bi-monthly research notes

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Vol. 30, No. 2, MARCH-APRIL, 1974.

Environment Canada | Environnement Canada

Forestry Service | Service des forêts

bi-monthly research notes

"A selection of notes on current research conducted by the Canadian Forestry Service and published under the authority of the Minister of the Department of the Environment. A French edition is published under the title of Revue Bimestrielle de Recherches".

ENTOMOLOGY

Test with a Highly Concentrated Low-volume Formulation of *Bacillus thuringiensis* Against Spruce Budworm.—Prior field tests have shown *Bacillus thuringiensis* will control damage by spruce budworm (Smirnoff *et al.*, Can. J. For. Res. 3:228-236, 1973; Smirnoff, Fettes and Desaulniers, Rapp. Inf. Q-X-31, 1973). However, due to the relatively high cost and the quantity required for application (2 gal/acre), the possibility of spraying vast forest territories with *B. thuringiensis* has been considered problematic.

Results of 1972 experiments revealed larval mortality was satisfactory in areas that received a spray deposit of 0.4 gal/acre. Studies were then started to develop a low volume formulation containing the necessary potency required to kill spruce budworm and reduce loss through evaporation during application. A formulation was developed by the Laurentian Forest Research Centre in cooperation with Abbott Laboratories. Although we cannot reveal details of this formulation, it can be mentioned that it is composed of a concentrated *B. thuringiensis* cell cream, a high specific gravity spray adjuvant, and Chevron spray sticker®. Five milligrams per acre of the enzyme chitinase were added to the formulation. Potency of this information was 13.6×10^9 I.U. per gallon of final spray. It was tested in the field in 1973 at 0.5 gal/acre. Results are reported herein.

Three hundred acres of balsam fir, of which 90% was mature, infested by budworm for the fourth consecutive year were sprayed from the air from a twin engined CL-215 (loading capacity 2,000 gallons) and a TBM Avenger (loading capacity 625 gallons). Both aircraft were equipped with a conventional boom and nozzle spray system capable of producing droplets of 70 to 250 microns diameter. Nine sample plots were established in the area to be treated and eight in the control area.

Before spraying only 29% of the current year's shoots and 1% of the 1972 foliage were present on trees. The budworm population prior to treatment was 34 larvae per 18-inch branch tip in both areas. Thus, foliage conditions were poor and with the high larval population present it could be foreseen that foliage protection was impossible. However, it was hoped that the experiment would determine if the low dosage used might be sufficient to control the larval population.

Sprays were applied on June 6th when 6% of the larvae were in the second instar, 87% in the third and 7% in the fourth. Deposit was assessed by the use of petri dishes containing nutrient agar and Kromekote papers. Analyses of samples revealed that coverage was good: 1,400 *B. thuringiensis* colonies were present per petri dish (68 cm^2). In this trial, 23 droplets per cm^2 were found on test papers compared to 32 droplets per cm^2 in 1972 trial. The volume deposited was 0.17 gal/acre compared to 0.37 gal/acre in 1972; evaporation was 66% and 81% in 1973 and 1972 respectively. It should be noted, in 1972 spray rate was 2 gal/acre, but the spray rate was only 0.5 gal/acre in 1973.

Post-spray counts of the population were made 5, 12, and 22 days after treatment at which time average larval mortality was 32%, 44%, and 83% respectively. Effectiveness of the treatment determined at the last count after adjustment for check mortality (using Abbott's formula) was 70%. Average mortality in the control plots was 44% at the last count.

Fourteen days after treatment 58% of the current year's shoots that were present prior to spraying were preserved in the treated area, but all current year's shoots were destroyed in the control areas. This protection could be most important during the period of active tree growth, as the current year's shoot are of prime importance in the accumulation of energy reserves. Due to the high larval population, the residual foliage was finally destroyed, but no trace of backfeeding was observed in the treated area while backfeeding was severe throughout the control area.

Egg-mass counts in August indicate low to severe defoliation in 1974 in the treated areas.

As in previous experiments, the *B. thuringiensis* and chitinase formulation provoked an active disease in larvae of *C. fumiferana* characterized by a strong reduction of the vital resources of the insect. These pronounced metabolic perturbations affect fecundity and numbers of the following year's population.

The 1973 experiment showed that an application of 0.5 gal/acre of a *B. thuringiensis* formulation was sufficient to considerably reduce spruce budworm numbers. In fact, larval mortality and the metabolic perturbations in residual populations were the same as those observed with an application of 2 gal/acre of the *Bacillus* in 1972.

In order to protect foliage with this new formula of *B. thuringiensis*, a sufficient quantity of foliage must be present on trees and spruce budworm populations should not exceed 25 larvae per 18-inch branch tip.—W. A. Smirnoff, Laurentian Forest Research Centre, Canadian Forestry Service, Ste-Foy, Quebec; L. V. Larson, Abbott Laboratories, North Chicago, Illinois, U.S.A.; A. Juneau and J. Valéro, Laurentian Forest Research Centre, Canadian Forestry Service, Ste-Foy, Quebec.

Interaction Between Three Parasites of the European Pine Shoot Moth.—Screening of exotic parasites as candidates for introduction into Canada to control the European pine shoot moth [*Rhyacionia buoliana* (Schiff.)] is done to detect hyper- or cleptoparasitic tendencies. Our concern with this aspect of screening is justified by the work of Arthur, Stainer and Turnbull (Can. Entomol. 96:1030-1034, 1964) on the ichneumonid, *Temelucha interruptor* (Grav.) and the braconid, *Orgilus obscurator* (Nees). They proved that *T. interruptor* is a cleptoparasite that shows a predilection for hosts already parasitized by *O. obscurator*, the most common, widespread and effective internal parasite of *R. buolina* in Ontario. Unfortunately, *T. interruptor* had been introduced by the thousands into Canada and the United States (Arthur and Juillet, Can. Entomol. 93:297-312, 1961) before its cleptoparasitic behavior was discovered. As an illustration of the effects of this cleptoparasite, the results of dissection of a routine sample of shoot moth from the Elmira, Ont., area in the fall of 1973 are shown in Table 1. No statistical interpretation of these data is necessary. Since *T. interruptor* always prevails in competition with *O. obscurator*, *T. interruptor* clearly has had a devastating effect on *O. obscurator*.

A nonspecific bethylid ectoparasite, *Parasierola nigrifemur* (Ashmead), of shoot moth has been successfully released in Argentina, where it apparently caused significant mortality of the pest (Brewer and Varas, Rev. Per. Entomol. 14:352-361, 1971). In June 1973, 27 specimens were received at the

TABLE 1

Numbers of shoot moth larvae with and without *O. obscurator*, that were attacked, or not attacked, by *T. interruptor* in the field, Elimra, 1973

	T. interruptor		
	Attacked	Not Attacked	Total
Hosts with *O. obscurator*	64	71	135
Hosts without *O. obscurator*	0	185	185
Total	64	256	320

Elmira Field Establishment, Waterloo County, Ont. and successfully reared on large and small shoot moth larvae throughout the summer. In October 1973, 26 more parasites were received at the Great Lakes Forest Research Centre, Sault Ste. Marie, Ont. These and their progeny were used to determine whether *P. nigrifemur* behaved cleptoparasitically towards *O. obscurator*, although Brewer and Naumann (Acta zool. lilloana 26:129-144, 1970; 26:157-178, 1971) indicated that it showed no such tendencies towards endoparasites in Argentina. Half-grown shoot moth larvae from the Elmira area were reared on artificial medium as described by Syme and Green (Can. Entomol. 104:523-530, 1972) until they reached the fifth or sixth instar. At this stage, *O. obscurator*-infested larvae can be separated from normal larvae by weight (Syme and Green, *loc. cit.*). Thirty-four female *P. nigrifemur* were each confined with one large, healthy, shoot moth larva and one small, presumably *O. obscurator*-infested larva for 2-3 days. Some of these were reconfined with fresh hosts up to five times. In 21 cases, there was attack with oviposition on at least one of the pair. All hosts were dissected to confirm the presence or absence of *O. obscurator* and the results are shown in Table 2.

TABLE 2
Numbers of shoot moth larvae with and without *O. obscurator*, that were attacked, or not attacked by *P. nigrifemur* in the labortary, 1973

	P. nigrifemur		
	Attacked	Not Attacked	Total
Hosts with *O. obscurator*	11	4	15
Hosts without *O. obscurator*	10	17	27
Total	21	21	42

Chi-square is 3.73, $P > 0.05$, indicating that there is no selection by *P. nigrifemur* for or against *O. obscurator*-infested hosts. From these results and those of Brewer and Naumann (*loc. cit.*) we can conclude that if *P. nigrifemur* is introduced into Ontario in an attempt to control shoot moth, it will have no detrimental effects on *O. obscurator*, the most effetcive established parasite of this pest.—Paul D. Syme, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

Molecular Vibration and Insect Attraction: *Dendroctonus rufipennis.*—If non-toxic, behavior-controlling chemicals are to become useful supplements to or substitutes for conventional pesticides, the availability, efficacy and cost will be dominant considerations. Two methods have hitherto been used to identify potentially useful substances.

The first and simplest method is to expose a diversified selection of chemicals in traps in the field and to retest those chemicals that show indications of biological activity. Some effective attractants have been found in this way, e.g. for the Mediterranean fruit fly [*Ceratitis capitata*, (Wied.)]. This method was not successful for tests with 100 chemical compounds near Lake Cowichan, B.C., which failed to yield a single one with any sign of attractancy for scolytid or other beetles although there were many in the area (Chapman and Wright, Interim Res. Rep., Forest Entomology and Pathology Laboratory, Victoria, B.C., May, 1964).

The second method is to isolate, identify and then synthesize the natural sex pheromone or host emanation to which a given species responds. This has been spectacularly successful in a few cases, but it is necessarily a lengthy, expensive process and the resulting compounds are usually complex and costly.

Neither method gives any insight into the molecular basis of the biological specificity so that no general, chemical relationships have emerged from a great amount of meticulous analytical and chemical work. There is however, evidence that the olfactory specificity of a chemical compound is related to the low-frequency vibrations of its molecules (R. H. Wright, Proc. N. Y. Acad. Sci., Conference on Odor, Oct. 1, 2, 3, 1973. in press). The frequencies in question are most readily charted by recording the far infrared absorption spectrum of a compound.

When frontalin (1,5-dimethyl-6,8-dioxabicyclo- [3.2.1] octane) was identified as an aggregating pheromone for some species of *Dendroctonus* (Kinzer *et al.*, Nature 221: 477-478, 1969; Dyer and Chapman, Bi-Mon. Res. Notes 27: 10-11, 1971), its far infrared spectrum was recorded in the region 500 to 130 cm^{-1} using a Perkin-Elmer Model 301 Far Infrared Spectrophotometer with the sample dissolved in benzene. Nine well-defined absorption maxima were found at the positions shown in Table 1, and a tenth rather weak one was found near 330 cm^{-1}.

Four compounds with some degree of spectral similarity to frontalin, as shown in Table 1, were selected for field testing near Hixon, B.C., during the summer of 1973. All were dispensed in 1 ml polyethylene vial caps. Three different testing methods were used to have a variety of environmental sites and beetle populations. Although all tests were made in the vicinity of mature *Picea - Abies* forests, no host trees (*Picea*) were closer than 20 m from any position of chemical testing. The object of the experiment was to demonstrate the practical usefulness of far infrared spectra in selecting candidate attractants.

Table 2 shows the total catch over a period of 6 weeks, using 12 x 12 inch (30.5 x 30.5 cm) glass barrier traps mounted at breast height, 66 feet (20.1 m) apart, on four sides of non-host trees (*Abies*) and with the chemicals exposed in polyethylene caps. This method was used to avoid any secondary attraction that might arise if host trees were attacked by the beetles. Three replicates of each chemical were used.

Also shown are the results of a second experiment, lasting 4 weeks, with glass barrier traps placed 50 feet (15.2 m) apart on top of convection boxes with black polyethylene sides and screened tops so that air convected upward into and through the traps. The chemicals were moved each week to a new random distribution of the boxes.

Finally, Table 2 shows the results of a test in which the *Dendroctonus* were handpicked from six vertical canvas sleeves about 10 feet (3 m) high, through which air was driven upward by fans. Four tests, lasting 1 hr each, were made when the temperature exceeded about 21 C. As these were done where beetle flight was relatively weak, the results may be less significant than the others.

Ortho-phenyl anisole, or methyl diphenyl ether as it is commonly known in the perfumery trade, appears to be approximately comparable to the pheromone itself under the conditions of the test; that is, in the absence of any secondary attraction from infested host trees. Figure 1 shows its chemical and stereochemical configuration with that of frontalin. Clearly, none of the usual criteria of molecular similarity would have led to it being selected for test, which emphasizes the special value of the far infrared spectroscopic properties.

The other three candidates show some biological activity when air is circulated through the traps. This emphasizes an important distinction between intrinsic attraction and the strength of the attractant effect, which will normally depend upon volatility and chemical stability of the substance and which is not related to attractiveness *per se*. The success achieved with only four candidates is in striking contrast to the total failure of the 1963 experiments in which the 100 chemicals of unknown molecular-vibrational characteristics were used. Furthermore, the simplicity and commercial availability of methyl diphenyl ether in drum lots at a cost of about $1.50 per pound show that complexity and cost are not necessary attributes of insect pheromone-mimics.

TABLE 1
Far Infrared Resemblance of Selected Compounds to Frontalin

	cm^{-1}									
Frontalin	176	242	284	296	330	358	396	439	474	493
Methyl diphenyl ether	—	246	—	295	322	350	—	444	—	491
Methyl 2-naphthyl ketone	170	236	—	—	321	360	404	—	473	—
Menthyl acetate	—	—	287	299	330	360	396	442	475	—
Thujamber (8, 14 Cedran oxide)	177	246	285	—	323	—	—	—	—	—

TABLE 2
Results of Field Bioassays

		Glass Barrier Traps	Traps with Convection Boxes	Traps with Forced Circulation
	male	9	42	14
Frontalin	female	10	50	21
	total	19	92	35
Methyl	male	82	9	27
diphenyl	female	33	17	4
ether	total	115	26	31
Methyl	male	0	3	11
2-naphthyl	female	1	2	4
ketone	total	1	5	15
Menthyl	male	1	1	10
acetate	female	0	4	0
	total	1	5	10
Thujamber	male	0	7	16
	female	0	5	7
	total	0	12	23
No chemical	male			1
	female	—	—	0
	total			1

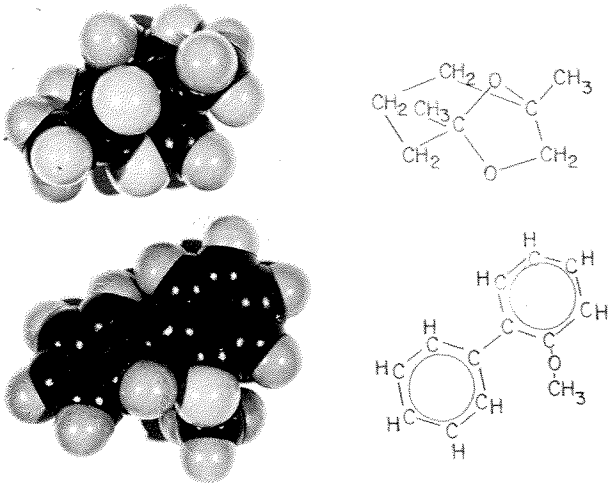

Figure 1. Frontain (upper) and methyl diphenyl ether (lower) have little if any structural or steric resemblance likely to suggest a similarity in their ability to attract *Dendroctonus rufipennis*.

At the same time, it is important to recognize that intrinsic attractancy and cost are not the only criteria of really useful compounds. It depends upon the conditions of use. A compound that caught 25 or more insects in the first week and none thereafter might be rated "stronger" or "weaker" than one that caught 5 per week for five or more weeks.

Taken in conjunction with other predictive successes of the theory (Wright, Israel J. Entomol. 4:83, 1969; Can. Entomol. 103:284, 1971; Wright, Chambers, and Keiser, Can. Entomol., 103:627, 1971; Wright, and Brand, Nature, 239:225, 1972), far infrared (vibrational) spectra can be usefully employed in the development of selective insect attractants.—R. H. Wright, 6822 Blenheim St., Vancouver, B.C., John A. Chapman and E. D. A. Dyer, Pacific Forest Research Centre, Environment Canada, Victoria, B.C.

FIRE

Effect of Duff Weight on Drying Rate.—The Duff Moisture Code (DMC) of the Fire Weather Index (FWI) (Can. For. Serv. 1970) was designed to follow the day-to-day moisture changes in a pine forest duff layer of 1 lb./ft^2 dry weight (about 5 kg/m^2). During work on the DMC (Van Wagner, Can. For. Serv. Publ. 1288, 1970), trays of duff layers of many different weights were exposed for study, and the results had to be normalized to match the 1 lb./ft^2 standards. It was discovered that this could be neatly and adequately done by simply correlating daily log drying rate with the inverse of duff weight. (The log drying rate is the slope of the semilog graph of free moisture content against time, a fairly straight line for most forest fuels, including duff). The range of weights covered during this work was 2 to 6 kg/m^2; since then data have been collected for both heavier and lighter layers, and it appears that the principle can be extended.

Figure 1 shows the earlier data from a red pine plantation

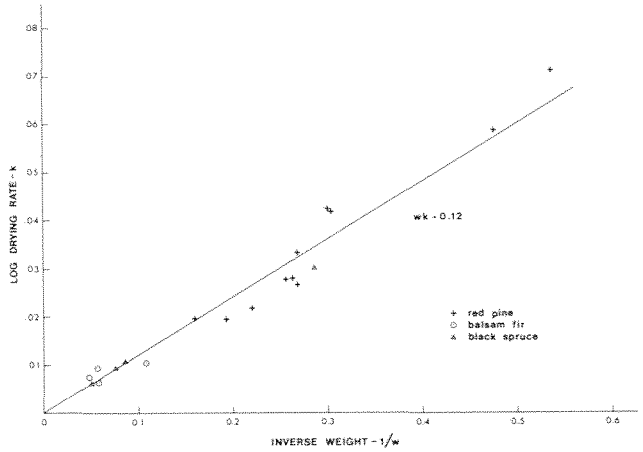

Figure 1. Relationship between log drying rate k and dry weight w of the duff layer.

(Van Wagner, Can. J. For. Res. 34-39, 1972) with the addition of results from tray exposures in two forest stands with heavy duff layers weighing up to 20.7 kg/m^2: a balsam fir stand at Petawawa, Ont. (46°N); and a black spruce stand at Nicauba, Quebec (50°N). The latter was obtained through the cooperation of J. T. Arnott. In Fig. 1, log drying rate k has been plotted against the inverse of duff weight w. For practical purposes, the simple relation $wk = 0.12$ fits fairly well. Each point represents an average of several drying runs during a whole season, each adjusted to normal noon weather of 70 F and 45% RH by the techniques used to construct the DMC. They refer to upland stands only, with duff layers well above the soil water table. Furthermore, the log drying rates apply to rainless periods of 3-10 days broken by significant amounts of rain. Very long dry spells, especially with very heavy duff layers, may result in somewhat lower log drying rates.

At the light end of the weight scale, litter layers are very responsive to the daily cycle of temperature and humidity.

Nevertheless, if the starting moisture content of litter is well above equilibrium, the drying process may take several days and a daily log drying rate can be measured. The Fine Fuel Moisture Code (FFMC) of the FWI, based largely on old research (Wright, Forest Fire Hazard Tables, Dom. For. Serv. 1937), has a log drying rate of 0.5/day at 70 F and 50% RH; since the FFMC refers to a layer of pine litter of about 0.25 kg/m^2, it follows the same trend of wk = 0.12 very well. A set of short outdoor experimental drying runs with jack pine needle litter at 0.5 kg/m^2 had an average log drying rate over the season of about 0.3/day. This is somewhat higher than the graph predicts, but still passably close.

I conclude that the log drying rates of litter and duff layers of the same general nature may be expected to correlate fairly well with the inverse of their dry weight per unit area. This is a useful principle in fuel moisture prediction and fire danger rating.—C. E. Van Wagner, Petawawa Forest Experiment Station, Chalk River, Ont.

FOREST PRODUCTS

Composition of Volatile Oil From the Bark of Lodgepole Pine.—The composition of volatile oil in bark (phloem and rhytidome) of lodgepole pine (*Pinus contorta* Dougl. var *latifolia* Englm.) was examined as part of a study on interactions between this pine and the mountain pine beetle with its blue stain fungi. These beetles mine in the phloem region, and the fungi attack living cells in both wood and bark; the tree responds by producing increased amounts of volatile oil and other compounds in both wood and bark (Shrimpton, Can. J. Bot. 51:527, 1973). The composition of volatile oil from foliage (Pauly and von Rudloff, Can. J. Bot. 49:1201, 1971) and wood (Shrimpton, *op. cit.*) of lodgepole pine has been described, but bark has not. The resin ducts are not continuous from needles to wood and, in the bark, much of the oil is in discrete pockets. It was, therefore, of interest to compare the oil from bark with that from foliage and wood. The terpene hydrocarbons in bark were similar in composition to those found in needles and wood, but the relative amount of higher boiling components was much greater in the bark.

Five butt logs were cut near Horsethief Creek in the East Kootenay region of British Columbia, in early September 1971. In the laboratory, bark was ground with added dry ice in a Wiley mill to pass a 2 mm screen. Bark millings were steam-distilled for 8 hrs. The oil was recovered, weighed and analyzed by gas chromatography over both OV-17 and Carbowax 20M with and without the addition of isopropylbenzene as an internal standard (Shrimpton, *op. cit.*). Individual components were identified from retention characteristics and by peak enhancement with authentic standards.

The predominant monoterpene hydrocarbons were α-pinene, camphene, β-pinene, 3-carene, β-phellandrene and terpinolene. Also present were myrcene, α-terpinene, limonene and trans-ocimene. Oxygenated terpenes present were linalool, α-fenchol, bornyl acetate, terpinen-4-ol, estragole, isoborneol, α-terpineol, borneol, citronellol and cis-anethole. One sesquiterpene, β-caryophyllene, was also present. Some oil in each sample, mostly eluted beyond anethole, was unidentified; the amount varied between 2 and 16%. Sesquiterpenes and some volatile diterpenes have been isolated from lodgepole pine bark (Rowe *et al.* Phytochemistry 11:365, 1972); such compounds probably account for this unidentified fraction. The internal standard indicated that about 5% was unaccounted for from each sample. Table 1 shows the relative composition of oil from the five bark samples, amount of oil recovered and weight of bark used.

The terpene hydrocarbons found in volatile oil of lodgepole pine bark have been reported in oil from foliage (Pauly and von Rudloff, *op. cit.*) and from wood (Shrimpton, *op. cit.*). The relative composition is variable from tree to tree. Differences between oil from bark and from wood or needles are the generally high proportion of oxygenated terpene in all samples and a large unidentified fraction that eluted beyond the oxygenated fraction.—D. M. Shrimpton, Pacific Forest Research Centre, Victoria, B.C.

TABLE 1
Yield and composition of the volatile oil from bark of five lodgepole pines

	Tree Number				
	1	2	3	4	5
α-pinene	*5.5	0.7	2.1	0.9	1.2
camphene	2.2	5.5	3.3	0.5	0.5
β-pinene	2.2	2.1	4.3	2.5	1.8
3-carene	2.4	2.1	3.8	1.5	1.8
myrcene	0.7	tr	tr	tr	tr
limonene	0.9	1.8	2.6	0.5	0.5
α-terpinene	—	tr	—	tr	tr
β-phellandrene	6.5	11.8	34.1	8.4	10.6
trans-ocimene	0.5	0.6	—	0.6	0.6
terpinolene	0.8	1.0	1.5	1.2	1.9
linalool	1.1	0.5	tr	0.7	tr
α-fenchol	0.5	1.4	0.5	1.2	0.8
bornyl-acetate	1.3	0.5	tr	1.6	tr
terpinen-4-ol	16.1	3.1	1.5	3.1	3.4
β-caryophyllene	1.7	1.0	1.2	6.5	3.5
estragole	5.7	5.6	6.0	8.3	4.2
isoborneol	12.5	12.1	10.1	17.4	15.2
α-terpineol	19.0	26.9	22.4	19.3	22.3
borneol	6.9	5.7	3.6	8.6	10.1
citronellol	0.8	1.8	0.6	tr	tr
cis-anethole	—	tr	—	1.0	5.7
unidentified (total)	12.5	14.1	2.0	16.2	14.6
Fresh weight of bark (gm)	99.8	98.3	99.6	100.0	98.7
	218.0	255.0	300.0	205.0	315.0
Weight of oil (gm)	0.10	0.27	0.42	0.21	0.15
Yield of oil (percentage)	0.10	0.10	0.15	0.10	0.05

* Values are percentages of the fraction.
Note: minus indicates not found; tr, trace quantities less than 0.5%

PATHOLOGY

Bacteria From Balsam Fir Roots Inhibit Growth of Decay-causing Fungi.—Bacteria, some of which may promote growth of decay fungi, have been reported to occur in the stems of balsam fir [*Abies balsamea* (L.) Mill.] (Etheridge and Morin, Can. J. Bot. 45:1003-1010, 1967; Bourchier, Proc. 33rd Ses., Can. Phytopath. Soc. No. 34), but no information could be found on the occurrence of bacteria in the roots. In root inoculation studies with *Scytinostroma galactinum* (Fr.) Donk in New Brunswick, bacteria were frequently isolated from uninoculated roots and from wood associated with control inoculations and abortive *S. galactinum* inoculations. Since bacteria were seldom isolated from tissue which yielded the decay fungus and vice-versa, preliminary work was done to investigate the possible inhibitory nature of the bacteria.

Forty-eight isolates of gram-negative rod bacteria obtained from 48 different roots of balsam fir were tested for their influence on the growth of *S. galactinum* and *Coniophora puteana* (Schum. ex Fr.) Karst. The organisms were grown together on malt agar medium and malt agar medium containing ground wood obtained from the center of decay-free roots. Three agar plugs containing mycelium of one of the fungi were placed in a line between two diverging bacterial streaks (Fig. 1). The cultures were incubated, in the dark, for 14 days at 25 C.

Forty-four of the bacterial isolates inhibited *S. galactinum* to some degree on one or both of the media while 45 were inhibitory to *C. puteana*. It was apparent that the type of medium employed influenced the results of the *in vitro* antagonism tests. Nine isolates were inhibitory to *S. galactinum* only when grown on malt agar medium; of these three were

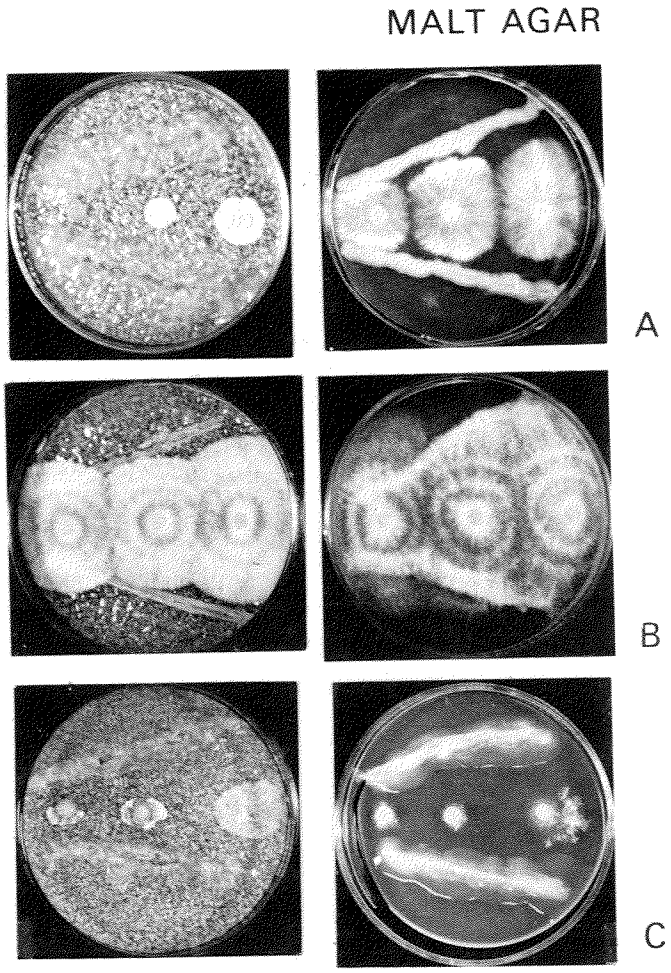

Figure 1. Examples of inhibition (A,C) and noninhibition (B) on rootwood and malt agar media.
A. inhibition of *C. puteana* by bacterial isolate #6
B. noninhibition of *S. galactinum* by bacterial isolate #17
C. strong inhibition of *C. puteana* by bacterial isolate #23

also inhibitory to *C. puteana* on the same medium. On woodmeal medium four were inhibitory to *C. puteana* and two of these were also inhibitory to *S. galactinum*. On both media four isolates were non-inhibitory to *S. galactinum* and three to *C. puteana*; two were common to both. Eleven isolates were exceptionally inhibitory (inhibition zone of 10-12 mm) to both fungi on both media (Fig. 1-c). There was no apparent relationship between the origin of the bacterial isolates, i.e. discolored, decayed, or clear wood, and the degree of inhibition.

It is evident from these results that bacteria do occur in roots of balsam fir and that many of them inhibit, *in vitro*, the growth of *S. galactinum* and *C. puteana*. Since one of the media used contained ground root wood, it is suggested that some of the bacteria may also influence the growth of these two fungi in nature.—T. E. Sterner, Maritimes Forest Research Centre, Fredericton, N.B.

SYLVICULTURE

Eucalypts for Southern Coastal British Columbia.—The spectacular growth of eucalypts and the success with which they have been introduced to other countries, prompted a search in 1968 for a species suitable for the southern coastal region of British Columbia.

The eucalypts are known to be generally sensitive to low temperatures, but in the Australian Alps, commercial forests occur above 1200 m (4000 ft) elevation in an area that has intermittent or continuous snow cover for about 4 months of the year. During that period, frost occurs on almost every clear night.

Three species were selected for the trial: *Eucalyptus nitens*, *E. rubida* and *E. delegatensis*. The selection was, of necessity, a compromise between fast growth of high quality timber and frost resistance. The seed came from the Australian Alps, about 1100 m (3500 ft) a.s.l. While exact meteorological data are not known, the following table summarizes the most important differences in the climate of the seed source and then southern tip of Vancouver Island where the trees were grown.

	Area of seed origin	Planting trials Vancouver Is.
Latitude	36-38° S	49-51° N
Altitude	approx. 1100 m	30 to 200 m
Rainfall	200 to 250 cm (80 to 100″)	80 to 150 cm (30 to 60″)
Rainfall during 4 summer months	40 to 50 cm (16 to 20″)	15 to 30 cm (6 to 12″)
Morning frost	frequent during 4 winter months	frequent during 5 winter months
Frost lasting several days	occasional	several periods every winter
Minimum temperature	—12 to —9° C (10 to 15° F)	—18 to —14° C (0 to 6°F)

Since the area of seed origin has a moister climate with higher winter temperatures than southern Vancouver Island, mortality due to frost was expected. It was hoped, however, that the genotypic variation would enable some individuals to withstand cooler winters.

In March 1969, the seed was sown in flats, and grown in a greenhouse until early June. By that time, the seedlings were 10 to 15 cm (4 to 6 in.) high. Approximately 200 seedlings, equally divided among the three species, were planted in each of three localities on southeastern Vancouver Island. The sites included a deforested, slash-burned eastern slope at 200 m (650 ft) elevation, a known frost pocket at 100 m (330 ft) and a recently bulldozed loamy subsoil at 30 m (100 ft). Survival averaged 91%. Apart from an occasional weeding on the low-elevation plot, the seedlings received no irrigation, fertilization or other treatment.

In the winters of 1969/70 and 1970/71, December frosts caused moderate damage to leaves, branch tips and naked buds. Because of this damage, flushing was delayed until mid-June, coinciding with the onset of summer drought on Vancouver Island. Consequently, the growth during the summer was slow, but increased with rains in late September. During October, the height increment of many trees averaged more than 2 cm (0.8 in.) per day. A gradual decrease of temperatures brought about cessation of growth and a degree of hardening on most trees by mid-December. By the end of the third growing season (December 1971), the average height on all three plots was 3 to 4 m (10 to 13 ft), with a few individuals reaching 5½ m (18 ft). During that time, Douglas-fir planted simultaneously as 1+0 and 2+0 bare-root stock on two "high-elevation" plots averaged 45 cm (18 in.).

At the end of the third growing season, 27 Dec. 1971, a frost of —12 to —7°C (10 to 19°F), depending on plot location combined with a 20 mph wind caused heavy damage; some trees were killed to ground level, while on others, branch tips and buds, including accessory buds, were destroyed. Trees

killed to ground level were removed from the plots. On the remaining trees, 1972 growth had to initiate from epicormic bud strands. Consequently, flushing occurred very late — toward the end of June. On October 29, while trees were at the peak of their growth, a sudden, unseasonal frost of −7 to −4°C (20 to 25°F) occurred. Soon after this, the bark began to split at ground level (Fig. 1), indicating that the stems were dead. In the spring of 1973, only about half of the trees in the "low-elevation" plot sprouted from the lignotubers, enlarged, knob-like bases typical for eucalypts.

Figure 1. Heavy stem damage caused by unseasonal frost.

Although the original attempt to find a few individuals able to withstand the winter temperatures on southern Vancouver Island failed, there are several observations worth mentioning:

1. A combination of frost damage and summer drought imposed a phenological time table on the studied species similar to that of plants adapted to dry climates, i.e., they only flushed before the beginning of summer drought and during the dry hot summer they remained almost dormant. However, immediately following the first heavy rain in the fall, and regardless of lower temperature, their growth rate sharply increased. This made them particularly susceptible to early frost.

2. The three species studied did not differ in their frost resistance, but within each species, there was a large variation among individual trees in the time of flushing and hardening. Individuals that flushed early, hardened early and suffered the least damage.

3. Several eucalpyts planted as ornamentals in somewhat protected situations in parks and gardens survived the unseasonal frost with only moderate damage. While temperature data are not available, it is improbable that these situations are more than that 2°C (4°F) warmer than the "low-elevation" plot.

4. In any future trials, seed from higher elevations is desirable.

E. delegatensis grows at higher elevations in Tasmania and *E. rubida* at Mt. Kosciusko. Also, attention should be turned to other species, with greater frost resistance, even though their growth may be slower. *E. fraxinoides* and *E. oreades* as commercial species and *E. parvifolia* as an ornamental appear to be a good choice. Because higher elevations receive higher rainfall, the trees should be planted on protected southern slopes or on moist alluvial soils in the valleys on the southwest coast of Vancouver Island. This may help their phenological adaptation, by providing sufficient moisture for summer growth and hardening with lower temperatures in the fall.—S. Eis, Pacific Forest Research Centre, Victoria, B.C.

SOILS

DDT Residues May Be Lost From Soil by Direct Volatilization.—Large quantities of technical DDT were sprayed in New Brunswick forest areas between 1952 and 1968 for the control of spruce budworm [*Choristoneura fumiferana* (Clemens)] and much of it still persists in the forest soil [Yule, Bull. Env. Contam. and Toxicol. 9: 57-64, 1973]. Recent analysis of the top 6 inches (15.2 cm) of soil collected from Priceville Ecology Study area during the middle of 1972 showed an average "oven-dry" concentration of 0.097 (12%) *o,p*-DDT, 0.638 (78.6%) *p,p'*-DDT and 0.076 (9.4%) ppm of DDE respectively.

Volatilization and vapor phase transport, apart from microbial degradation and leaching, are the major sources of dissipation of "non-volatile" pesticides such as DDT from soil. The volatilization process depends basically on the vapor pressure of the individual compounds. Recent vapor pressure studies of DDT isomers and DDE by Spencer and Cliath [J. Agr. Food Chem. 20: 645, 1972] indicated that the *o,p*-isomer and DDE are more volatile from soils than the *p,p'*-DDT due to their higher vapor pressures. This report deals with the relative concentration of these components found in air samples collected at zero and 6 ft (1.8 m) above ground in forest environments in the Priceville area.

Air-sampling apparatus used was similar to that of Yule and Cole [Proc. 4th Int. Agric. Aviat. Congr. Kingston 346-353, 1969] consisting of a generator powered Gelman pump operating at the rate of 16 lpm (16 x 10^{-3} m^3/min) for 3 hours coupled with a florisil (20 g) sampler and dimethylformamide (DMF) (150 ml) bubbler. Three sampling stations, A, B, and C were established in the Priceville area close to where soil samples were collected for the analysis. Air samples were collected at ground level and 6 ft above the ground on the windless sunny forenoon (temp 18 ± 2 C) of 9 Aug. 1972. Duplicate samples were collected in the afternoon under nearly similar weather conditions. The DDT residues were extracted from the florisil with benzene (150 ml) and partitioned from the DMF with aqueous sodium sulphate (5%, 500 ml) and *n*-hexane (2 x 100 ml) prior to gass chromatographic analysis. The benzene and hexane fractions of each sample were pooled, flashed (0.5 or 1.0 ml) and analysed using a HP 5750 GC instrument fitted with electron capture (Ni 63) detector. The operating conditions were similar to those used by Yule [*loc. cit.*]

Table 1 shows that appreciable amounts of DDT residues in Priceville forest soil are dissipated by volatilization. Even though the technical material sprayed initially and the soil analysed recently contained *ca* 20 and 12% of *o,p*-DDT respectively, the results indicate that the *o,p*-isomer disappears more rapidly from the soil than *p,p'*-DDT. The average *o,p*/*p,p'*

ratios were 0.76 and 2.02 at ground level and at 6 ft respectively compared to the soil value of 0.15. The average concentration of the *o,p*-isomer in air at ground level was found to be 8.56 ng/^{3} compared to 11.63 ng/m^3 of the *p,p'*-isomer but the concentration of the former at 6 ft above the ground level was twice as high (11.34 vs 5.55 ng/m^3) as that of *p,p'*-DDT probably due to high kinetic energy of the unsymmetrical *o,p*-DDT molecules. The variation in concentration of the metabolite DDE, was not appreciable, (3.87 vs 4.10 ng/m^3 at 6 ft) between the two levels. The average DDE/*p,p'*-DDT ratios between the two levels were 0.37 and 0.73 compared to the soil value of 0.11.

TABLE 1

Concentration (ng/m^3) of DDT residues in air at ground level and at 6 ft (1.8m) high at three points in Priceville area*

CHEM CAL	SAMPLING STATIONS					
	A		B		C	
	Ground Level	6 ft High (1.8 m)	Ground Level	6 ft High (1.8 m)	Ground Level	6 ft (1.8 m)
o,p-DDT	7.81 (33)	10.41 (55)	10.59 (35)	14.75 (56)	7.29 (39)	8.53 (50)
p,p'-DDT	13.02 (55)	5.20 (28)	14.06 (47)	6.42 (24)	7.81 (42)	5.03 (28)
DDE	2.77 (12)	3.12 (17)	5.38 (18)	5.38 (20)	3.47 (19)	3.81 (22)
Total DDT (*o,p* + *p,p'* + DDE)	23.60	18.73	30.03	26.55	18.57	17.69
o,p/*p,p'* ratio	0.60	2.00	0.75	2.30	0.93	1.76
DDE/*p,p'* ratio	0.21	0.60	0.38	0.84	0.54	0.76

* Average of two determinants. Values in parenthesis show percentages.

The vapor pressures (mm x 10^{-7}) at 30 C of *o,p* and *p,p'*-isomers and DDE are 55.3, 7.26 and 64.9 respectively [Spencer and Cliath, *loc. cit.*]. The composition of DDT residues in the air samples (Table 1) shows that the *o,p*-isomer is more volatile than *p,p'*-DDT presumably due to its higher (7.5 times) vapor pressure.

A small variation in concentration of 0.23 ng/m^3 (avg) was observed for the breakdown product DDE, between these two levels in spite of its high vapor pressure. The comparatively small amount of DDE in the atmosphere may be due to its low concentration (0.076 ppm) in the soil and its adsorptive interaction with the substrate particles on the forest floor causing temperature dependent binding. It appears then, that the volatilization process in addition to biodegradation, results in the removal of more volatile *o,p*-DDT from the soil, depleting its initial concentration in technical DDT from 20% [Spencer and Cliath, *loc. cit.*] to the present value of 12%. Under aerobic conditions, the usual state of most forest soils, a part of the DDT sprayed degrades to DDE that volatilizes slowly due to its adsorptive interactions with the soil matter; relatively less is vaporized as *p,p'*-DDT but most of the *o,p*-DDT is volatilized and lost from the soil, decreasing rather rapidly compared to the other isomer. The author thanks Dr. I. W. Varty of MFRC, Fredericton for the assistance in collecting the air samples.—K. M. S. Sundaram, Chemical Control Research Institute, Ottawa, Ont.

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