin hibernacula and moult (11 days at 30°C, 18 days at 13°C).

Larvae for the second experiment (establishment of L_2 in feeding sites) were collected in the field as they emerged from hibernacula. One balsam fir twig tip, with three swollen terminal buds plus the previous year's needles, was placed in each of 210 containers. The cut base of each twig was kept in water so that the buds could continue to swell and open. Relative humidities were maintained with saturated salt solutions. Five temperatures and six relative humidities were used. Three larvae were placed in each container and the experiment was replicated seven times. After sufficient time for establishment had elapsed (6 days at 25.6°C, 13 days at 7°C), the buds and needles were dissected and the number of feeding larvae was recorded.

TABLE 1

Effect of temperature on egg hatch and survival of first-instar spruce budworm larvae

Temperature ± 0.5°C	No. of fertile eggs	% Hatch (eggs to L_1)	% Survival (L_1 to L_2)	% Survival (eggs to L_2)
13.1	253	48.2	43.4	20.9
15.8	198	52.0	23.3	12.1
17.2	248	74.2	64.7	48.0
19.4	261	60.9	53.5	32.6
21.0	197	55.3	45.9	25.4
23.0	206	62.1	45.3	28.2
24.8	222	68.9	47.1	32.4
26.5	171	80.1	48.9	39.2
28.0	208	76.4	45.9	35.1
30.0	232	31.0	8.3	2.6

TABLE 2

Effect of relative humidity on egg hatch and survival of first-instar spruce budworm larvae

Salt solution	Average RH	No. of fertile eggs	% Hatch (eggs to L_1)	% Survival (L_1 to L_2)	% Survival (eggs to L_2)
$LiCl_2$	12%	312	38.8	19.8	7.7
$CaCl_2$	34%	348	55.5	19.7	10.9
$MgNO_3$	55%	393	55.7	35.6	19.8
$NaCl$	75%	400	71.8	63.8	45.8
Na_2CO_3	90%	402	65.4	50.2	32.8
$CuSO_4$	98%	341	71.3	62.6	44.6

TABLE 3

Effect of temperature and relative humidity on the establishment of second-instar spruce budworm larvae swelling balsam fir buds and needles

Salt solution	Average RH	No. of larvae established*					
		Temperature ± 1.5°C					
		7.0	13.3	17.2	21.1	25.6	Total
$CaCl_2$	34%	13	9	12	16	13	63
$MgNO_3$	55%	12	14	15	17	11	69
$Mg(C_2H_3O_2)_2$	65%	13	11	17	16	19	76
$NaCl$	75%	19	12	12	13	13	69
Na_2CO_3	90%	18	9	15	14	17	73
$CuSO_4$	98%	13	7	12	18	11	61
Total		88	62	83	94	84	411

*Total of 21 larvae at each treatment (temperature x humidity).

In the testing of the effects of temperature on egg hatch and survival of L_1 to L_2 only the 30°C temperature had a marked effect (Table 1). Under the remaining temperature regimes, average egg hatch was 63.8% and average survival of L_1 to L_2 was 47.9%. Because of the low hatch and low survival of L_1 to L_2 at 30°C, the overall survival (eggs to L_2) was only 2.6% at 30°C (Table 1). Under the remaining temperature regimes overall survival averaged 33.2%; highest survival was at 17.2°C (Table 1).

The effects of constant relative humidity on egg hatch and survival of L_1 to L_2 are shown in Table 2. The lowest humidity, 12% significantly reduced egg hatch. Survival of L_1 to L_2 and overall survival (eggs to L_2) were noticeably lower at 12, 34, and 55% relative humidities.

The effects of temperature and relative humidity on the establishment of second-instar larvae in balsam fir buds and needles are shown in Table 3. The low number of larvae established at 13.3°C is regarded as an artifact, as establishment at the next higher and lower temperatures was much higher. Of 630 larvae, a total of 411, or 65%, successfully mined the buds and needles and fed. Temperature and relative humidity had little effect on the establishment of second-instar larvae.

Miller (1958) concluded that the failure of larvae to spin hibernacula accounted for only 4% of the fall "dispersal" loss. Harvey (Can. J. Zool. 35:549-572, 1957) noted that mortality of first-instar larvae was particularly high in inbred laboratory stock, while Thomson (Can. J. Zool. 36:499-511, 1958) reported 23% mortality during the first instar. The data presented here suggest that temperature and relative humidity are not likely to affect first-instar larval mortality. Miller also concluded that the failure of second-instar larvae to establish a feeding site in the spring accounted for only 5% of the spring "dispersal" loss. Although my data show a 35% mortality at this stage, there is no evidence to indicate that temperature and relative humidity have any effect on this mortality.—A.W. Thomas, Maritimes Forest Research Centre, Fredericton, N.B.

Estimating the Number of Eggs in Spruce Budworm Egg Masses in Newfoundland.—The present outbreak of the spruce budworm, *Choristoneura fumiferana* (Clem.), in Newfoundland and Labrador began in 1971 and has become the largest and most severe infestation ever recorded in the Province. Previous outbreaks of this insect were only of minor importance. Studies were initiated in 1972 on the biology and population behavior of the budworm to explore and, hopefully, to explain the differences from previous outbreaks and to facilitate the forecast of population levels and subsequent damage.

Egg-mass surveys are routinely used for predicting spruce budworm larval population levels and subsequent defoliation (Morris, Can. J. Zool. 32:302-313, 1954). However, the size of the egg mass and, consequently, the number of eggs per mass vary considerably (Miller, Can. J. Zool. 35:1-13, 1957; McKnight, USDA Forest Serv. Res. Note RM-146, 1969; Washburn and Brickell, USDA Forest Serv. Res. Pap. INT-138, 1973), and this may influence prediction. Egg-mass surveys used elsewhere for predicting larval population levels were adopted in Newfoundland (Bryant and Clark, Bi-mon. Res. Notes 31:12, 1975), but egg-mass size and variation in the number of eggs per mass were not determined.

This note presents data on the size of egg masses and the number of eggs per mass oviposited on balsam fir, *Abies balsamea* (L.) Mill., in Newfoundland. A total of 49 egg masses was collected in 1974 and of 121 egg masses in 1975 from 50-cm-long branch tips taken from the midcrown of dominant balsam fir trees in western Newfoundland after larval eclosion was completed. To facilitate the counting, the masses were stained by soaking in 1% aqueous solution of cotton blue for 10 seconds followed by washing for 5-10 seconds (destaining) in distilled water. This method gave better results than that described by Jennings and Addy (J. Econ. Entomol. 61:1766, 1968) and later modified by Leonard, Simmons, and Van Derwerker (J. Econ. Entomol. 66:992, 1973). The length and width of each egg mass were measured to the nearest 0.01 mm with an ocular micrometer on a stereomicroscope, and the number of rows in the egg mass and the number of eggs (chorions) in each row were counted. Linear regression analyses were used to relate the number of eggs per mass to the length or width of the egg mass separately for egg masses having two, three, and four rows of eggs.

Twenty-four percent of the masses examined contained two rows, 67% had three rows, and 9% had four rows of eggs. Length of masses ranged from 2.5 to 9.2 mm and averaged 5.2, 5.3, and 5.3 mm for masses containing two, three, and four rows of eggs, respectively. Miller (1957) reported that egg masses on balsam fir in New Brunswick generally had two complete rows of eggs and a partial third row, and the length varied from 2 to 9 mm. In Minnesota, Bean (J. Econ. Entomol. 54:1064, 1961) found that spruce budworm egg masses on balsam fir usually comprised two or three rows of eggs varying from 2 to 10 mm in length. Bean (1961) also reported a skewed frequency distribution of the egg-mass lengths and therefore cautioned against using an average number of eggs per mass for population studies. In the present study, the mean versus median lengths were 5.2 vs. 5.1 mm for two-row masses, 5.3 vs. 5.4 mm for three-row and 5.3 vs. 5.0 for four-row masses, indicating that the difference between the mean and median egg-mass length is negligible. The average number of eggs for masses with two, three, and four rows of eggs was 20, 26, and 34, respectively. The average length for all egg masses (n = 170), in the present study, was 5.2 mm and the average number of eggs per mass was 25. This is higher than the 15.7 in severe infestations and the 18.5 in light infestations reported by Miller (1957). It should be noted, however, that the average number of eggs given by Miller (1957) was based on 996 and 7,429 egg masses, respectively.

TABLE 1

Estimated number of spruce budworm eggs per mass based on length of egg mass and number of rows of eggs

Length of mass (mm)	Number of eggs		
	Two-row[a]	Three-row[b]	Four-row[c]
	egg mass		
1	3	4	5
2	7	9	12
3	11	14	19
4	15	19	25
5	19	24	32
6	23	29	38
7	27	34	45
8	31	39	52
9	35	44	58

[a] $Y = -0.75 + 3.94X$; $r^2 = 0.68$

[b] $Y = -1.27 + 5.04X$; $r^2 = 0.67$

[c] $Y = -1.06 + 6.54X$; $r^2 = 0.68$

Regression analyses showed that egg-mass length provided a better estimate of the number of eggs per mass than egg-mass width. The former explained 68% of the variance and the latter up to 25% of the variance.

The number of eggs per mass was predicted from regression equations for egg masses measuring from 1 to 9 mm in length and containing two, three, or four rows of eggs (Table 1). These predicted numbers of eggs are in fair agreement with the regression estimates for two- and three-row egg masses from Minnesota (Bean, 1961) but are different from the estimates presented for two-row, two-row with a partial third row, and three-row egg masses from Maine (Leonard, Simmons, and Van Derwerker, 1973), and from the estimates for two-row with a partial third row egg masses from New Brunswick (Miller, 1957). Therefore, the number of eggs per mass predicted from the regression equations in this study will be used provisionally. The accuracy of the equations will be tested for egg masses from infestations of different ages in balsam fir, and in black and white spruce stands at various locations across the Island.

The technical assistance of David S. Durling is gratefully acknowledged.—Imre S. Otvos, Newfoundland Forest Research Centre, St. John's, Nfld.

Insects Inhabiting Wood-chip Stockpiles in British Columbia.—Massive populations of insects in wood-chip stockpiles in British Columbia have been reported to the Forest Insect and Disease Survey at Victoria during the past several years. They have occurred through the central logging area of the southern interior at Quesnel, Williams Lake, 100 Mile House and Kelowna. Large quantities of chips were involved and there was a considerable diversity of insects. The main food source was the meso- and thermophilic microfungi which develop quickly with the changes in temperature and humidity during the various phases of chip degradation. Outstanding characteristics of the insects were their small size (1.5-3.0 mm), their incredible numbers—approximately 1,100 adults / liter (1 qt) of chips—and the short time apparently required for the populations to materialize. Populations are known to persist for at least 2 years and presumably could continue as long as their environment remained suitable. The insects caused no appreciable problems in the further processing of the chips for pulp production, as indicated by commercial laboratory tests and in actual utilization (pers. comm.).

Hereunder are given the localities, collection data, species, status, and relative abundance of the insects recovered. The individual collections show the insect associations; within them the species are listed in order of abundance. Carabids and staphylinids were identified at the Biosystematics Research Institute; other identifications were made by the author. Percentages are based on chip samples of approximately 3 liters, each containing 3,300± insects.

100 Mile House, June 29, 1971; chip stockpile: *Silvanus bidentatus* (Fabricius) (Coleoptera: Cucujidae) — a fungus feeder, 100% (no other insects found). Kelowna, Nov. 4, 1975; 25,000 BDU* spruce-pine chip stockpile (*bone-dry units: 1 020 kg [2,250 lb] dry weight), spot infestations throughout, wherever temperature and humidity were high: *Tachys nanus* Gyllandel (Coleoptera: Carabidae) — vegetarian, 91%; Arachnida (spiders) — predator, 3%; Staphylinidae (Coleoptera) — predator-scavenger, 2%; *Atheta* sp. (Staphylinidae) — predator-scavenger, 1.5%; *Metaclisa marginicollis* (Horn) (Coleoptera: Tenebrionidae) — vegetarian scavenger, 1%; *Falacria*

sp. (Staphylinidae)—predator-scavenger, 1%; *Nabis ferrus* (Linnaeus) (Hemiptera: Nabidae)—predator, 0.5%. Quesnel, Feb. 11, 1976; 4-ha (10-acre) spruce chip stockpile: *S. bidentatus*—100%. Williams Lake, Sept. 4, 1975; 4,000 BDU chip stockpile, 1 month old, 20°C at 13-m (40-ft) sample level: *Monotoma longicollis* Gyllandel (Coleoptera: Rhizophagidae)—vegetarian, 90%; *Typhaea stercoria* Linnaeus (Coleoptera: Mycetophagidae) — fungus feeder, 6%; *Corticaria* sp. (Coleoptera: Lathridiidae)—vegetarian scavenger, 2%; *Atheta* sp., 2%.

In view of the variety of insects recovered from a relatively few unscheduled collections, it seems probable that at least a few other species are common. It is likely that the predominant species (cucujids, carabids, rhizophagids) serve as food, directly or indirectly, for most of the minor species.—David Evans, Pacific Forest Research Centre, Victoria, B.C.

Variation in Shoot and Needle Growth Patterns on 46-cm Branch Tips of Healthy White Spruce.—The 46-cm (18-in.) branch tips of balsam fir (*Abies balsamea* [L.] Mill.) and white spruce (*Picea glauca* [Moench] Voss) have been widely used as a collection unit for spruce budworm (*Choristoneura fumiferana* [Clem.]) surveys in Canada (Harris, For. Chron. 39:199-204, 1963, and 40:195-201, 1964; Miller et al., Bi-mon. Res. Notes 28:31, 1972; DeBoo et al., Phytoprotection 54:9-22, 1973; Martineau and Benoit, Phytoprotection 54:23-31, 1973). This size of branch tip is often convenient to remove from tree crowns, is easy to store and examine, and has characteristics that relate to the oviposition, feeding, and resting sites of the budworm. Current-year shoot growth on the 46-cm tip may also be used to derive estimates of annual defoliation and bud damage.

There is interest in using the 46-cm branch tip to monitor spruce budworm larvae and damage in white spruce forests of northern Alberta and the Northwest Territories. However, no data exist from these areas on the within-crown variation of several foliage characteristics of the 46-cm unit for trees of different size that can aid in the sampling procedure and interpretation of results. This study reports on the variation in length of current-year shoots, total length of shoots, number of buds, needle density of current shoots, and dry needle weight of the 46-cm branch unit. Three naturally stocked stands of white spruce that showed no previous identifiable budworm damage were selected near High Level, Alta. Stand I (average age 83 yr) was predominantly white spruce with scattered trembling aspen (*Populus tremuloides* Michx.), while stand II average age of spruce 44 yr) and stand III (average age of spruce 30 yr) both had an overstory of trembling aspen (Table 1).

Ten codominant spruce were selected from each stand for the foliage analysis. The cardinal directions were marked on the main stem of each tree to designate four equal quadrants; then each tree was felled. On trees from stand I the live crown (average length 10.8 m) was divided into four equal levels, designated A (uppermost quarter), B, C, and D. A 46-cm branch tip was clipped from near the center of each level quadrant, the yield being 16 branch tips per tree. Procedures for sampling stands II and III were identical, except that because of their smaller size, three equal crown levels (A, B, C) were measured on stand II trees (12 branch tips per tree) and two equal levels (A,B) on stand III trees (8 branch tips per tree). The average lengths of live crown of trees from stands II and III were 8.5 and 5.5 m respectively. All foliage samples were collected in May and June, 1968, but to standardize sample units all 1968 shoot growths were excluded.

For each branch tip the foliated surface was estimated as the product of its length and the total midpoint width (Morris, Can. J. Zool. 33:225-294, 1955). The length of 1967-formed shoots was measured separately from the total foliated shoot length of the 46-cm tip because budworm larvae prefer current year's shoots as food over older needles. All live terminal, lateral, and internodal buds that produced new shoot growth in 1968 were counted, because all were considered potential feeding sites of second- and third-instar larvae. Needle counts were made on 15-cm lengths of 1967-formed shoots from each branch tip. The needle weight on the 1967-formed shoots was determined from a sample of 100 needles per branch tip after drying at 105°C. Needles formed prior to 1967 were measured as a group. Branches were air-dried to the point of needle drop. Needles were mixed and a sample of 100 needles representing several years' growth was dried at 105°C and weighed.

Analysis of the branch tips suggested no differences between quadrants within levels of each tree age class with respect to all branch characters. Branch-tip surface area varied between crown levels of trees within the same stand, and also between crown levels of the different stands (Table 1). Mean foliated surface area per tree was 1,261, 970, and 787 cm^2 respectively for stands I, II, and III. Within crowns of trees in each stand, foliated surface area was least in the A crown levels, while in stands I and II maximum foliated area appeared to be at midcrown level or below.

The pattern of total shoot length within and between crowns of the three stands appeared to be similar to that for surface area (Table 1). In stands I and II highest total shoot length occurred at or below midcrown level. An explanation for this may be that maximum shoot length coincided with maximum number of years of foliated shoot growth, although this was not verified. Growth of 1967-formed shoots in crown level D of stand I and level C of stand II was greatly reduced and occasionally absent. The longest growth of 1967-formed shoots occurred in the upper crown, as expected, but was progressively less in trees of the younger stands sampled.

TABLE 1

Summary of mean and S.E. of foliage area, shoot lengths, numbers of live buds, needle density, and dry needle weights on 46-cm branch tips from spruce crowns in northern Alberta

Stands	Age	No. of trees sampled	Crown levels	Foliated area, cm^2	Length 1967 shoots, cm	Total shoot length, cm	No. of live buds	No. of 1967- formed needles/cm shoot	Avg dry weight per needle, mg	
									1967- formed	Pre-1967- formed
I	83	10	A*	1 032 ± 51.3	137 ± 7.7	467 ± 27.0	88 ± 4.3	22.4 ± 0.34	4.5 ± 0.10	4.3 ± 0.08
			B	1 355 ± 54.6	111 ± 9.7	616 ± 35.5	65 ± 5.3	21.1 ± 0.34	4.6 ± 0.10	4.5 ± 0.07
			C	1 432 ± 57.0	36 ± 5.9	644 ± 36.4	25 ± 3.7	19.3 ± 0.40	4.4 ± 0.15	4.7 ± 0.12
			D	1 226 ± 46.3	13 ± 2.8	430 ± 23.7	10 ± 2.2	17.6 ± 0.46	4.2 ± 0.23	4.4 ± 0.10
II	44	10	A*	929 ± 28.1	88 ± 4.3	308 ± 13.3	47 ± 2.0	21.6 ± 0.50	4.6 ± 0.09	4.3 ± 0.07
			B	1 006 ± 25.0	47 ± 3.0	392 ± 19.2	31 ± 1.7	21.4 ± 0.51	4.4 ± 0.13	4.4 ± 0.09
			C	974 ± 30.1	16 ± 2.2	329 ± 17.0	12 ± 1.5	19.0 ± 0.62	4.3 ± 0.19	4.5 ± 0.08
III	30	10	A*	755 ± 21.1	68 ± 3.3	240 ± 7.3	40 ± 1.8	26.5 ± 0.47	4.3 ± 0.12	4.1 ± 0.07
			B	819 ± 23.4	20 ± 3.0	283 ± 6.8	13 ± 1.8	25.7 ± 0.75	4.1 ± 0.15	4.2 ± 0.09

*Crown level A was uppermost.

Within each age class of trees the numbers of live buds per branch tip decreased from the upper level to the lower level and, on the average, were considerably less on trees in stands II and III than on trees in stand I. Data obtained in 1971 revealed that 46-cm branch tips in two spruce stands similar in site and stand characteristics to stand I had nearly identical numbers of buds in the four crown levels as stand I, even though they were from different areas and were collected at different times (Cerezke, unpublished data).

Density of needles per unit length of shoot affects both the quantity of food available to larvae and the choice of oviposition site by female moths (Greenbank, Entomol. Soc. Can. Mem. 31: 202-218, 1963; Miller, Entomol. Soc. Can. Mem. 31:75-87, 1963). In the present study highest needle densities per centimeter of shoot length occurred in the upper crown levels and decreased toward the base (Table 1). This finding lends support to the observed distribution of eggs and larvae in tree crowns (Morris, 1955; Harris, 1963 and 1964) and to the fact that female moths prefer to oviposit on relatively new needles and on shoots with closely spaced needles (Greenbank, 1963). However, needle density per centimeter of shoot may vary with rate of shoot growth (Smith, Can. J. Forest Res. 2:173-178, 1972).

Average dry weights per needle of 1967-formed and older needles for each age class of tree were similar, but within crowns of the three age classes different trends were apparent. On trees from the younger stands, II and III, dry weights of the 1967-formed needles decreased down the crown, whereas dry weight of older needles showed a trend of increase down the crown. These data agree with those of Smith (1972), who reported a decrease in dry needle weight down the crown of Douglas-fir and western hemlock and a general increase with age of needles. On trees from stand I maximum weight of both 1967-formed and older needles appeared to be near midcrown level. Similar data collected on open-grown Douglas-fir revealed significant differences in dry needle weight between upper and lower crown, between old and new needles, and between tall and short trees (Mitchell, USDA Forest Res. Pap. PNW-181:1-14, 1974). In the present study on spruce only the pattern of dry weight of 1967-formed needles in trees from stands II and III was consistent with findings in Mitchell's study. Some of the variability in needle dry weight may be attributed to variation in needle size.

The results of this study provide a general description of the 46-cm branch tip as a collection unit on nondefoliated northern white spruce and may serve to identify some problems inherent in its use for surveys of spruce budworm abundance and damage, such as are encountered when changes in growth pattern occur after budworm feeding. Variability in the collection unit may change with duration and intensity of defoliation. On trees subjected to several years of heavy budworm feeding, the effects of defoliation may alter the normal growth pattern of branch tips differentially down the crown through loss of needles, twig and bud mortality, and stimulation of epicormic shoots (Batzer, Environ. Entomol. 2:727-728, 1973). As an example, in a budworm outbreak near Fort McMurray, Alta., bud numbers on 46-cm tips increased two- to threefold (average 101 ±S.E. 5.7), and subsequently the branch tips grew somewhat three-dimensionally in form. Such a change in branch form may result in increased current-year shoot growths on the 46-cm tip and possibly provide a less meaningful measurement of relative budworm abundance.

Bud numbers per branch tip may be a useful criterion for expressing abundance of second- and third-instar larvae since they initially feed within the buds. Early spring mining of needles has not been observed thus far in northern Alberta. Larval and egg abundance may also be expressed in terms of weight of the 46-cm tip as discussed by Morris (1955).

For most general surveys of the budworm in northern spruce forests, the 46-cm tip as a sample unit is probably adequate and should be taken from the midcrown level of the tree (Miller et al., 1972). However, data in Table 1 indicate that 46-cm midcrown tips from trees of different age are not equal as sampling units with respect to several foliage characters, and caution is therefore necessary in comparing budworm abundance and damage in different stands. When the midcrown level is sampled with conventional pruning tools, this height is convenient to reach in most immature spruce forests, but difficult in mature forests.—H.F. Cerezke, Northern Forest Research Centre, Edmonton, Alta.

Introduction of the Birch Casebearer Parasites *Campoplex* and *Apanteles* into Newfoundland.—The birch casebearer (*Coleophora fuscedinella* Zeller) is native to Europe and was accidentally introduced into eastern North America about 1920 (Gillespie, Maine Forest Serv. Bull. 7,1932). This insect was discovered in Newfoundland in 1953. By 1971 it had spread throughout the Island and has become the most important pest of white birch (*Betula papyrifera* Marsh.) (Raske and Bryant, Can. Entomol. 108:407-414, 1976). The most common damage is the browning of foliage; but, when populations are high, the larvae destroy the flushing buds and may cause twig, branch and sometimes tree mortality.

In 1968 the Canadian Forestry Service, in cooperation with the Commonwealth Institute of Biological Control, initiated a biological control program against the birch casebearer by studying the biologies of European hymenopterous parasite species with the aim of introducing some of these into Newfoundland. Introductions began in 1971 and were terminated in 1975. Details of the releases in 1971 and 1972 have been published (Raske, Nfld. Forest Res. Centre Inf. Rep. N-X-108, 1974), and this report presents data on all the releases and on the recovery of parasite progeny.

The parasite species released in all years were two species complexes: *Campoplex* spp. (Ichneumonidae) and *Apanteles* spp. (Braconidae). The *Campoplex* complex consisted of *C. borealis* and an undescribed species. The *Apanteles* complex included three species: predominantly *A. coleophorae*, and a few each of *A. mesoxanthus* and *A. corvinus* (H. Pschorn-Walcher, unpublished). Living individuals of both species complexes could not be identified; therefore exact numbers of each species released are not known.

Campoplex spp. were released in western Newfoundland (Cormack) in 1971 and in central Newfoundland (Badger) in 1972 to 1975. *Apanteles* spp. were released in eastern Newfoundland (Gambo) in 1974 and 1975 (Table 1). All parasites were released in August, when a high percentage of the host is in the first-instar larval stage, susceptible to the parasite.

In 1974 at Gambo, the parasites *Apanteles* spp. were released onto two trees caged in the same manner as for the 1971 and 1972 releases (Raske 1974). Parasites were released beneath uncaged trees at all other times, but always within 40 m of the trees caged in the previous years.

Birch casebearer pupae were collected at the release site in mid to late July before parasite emergence began, and placed in closed opaque containers for rearing. At Gambo host pupae were collected from four

TABLE 1

Number of parasites released from 1971 to 1975 against the birch casebearer in Newfoundland, and recovery of parasite progeny at the release sites in 1973 to 1975[1]

Locality and year	No. parasites released		No. hosts reared (and parasites recovered)		
			1973	1974	1975
	CAMPOPLEX spp.				
Cormack					
1971	215	179	5278(2)	2344(1)	5329(10)
Badger					
1972	31	26	—[2]		
1973	104	98	—		
1974	291	230		961(0)	
1975	154	144			2053(2)
	APANTELES spp.				
Gambo					
1974	147	114		—	
1975	90	59			202(8)[3]

[1]All parasite progeny identified by W.R.M. Mason, Biosystematics Research Institute, Ottawa.
[2]Dash indicates no host pupae reared.
[3]All from trees caged in 1974.

to five branches of each caged tree. At Cormack and Badger host pupae were collected from two midcrown branches of several trees, 3 m to 5 m high, in the vicinity of trees used for parasite release in previous years.

Only 23 specimens of parasite progeny were recovered from over 16,000 host pupae (Table 1), but each species complex was represented. Members of these parasite genera are strong fliers that disperse well. Therefore low populations may spread over large areas before their numbers increase significantly at a locality, and it may therefore be 2 to 3 years before establishment can be determined and maybe more than 10 years before the effectiveness of the parasites can be evaluated.—A.G. Raske, Newfoundland Forest Research Centre, St. John's, Nfld.

PATHOLOGY

Microflora Associated with Elm Bark Beetle Feeding Niches Suggests Biological Control of Dutch Elm Disease.—In a study by Gardiner (Alternatives in Forest Insect Control, Great Lakes Forest Research Centre, Symposium Proceedings O-P-2, June 1973) the importance of overwintering native elm bark beetles, *Hylurgopinus rufipes* (Eichh.), transmission of *Ceratocystis ulmi* (Buism.) C. Moreau, the causal fungus of Dutch elm disease (DED), was discussed. His results showed that adult beetles that overwinter in the bark on the lower trunks of healthy elms and that feed in the spring in the upper branches are prime suspects in the transmission of *C. ulmi*. No evidence was found to suggest that adults from the overwintering larval group feed in the upper branches in the way the overwintering beetles do.

The importance of the overwintering adult groups in disease transmission warranted further investigation. Consequently, a study was initiated in the spring of 1975 to provide data concerning the incidence of *C. ulmi* and the possible interaction between the pathogen and other microorganisms that might be found in wood surrounding feeding niches made by overwintering adults.

Eighteen apparently healthy elms, 10 to 15 cm dbh, were selected for examination. Nine of the trees were in the City of Fredericton, N.B. (Area 1, Table 1), where a program of sanitation (pruning of dead limbs and removal of dead and diseased trees) was initiated in 1952 to reduce the population of the native elm bark beetle. Also, three trees were examined at each of three locations outside the sanitation area. Area 2 was adjacent to the north boundary of the sanitation area while Areas 3 and 4, Taymouth and Jemseg, were beyond the city limits, 30 km north and 80 km east, respectively.

All trees were cut at ground level, sectioned, transported to the laboratory, and examined during June 1975. The trees were peeled, except for the tips of branches less than 1.5 cm diameter, to reveal feeding niches resulting from the activity of overwintering adults of the native elm bark beetle. All beetle-feeding niches that penetrated the xylem were recorded and a small piece of wood near each wound was excised aseptically and imbedded in 2% potato-dextrose agar in petri dishes. The petri dish culture was then inoculated with *C. ulmi* (F.S.C.-92) opposite the wood chip. The cultures were allowed to grow 1 to 2 weeks, and any evidence of inhibition of growth of *C. ulmi* was measured and recorded. Many fungi from the woodchips grew over *C. ulmi* before it became well established and these were subcultured into plates in which *C. ulmi* was established. Mixed cultures that inhibited *C. ulmi* were separated, and each microorganism was plated separately against *C. ulmi*. Microorganisms that strongly inhibited *C. ulmi* were stored for future work.

The level of bark beetle activity within the sanitation area was markedly different from that found in outside areas. Of the nine trees examined in the sanitation area, five had no feeding niches and four contained a total of 39 niches. Thirty of these wounds were in one tree, which was growing near the bank of the St. John River at the extreme edge of the sanitation area and immediately adjacent to a group of elms infected with *C. ulmi* (DED). By contrast, 854 feeding niches were found in the nine trees examined from the three outside areas (Table 1). These observations are in keeping with those recently reported by Sterner (Bi-mon. Res. Notes 32:20, 1976). His survey revealed that the number of elm beetles in the sanitation area of Fredericton was significantly lower than that found outside the protected area.

Isolation attempts from wood near the 893 feeding niches resulted in growth of 695 isolates of microorganisms of which only 18 were identified as *C. ulmi*. Of the remaining 677 cultures of bacteria and fungi, 97 (14.3%) were found to inhibit the growth in vitro of *C. ulmi* (Table 1). Furthermore, it was noted that most of the 677 microorganisms grew faster than *C. ulmi* in culture. This suggests that many of these organisms may effectively reduce the incidence and spread of *C. ulmi* in nature.

TABLE 1

Number of elm bark beetle feeding niches and type of microorganisms isolated from wood near niches in healthy elms examined from four areas in New Brunswick, June 1975.

			Isolations								
					Unidentified Cultures						
Area	No. of trees	No. of feeding niches	Unsuccessful (sterile)	*C. ulmi*	Fungi	Bacteria	Fungus and bacterium	Two fungi	Two bacteria	Isolates inhibitory to *C. ulmi*
1	9	39	20	1	2	3	12	1	0	4(3)
2	3	78	53	1	2	2	13	2	5	5(4)
3	3	220	43	2	19	21	134	1	0	30(28)
4	3	556	82	14	116	67	252	25	0	58(41)
Total	18	893	198	18	139	93	411	29	5	97

( ) Bacteria.

More recent investigations by Gardiner (Great Lakes Forest Res. Cent., Forest Res. Newsl., 5[4], 1976) revealed that overwintering native elm bark beetle adults carry a significantly greater number of spores of *C. ulmi* than do either adults from overwintering native larvae or adults of the spring flight of the European beetles. This has prompted him to suggest that further control of DED might be accomplished by applying an insecticidal barrier to the lower 2 m of the trunks of healthy elms to prevent overwintering of the native beetles.

The present findings suggest that overwintering adults may be vectors of both antagonists and pathogen or that, at least, their feeding niches may provide entry sites for antagonists. In either instance, it may be possible to further enhance what appears to be natural biological control of *C. ulmi*; i.e. apply either organic nutrients to the lower trunks of healthy elms to encourage growth of naturally occurring antagonists, or heavy concentrations of microorganisms that are highly competitive or antagonistic to growth of *C. ulmi*.—M.A. Stillwell, Maritimes Forest Research Centre, Fredericton, N.B.

Growth of *Cordyceps militaris* in Liquid Shake Culture.—The general culturing of the parasitic fungus *Cordyceps militaris* (L.)

Link and its preparation as a spray to control forest Lepidoptera have been described earlier (Bi-Mon. Res. Notes 29:25, 1973; *ibid.* 32:3, 1976). Additional observations of the behavior of this fungus in liquid shake culture have revealed previously unreported characteristics which possibly contribute to the knowledge of its ecology and potential usefulness in control.

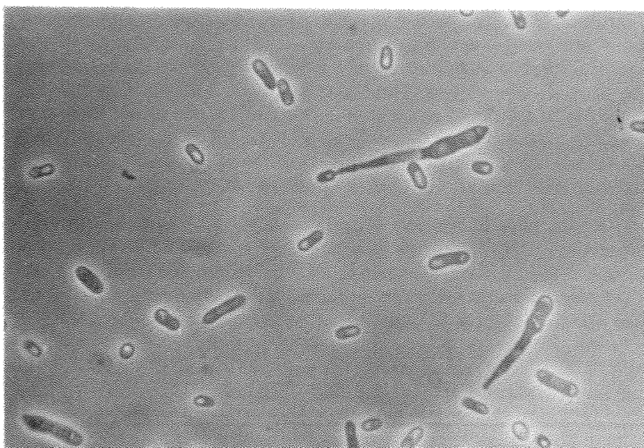


Figure 1. Unicellular growth of *Cordyceps militaris* in shake culture, showing phialoconidia and hyphal bodies with phialides.

Cultures were grown in 3% malt extract, both at 23°C. The mediu was dispensed at 50 ml per 250 ml Erlenmeyer flask and shaken at 120 rpm on a rotary shaker. Blended agar culture was used as the primary inoculum. Comparable results were obtained with Czapek-Dox broth and Sabouraud broth.

Growth in the shake flasks was entirely unicellular in the early phase (3-5 days). The cells were produced as small, rectangular phialoconidia (4-6 x 2 µ). The phialoconidia enlarged to form hyphal bodies that were usually constricted in the middle and measured 10-12 x 3 µ. Phialides were then formed on the hyphal bodies and the process was repeated (Fig. 1). No true budding was noted, and apparently all cells were produced as phialoconidia. The phialides continued to elongate and formed hyphal strands, which became polyphialidic.

Shake flasks inoculated with a single loopful of cells from a fresh shake flask produced an average of 2.6 x 10^6 cells/ml in 3 days. The unicellular growth was not tested for infectivity in insects.

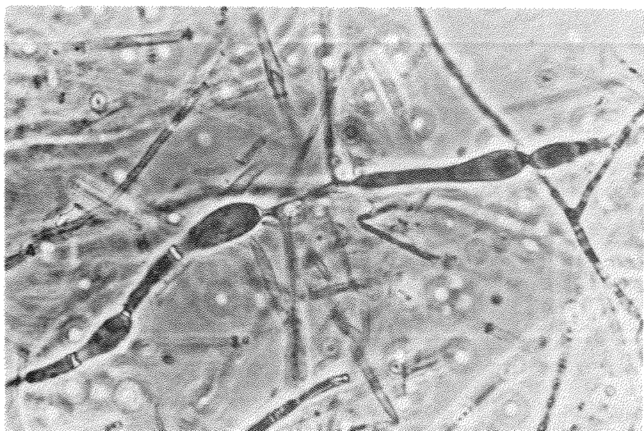


Figure 2. Ampulliform hyphae of *Cordyceps militaris*.

Ampulliform hyphae (Fig. 2) were produced in later stages of growth (2-3 weeks). They consisted of a series of enlargements in the hyphal strands and were separated by heavy septa. They were also formed in agar culture and might represent the early stage of chlamydospore formation. Densely stromatic hyphal pellets were also formed in the later stages of shake culture.—A. Funk, Pacific Forest Research Centre, Victoria, B.C.

Monoammonium Scytalidamate (MASA): a Fungitoxic Water-soluble Preparation from Scytalidin.—Scytalidin, I, a metabolite of *Scytalidium* sp. (Strunz et al., J. Chem. Soc. Perkin Trans. 1:2280, 1972; Overeem and Mackor, Rec. Trav. Chim. Pays-Bas 92:349, 1973) has been shown to be active in vitro against a wide spectrum of fungi, including *Ceratocystis ulmi*, the fungus associated with Dutch elm disease, as well as many organisms that cause stain and decay of pulpwood chips in outside storage (Stillwell et al., Can. J. Microbiol. 19:597, 1973).

The solubility of scytalidin in water at ambient temperature is low and, for further biological evaluation, a water-soluble modification of the metabolite retaining activity against the above microorganisms was required. Material produced by reaction of scytalidin with liquid ammonia, as described below, is believed to consist mainly of a mixture of "monoammonium scytalidamates," designated MASA, and possesses the desired solubility characteristics and fungitoxic properties.

In a typical preparation, liquid ammonia (ca. 15 ml) was distilled into a two-necked flask containing scytalidin (100 mg). The mixture, when stirred under reflux (dry-ice condenser, soda-lime drying tube) for 90 min, gave a cloudy white suspension. The ammonia was then allowed to evaporate, its removal being facilitated by a stream of nitrogen and, finally, by vacuum. The absence of unreacted starting material was demonstrated by thin-layer chromatography analysis of the colorless crystalline product. Evidence that a major component of the product mixture retains one intact anhydride function is found in the infrared (KBr) spectrum, which still shows the appropriate absorptions at 1,845 (w), 1,825 (w), and 1,767 cm^{-1}, besides bands at lower frequencies attributable to amide and carboxylate functionality.

Further support for this conclusion is found in the observed nitrogen content, 7.8% (calculated for monoammonium scytalidamate, $C_{22}H_{34}N_2O_7$, 6.39%; for diammonium scytalidamate, $C_{22}H_{40}N_4O_7$, 11.86%).

The most abundant ion in the high mass region of the mass spectrum at m/e 403 is interpretable in terms of the imide resulting from pyrolysis of a (mono) ammonium "amic acid" salt. (Such a transformation can also be effected by refluxing MASA in toluene.)

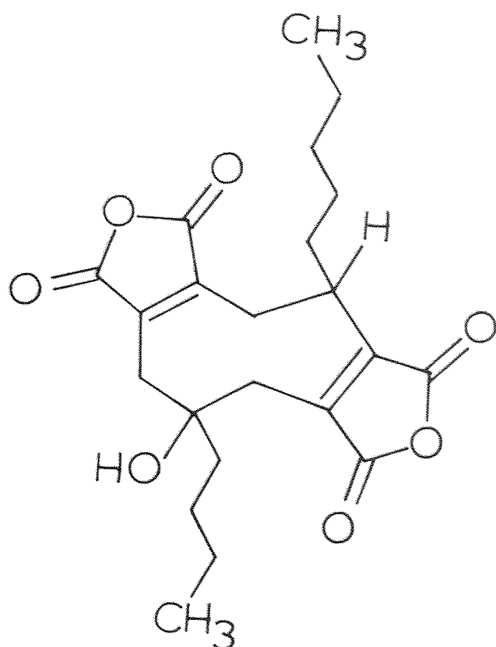
Four isomeric monoammonium scytalidamates, IIa, IIb, IIIa, and IIIb, are theoretically possible, and MASA may comprise a mixture of all four isomers (Fig. 1). Furthermore, four additional species may result if both anhydride groups undergo reaction with ammonia: the presence of such compounds as minor products appears likely. Chromatographic studies were not informative with respect to these possibilities.

The survival of one anhydride group under ammonolysis conditions may be due to polar and/or solubility factors. Undoubtedly, by altering reaction conditions, e.g. by the use of cosolvents, the composition of the ammonium scytalidamate mixture can be altered.

Solutions of MASA (50 mg) in water (50 ml) gave pH readings of 7.0 ± 0.2. On gradual addition of 1N HCl, negligible turbidity (precipitation) was evident until the pH dropped below 5.8.

After adjustment of the pH to ca. 1, the suspension was stirred thoroughly for several minutes and was then extracted with chloroform. Crude scytalidin could be recovered from the extracts in high yield.

The results of the biological evaluation of MASA will be published in a future communication by M.A. Stillwell et al.—G.M. Strunz, P. Kazinoti, and W.Y. Ren, Maritimes Forest Research Centre, Fredericton, N.B.



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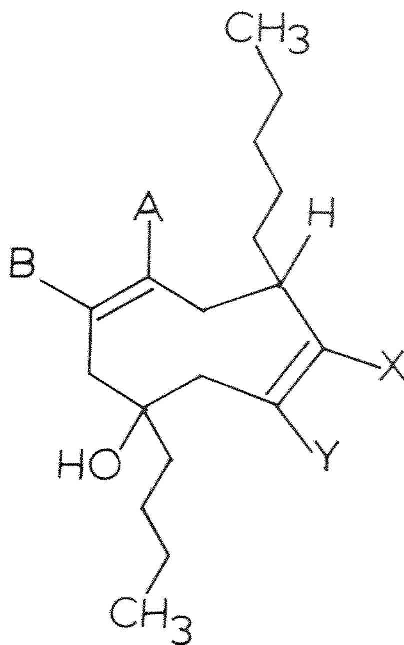

II, III

Figure 1. II A,B= -CO.O.CO-
(a) X= $CONH_2$
Y= $COO^-NH_4^+$
(b) X= $COO^-NH_4^+$
Y= $CONH_2$

III X,Y = -CO.O.CO-
(a) A = $CONH_2$
B = $COO^-NH_4^+$
(b) A= $COO^-NH_4^+$
B= $CONH_2$

A Six-year Summary of Four Years of Field Experiments with MBC-P Solutions to Control Dutch Elm Disease.—Since Dutch elm disease (DED) was discovered in Europe in 1919, many hundreds of fungitoxicants have been screened for use in control of the disease. However, it was not until the discovery of benzimidazole and related compounds in the late 1960's that direct chemical control of *Ceratocystis ulmi* (Buism.) C. Moreau became a real possibility. Laboratory and preliminary field experiments on this group of compounds in the late 1960's provided very encouraging results. With the realization that chemical compounds injected into elms must be wholly water soluble for maximum effectiveness, several water-soluble salts of Methyl-2-benzimidazole carbamate (MBC) were formulated (Kondo et al., Can. J. Forest Res. 3(4):548-554, 1973). This note is a 6-year summary of the first 4 years of field experiments conducted by staff of the Great Lakes Forest Research Centre (GLFRC) to evaluate MBC-phosphate (CFS-1020)(Lignasan-P, DuPont of Canada®), one of the water-soluble salts of MBC, as a means of controlling DED directly.

A summary of the condition of elms injected with various concentrations of MBC-P aqueous solutions (250 to 1,000 ppm) during the period of chemical effectiveness in the tree is presented in Tables 1 and 2. All elms were injected, as described earlier (Kondo and Huntley, Can. For. Serv. Inf. Rep. 0-X-182, 1973), with prescribed dosages of MBC-P solution (Kondo and Huntley, Can. For. Serv. Rep. 0-X-235 and 0-X-237, 1975). The Disease Index (DI) employed was according to Kondo and Huntley (Can. For. Serv. Inf. Rep. 0-X-201, 1974). All except three elms in Tables 1 and 2 were *Ulmus americana* L. and all were considered high-value, mature shade and street trees.

On the assumption that MBC-P functions in injected elms solely as a fungitoxicant, the period of chemical effectiveness was established as two growing seasons for root injections (Kondo, Can. For. Serv. Inf. Rep. 0-X-171, 1972) and one growing season for root-flare or flare injections (Kondo and Huntley, Can. For. Serv. Rep. 0-X-235, 1975). The period of chemical effectiveness was established from extensive bioassay and chemical analysis of samples obtained from elms injected with MBC-P solutions over a 6-year period. Approximately 50% of the 438 elms in Table 1 were sampled at one time or another for chemical distribution during the last 6 years. It is important to emphasize that, although we have made a simplistic assumption, we recognize that properties of the chemical other than its fungitoxicity may be contributing to, or causing, the results reported in this note.

Table 1 includes only elms that have been injected and monitored by trained crews supervised by GLFRC research staff. All injected elms were assessed the year after treatment before the period of disease manifestation but after leaf expansion. Losses were therefore based on the condition of the trees following overwintering. Damage to elms from DED in the fall and winter cannot be assessed until growth resumes the following spring. It is evident that no healthy elm that was root injected or root-flare injected became naturally infected during the period of chemical effectiveness. The control elms associated with the elms treated usually became infected at a rate similar to the infection rate for that particular area. This varied from approximately 5% to 40%, depending on the year and the area.

Table 1 also shows that of 119 diseased elms with a DI of less than 50 that were root-injected with MBC-P only nine were lost to DED during the period of chemical effectiveness. However, detailed examination of the data collected revealed that all nine of these elms had little chemical distribution. Eight of the losses were attributed directly to poor injection techniques by one crew early in the injection season in 1973, and the other loss was attributed to little or no chemical uptake owing to the wetness of the site. The injection data of the past 6 years generally confirm the observation that weather and site greatly affect uptake of chemical solution (Kondo and Huntley, Can. For. Serv. Rep. O-X-182, 1973). However, the long-term availability of water to elms greatly overrides short-term weather conditions as a factor influencing uptake and distribution of chemical solution. Consequently, chemical uptake and distribution in elms can vary greatly from one geographic location to another.

With root-flare injection of healthy elms there was no apparent infection of treated elms during the period of chemical effectiveness. It is interesting to note from additional data not presented here that, with repeated yearly flare injections of healthy elms, the treated tree appears

TABLE 1

Condition of elms injected by research crews with MBC-P during the period of chemical effectiveness

Year treated	Injection method	No. of elms treated: Healthy DI=0	No. of elms treated: Diseased DI ≤50	No. of elms treated: Diseased DI>50	Total no. of elms treated	No. of elms lost[a] to DED during period of chemical effectiveness[b]: Healthy DI=0	Lost: Diseased DI ≤50	Lost: Diseased DI>50
1971	(a) root	12	—	1	13	0	—	1
1972	(a) root	—	31	49	80	—	0	18
1973	(a) root	40	80	23	143	0	8[c]	18
	(b) flare	—	10	—	10	—	7	—
1974	(a) root	29	8	1	38	0	1[d]	1
	(b) flare	145	9	—	154	0	4	—
Totals		226	138	74	438	0	20	38

[a]"Lost" means the elm had little aesthetic value, owing to DED; however, the elm was not necessarily dead. In the case of healthy elms, "lost" means "became infected naturally with DED."
[b]Period of chemical effectiveness (a) Root injection — 2 years (year of injection plus the following year)
(b) Flare injection — 1 year (the year of injection only)
[c]The eight losses were traced to poor chemical distribution resulting from poor injection techniques employed by one crew during a 3-day period.
[d]Loss resulted from little or no chemical uptake because of the site on which the elm was located.

TABLE 2

Condition of elms injected with MBC-P by arborists trained at the first OSTC elm-injection course

Year treated	Injection method	No. of elms treated: Healthy DI=0	No. of elms treated: Diseased DI≤50	No. of elms treated: Diseased DI>50	Total no. of elms treated	No. of elms lost to DED during period of chemical effectiveness: Healthy DI=0	Lost: Diseased DI≤50	Lost: Diseased DI>50
1974	Commercial arborists[a]							
	(a) root	2	1	—	3	0	0	—
	(b) flare	27	22	4	53	0	0	4
	(c) combination (a+b)	14	24	4	42	0	0	2
1974	Government agencies[b]							
	(a) root	35	6	1	42	0	0	1
	(b) flare	23	1	—	24	0	0	—
	(c) combination (a+b)	12	8	1	21	0	4	1
Totals		113	62	10	185	0	4	8

[a]Two commercial arborists located in the Ottawa area.
[b]Government agencies include cities of Ottawa, Kingston and Hamilton and Niagara Parks Commission.

to be continuously protected against natural infection, regardless of when the first injection was made during the injection season, provided that it was reinjected before the end of June of the following year.

Table 1 shows that treatment of diseased elms with a DI greater than 50 usually results in high losses even during the period of chemical effectiveness. Generally the diseased elm appears to respond to treatment in the first year but gradually declines in spite of repeated injections. However, if enough chemical solution is injected yearly into the diseased elm through severed roots, the tree can be maintained, although each year more of the elm succumbs to the disease. Eventually the elm reaches a point at which it has little or no aesthetic value owing to the yearly necessity of pruning back branches with DED symptoms.

Root-flare injections of diseased elms with a DI of less than 50 usually resulted in relatively high losses during the period of chemical effectiveness in spite of repeated yearly treatment. Eleven of the 19 diseased elms were lost within the period of chemical effectiveness. No root-flare injections of diseased elms with a DI greater than 50 were carried out.

Injected elms that were not reinjected gradually returned to the degree of susceptibility to natural infection considered normal for that particular area after the period of chemical effectiveness. In general, by the second or third year after injection, the rate of natural infection of these formerly protected elms had approached a level similar to that of untreated elms in the vicinity. Thus, the importance of a continued reinjection program cannot be overemphasized, once the decision is made to inject the elm.

The first Ontario Shade Tree Council (OSTC) elm injection course employing MBC-P was given on July 15, 1974. Seven commercial arborists and ten individuals representing eight government agencies were trained in the proper use of MBC-P for direct control of DED. Eight groups from the 1974 course treated a total of 185 elms in 1974. The others did not begin elm injections until the spring of 1975. The results of their efforts are presented in Table 2 and are generally similar to those presented in Table 1 for root and root-flare injections. Although emphasis was placed on root injections, more elms were injected by commercial arborists by the root-flare method, reflecting the greater effort and costs required in root injections.

Table 2 contains a category of injection termed "combination," which comprises partial root injection and root-flare injection, i.e. a combination of the two methods of injection, involving root injection of

only the most accessible roots and root-flare injection in the remainder of the elm. Detailed examination of the data collected suggests that the greater the number of roots injected the greater the chances of arresting DED symptoms in elms with a DI of less than 50. Elms injected by trained commercial arborists and government groups have been monitored, and approximately 40 elms have been sampled for chemical distribution during and after the period of chemical effectiveness. With some minor exceptions the injections of elms by individuals attending the OSTC courses are of a high caliber.

Many cases of arrest of DED symptoms following root injection of MBC-P in diseased elms with a DI of less than 50 at the time of treatment have been documented. These elms continue to be monitored for recurrence of the disease. In each case of total remission of the disease, the arrest of symptoms occurred in the initial year of treatment. Subsequent reinjections were undertaken as a precaution against reinfection because these elms are all located in areas of high disease incidence.

The success rate for protection or arrest of DED with MBC-P injections is much higher with smaller elms (dbh less than 30 cm) than with relatively large elms (dbh greater than 90 cm). However, smaller elms tend to succumb to DED much more rapidly than relatively large elms if injected improperly. Larger, slow-growing elms generally take several years to succumb to DED even with no treatment.

The results to date suggest that there is a good chance of successful treatment of diseased elms if the correct amount of chemical is properly root injected as soon as symptoms appear. The chances of success appear to diminish with the severity of the disease in the tree. Little or no hope of recovery from DED can be expected from treatment of elms with a DI greater than 50 or elms infected for a number of years before treatment. Also, the results show that healthy elms can be protected from natural infection if properly root injected and/or root-flare injected.

More research is required to establish the exact mode of action of MBC-P injections. It is obvious that the fungitoxic property of the chemical alone is insufficient to account for the high rate of success.

Injection of elms is a time-consuming and costly operation and should therefore be considered only a part of an integrated DED control approach. Consequently, it is important to undertake and maintain such practices as sanitation, spraying with insecticides and pruning of elms on a regular basis.—E.S. Kondo, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

FOREST PRODUCTS

A Method for Differentiating Heartwood and Sapwood in Unseasoned Timber.—Initially, young tree stems are composed entirely of sapwood. As the stem increases in diameter, however, the wood in the central region becomes separated farther and farther from the bark, and the living cambial tissue eventually undergoes physiological changes and ultimately becomes heartwood. The process of transformation to heartwood is accompanied by changes in the nature and amounts of chemical extractive substances in the wood. In some species, the chemical changes associated with heartwood formation darken the color of the wood so that the demarcation between sap and heart is readily apparent (cedars and oaks for example). In other species such as Douglas-fir and some of the pines, the difference is less pronounced but still usually visible. In still other species (spruces and poplars for example), there is no apparent difference between the two zones.

From a technological point of view, the most important differences between heartwood and sapwood are probably the differences in natural resistance to decay and in permeability. Natural resistance to decay often increases in heartwood (markedly in some species such as the cedars and white oaks) because certain heartwood extractives are toxic to microorganisms to some degree. Permeability, on the other hand, usually decreases in heartwood because many of the pathways in the fine structure of wood become blocked by encrusting substances. A means of distinguishing between sapwood and heartwood is important: the differences in permeability between these two types of material influence not only the treatability

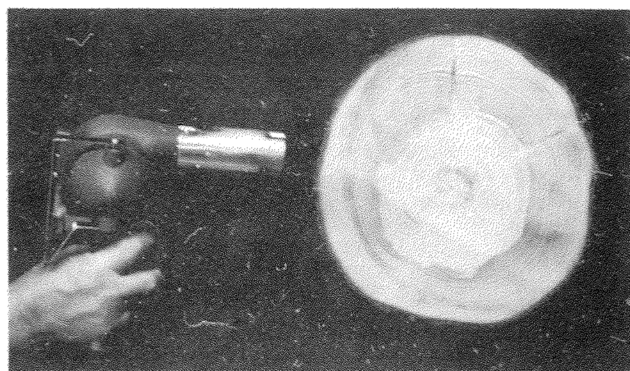

Figure 1. Heat gun being used to differentiate sapwood and heartwood on spruce disk.

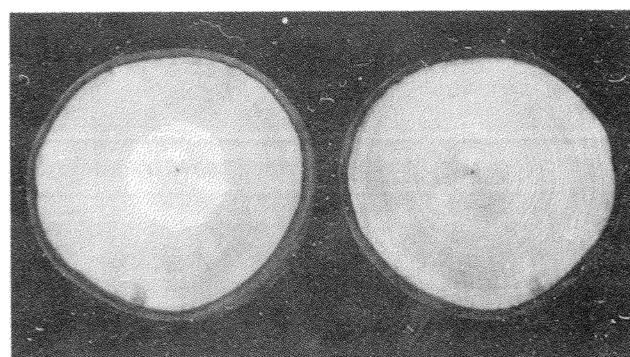

Figure 2. Adjacent sections from a poplar stem. Heartwood zone in left section revealed by heat-gun treatment.

of wood with preservative or fire-retardant chemicals, but also the rate at which moisture can move out of the wood and hence its seasoning behavior.

As reported by G.M. Barton (Can. Forest Ind. 93[2]:57-62, 1973), chemical color indicators have been developed to distinguish between sapwood and heartwood in some species such as the pines and western hemlock. Unfortunately these do not work at all for other species.

Some years ago, a technique was developed in this laboratory for differentiating heartwood and sapwood in stem cross sections of trembling aspen. The method consisted in fanning the surface of a disk (end-grain surface of wood) with the flame of a bunsen burner. The heartwood zone soon begins to dry on the surface and contrasts with the sapwood, which remains moist. This happens presumably because the heartwood, with its lower permeability, is unable to conduct moisture to the surface rapidly enough to prevent surface drying. The method is used with wood in the green condition. If some drying has taken place, the material is soaked in water before the sapwood-heartwood determination is made.

We have subsequently extended the use of this method to other species and have found that it can be used successfully for a variety of both softwoods and hardwoods. We have also found that the differential surface drying effect can be accomplished in a number of different ways. For example, we have used the warm air stream in a cross-circulation laboratory oven. We have used a portable electric room heater, an electric hair drier, and even the warm summer sunshine—simply exposing moist disks on an outside window ledge. Very recently we tried a commercial heat gun (temp $> 150^{\circ}C$) and found it to be the fastest and most effective technique observed thus far. This gun is shown in Fig. 1 being used to bring out the sapwood-heartwood boundary in white spruce. Fig. 2 shows adjacent

sections of a poplar stem after exposure of the left-hand section to heat-gun treatment. We believe that the technique described here establishes a basis on which a commercial system could be developed to segregate freshly sawn timber as essentially heartwood or sapwood where such separation is important for subsequent drying or other treatment.—C.T. Keith, Eastern Forest Products Laboratory, Ottawa, Ont.

RECENT PUBLICATIONS—MAY-JUNE 1977

12 **Barrett, J.D. 1976.** Effect of crack-front width on fracture toughness of Douglas-fir. Eng. Fract. Mech. 8:711-717. Pergamon Press.

12 **Barrett, J.D., and R.O. Foschi. 1977.** Shear strength of uniformly loaded dimension lumber. Can. J. Civ. Eng. 4(1):86-95.

11 **Dangerfield, J.A. 1975.** Mycorrhizae-plant relationships. Proc. Int. Plant Propagators' Soc. 25:105-111.

13 **Desai, Raman L., and Allan J. Dolenko. 1975.** Solvent supply uncertainly spurs research into water-based systems. Can. Paint & Finishing. Aug. 1975.

14 **Dhir, N.K. 1975.** Stand, family and site effects in upper Ottawa valley white spruce. USDA Forest Serv., Gen. Tech. Rep. NC-26:88-97.

11 **Dyer, E.D.A., and L. Safranyik. 1977.** Assessment of the impact of pheromone-baited trees on a spruce beetle population (Coleoptera: Scolytidae). Can. Entomol. 109: 77-80.

12 **Giwa, S.A.O., and Eric. P. Swan. 1975.** Heartwood extractives of a western larch tree (*Larix occidentalis* Nutt.). Wood and Fiber 7(3):216-221.

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