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BOTANY

Photosynthesis by Dwarf Mistletoe Seeds.—An interesting feature of the seeds of dwarf mistletoe [*Arceuthobium sp.*], a parasitic plant of conifers, is that the endosperm and radicle tissues are green and presumably capable of photosynthesis. Other morphological features of seeds that suggested a photosynthetic ability were described by Kuijt (Univ. Calif. Publ. Bot. 30:337-436, 1960); however, only the aerial shoots have been studied experimentally for evidence of photosynthesis (Rediske and Shea, Amer. J. Bot. 48:447-452, 1961; Hull and Leonard, Plant Physiol. 39:1008-1017, 1964).

In the present study germinating seeds of A. *campyopodum* Engelm. f. *campylopodum* were exposed to radioactive carbon dioxide ($C^{14}O_2$) in light and in dark to determine the amount of carbon dioxide fixation.

In January and March 1969, seeds of the dwarf mistletoe were collected on digger pine [*Pinus sabiniana* Dougl.] at Mount Diablo, California, and were treated at the Department of Plant Pathology, University of California, Berkeley. Seeds were surface-sterilized by soaking them 3-5 hours in 3% hydrogen peroxide and then placed on sterilized, moist filter paper in petri plates or on water agar media in test tubes for about 3 weeks to germinate. Ten germinating seeds with radicles 1-3 mm long were placed on moist filter paper either in two small petri plates in the first experiment or in two test tubes in the second. One container in each experiment was completely covered with aluminum foil to exclude light, and containers were illuminated by a fluorescent lamp. Just before illumination of the containers, radioactive carbon dioxide was generated in the containers by adding 85% lactic acid to C^{14} -barium carbonate. Seeds were exposed to $C^{14}O_2$ for 24 hours in the first and 48 hours in the second experiment. Radioactive carbon dioxide fixed by individual seeds was measured as counts per minute (cpm) in a Nuclear-Chicago gas flow counter. In the first experiment seeds were squashed on planchets before counting; in the second, seeds were left whole.

In the first experiment radioactivity of seeds exposed 24 hours to $C^{14}O_2$ in the light averaged 138 cpm and in the dark 103 cpm. In the second experiment where seeds were exposed 48 hours, radioactivity for seeds in the light averaged 2,440 cpm and in the dark 310 cpm. Background radioactivity was 47 cpm in the first, and 37 cpm in the second experiment. Within each experiment the difference between light and dark treatments was highly significant ($p = 0.01$).

These results indicate that dwarf mistletoe seeds are able to photosynthetically fix carbon dioxide. The amounts of labelled carbon dioxide fixed was small, similar to results of Hull and Leonard (*ibid.*) for aerial shoots. However, because of the small food reserves of seeds, dry weight of 0.002-0.003 g per seed, photosynthates could be a significant source of energy and carbon compounds during germination and also could help to maintain seed germinability during long periods of unfavorable winter weather.—John A. Muir, Northern Forest Research Centre, Edmonton, Edmonton, Alta.

ENTOMOLOGY

A Fluorescent Dye Used to Trace Insecticide Deposit in Aerial Spraying.—The amount of spray material deposited in aerial applications of insecticides to forests is difficult to measure because such operations produce a highly variable deposit. Conventional analysis of the insecticide itself on foliage samples by gas chromatography is limited by the cost, and the use of Kromekote cards for droplet measurement and tally introduces sampling artifacts. Himel *et al.* (U.S. For. Serv. Res. Note PSW 87, 1963) reported on the use of fluorescent materials to trace insecticide deposite, and Maksymiuk (U.S. Dep. Agric., For. Serv., Pers. comm., 1971) tested Rhodamine B Extra Base as a tracer for the carbamate insecticide Zectran on conifers in Oregon.

My problem was to evaluate the distribution of fenitrothion deposits on red maple [*Acer rubrum* L.] from spray operations against spruce budworm on adjacent conifers. By courtesy of Forest Protection (New Brunswick) Ltd., and the Maritimes Forest Research Centre, I conducted a nested four-stage sampling experiment to trace the insecticide by the use of Rhodamine WT. The objective was to measure the distribution of deposits in maple crowns relative to a) branch orientation, b) intertree variation, c) interbranch variation, d) variation among shoots, and e) variation among leaves. Knowledge of these variations is necessary in the design of survey techniques to monitor effectiveness of applications of insecticides to forest canopies.

The 200 hectare experimental spray block located at the Priceville Study Area in central New Brunswick was sprayed between 8:20 and 9:00 a.m., 12 June 1974. The wind was less than 8 kph from the west and the air temperature was 15°C. Two Grumman Agcats sprayed the block from an average height of 15 m above tree tops, flying on bearings of 330° and 150°. The 8006 T Jet nozzles were calibrated to emit 1.4ℓ/ha and each spray swath was approximately 100 m wide (50m per aircraft). Table 1 gives the spray formulation.

TABLE 1

Composition of the spray mixture expressed as a percentage volume

Material	%
Water	73.5
Rhodamine WT*	3.5
Emulsifiable concentrate:	
— Emulsifier	5.0
— Solvent oil	2.0
— Fenitrothion (technical grade)	15.0

* Supplied by manufacturer as a concentrated aqueous solution (Dupont Chem. Co.).

Four hours after spraying, foliage samples were collected from 10 red maple trees randomly selected along a 600 m transect running at right angles to the flight path of the aircraft. Eight branches, two selected from each of the four quadrants facing the cardinal points, were cut from each tree. Two shoots were selected from each branch, placed in an envelope, air dried, and stored in the dark for 6 months. Two leaves were selected from each shoot after storage. Each leaf was weighed and eluted with 10 ml of 50% alcohol. Unsprayed red maple leaves similarly prepared were used as controls; standards prepared both from the emulsifiable concentrate containing dye and from the concentrated dye were used for comparison. The fluorescence of the eluted material was determined with a Model 110 fluorometer manufactured by Turner Associates. The fluorescence per mg of leaf tissue was determined and the data analysed with a BALANOVA program for the analysis of variance.

The analysis of variance (Table 2) and the overall mean and the means for the deposits in each cardinal quadrant

TABLE 2

Analysis of variance of raw fluorescence† per mg/leaf tissue

Source	df[1]	SS	MS	F	Denominator of F
Tree (T)	9	35.34	3.926	8.63**	B
Branch (B)	10	4.55	0.455	1.67	S
Orient (O)	3	6.01	2.003	2.77	TxO
Shoot (S)	20	5.43	0.272	2.28*	L
Leaf (L)	40	4.77	0.119	—	—
OxT	27	19.50	0.722	2.33*	OxB
OxB	30	9.29	0.309	1.18	OxS
OxS	60	15.67	0.261	2.31**	OxL
OxL	120	13.56	0.113	—	—
Total	319	114.12			

† To convert to ml Rhodamine WT/mg multiply SS (ϵ MS) by $(18.5 \times 10^{-9})^2$

* $\alpha = .05$. ** $\alpha = .01$.

TABLE 3

Table of mean deposits per mg of leaf tissue

Mean	Raw Fluorescence	ml RWT*	Equiv. Fenitrothion (mℓ)
Overall	0.608	11.25×10^{-9}	48.2×10^{-9}
North	0.770	14.25×10^{-9}	61.1×10^{-9}
East	0.593	10.98×10^{-9}	47.1×10^{-9}
South	0.396	7.33×10^{-9}	31.4×10^{-9}
West	0.670	12.40×10^{-9}	53.1×10^{-9}

* ml of concentrated Rhodamine WT(R) (conversion factor from raw fluorescence: 18.5×10^{-9} mℓ).

(Table 3) shown are raw florometer readings because conversion to absolute quantities (ml/mg leaf tissue) is cumbersome.

The variations due to branch orientation were not significant. Intertree variability is quite large and is attributable to the variability of spray deposition. The low *interbranch* variability may be explained by the structured of a red maple crown in which branches rarely shade each other; consequently the vertical level of the branch has little effect on its exposure to pesticide filtering down from above. Variability between shoots is, however, important and appears to be due to individual shoots sheltering one another.

Interaction effects found to be significant are more difficult to explain. It seems that adjacent trees may have sheltered sample trees, resulting in the uneven distribution detected (O x T). Orientation (relative to the drift of the spray cloud) may have strongly influenced the deposition on individual shoots (O x S), but not on whole branches (O x B).

The technique of using fluorescent tracers offers a rapid, accurate, and cheap method of assessing spray deposits quantitatively; approximately 200 samples can be processed in 8 hours (= 25¢/sample), and the cost of dye is 20¢/ha sprayed. The sensitivity of this technique is limited mainly by the quantity of dye that can be safely mixed with the emulsifiable concentrate, as well as by the basic sensitivity of the fluorometer and the characteristic fluorescence of the dye. With the combination of instrument and formulation used in this trial a deposit of ca.1 ppm fenitrothion could be detected.

The major disadvantage of the method is that the pesticide residue is not determined directly. Also, the method does not allow the study of the persistence or accumulation of residues over periods greater than one day because the dye's decay and flow characteristics are quite different from those of the insecticide. The toxicity of the dye to arthropods and other organisms is unknown but appears to be very low (Fluorometry reviews, June 1970, G. K. Turner Associates).—W. J. A. Volney, Research Contractor, Fredericton, N.B.

Chemical Control of the Spruce Needle Miner in Alberta.— The spruce needle miner [*Taniva albolineana* (Kft.)] occasionally severely defoliates most species of spruce throughout much of Canada and the United States (Cumming, Can. Entomol. 86:457-460, 1954; Tashiro, J. Econ. Entomol. 67:89-92, 1973). In the prairie provinces, ornamental spruce tend to be more susceptible to attack than forest trees, and heaviest injury usually occurs on young trees growing under adverse conditions (Cumming, *ibid.*).

Larvae feed primarily in the old needles, even when population levels are extremely high. The larvae chew a hole at the base of the needles and mine upwards to the distal end, leaving only the epidermis, but deposit frass outside the needle. In severe infestations the mid and lower portions of the trees become covered with a thick mat of frass and dead needles held together by silken threads. Feeding may continue into late September and the larvae overwinter within the mined needles. Feeding is resumed in the spring, with pupation occurring within the needle masses. Adults emerge in June and oviposit from late June to early July.

This note summarizes observations made on development and feeding damage of the spruce needle miner at Fleet, Alberta, and gives results of a chemical control test conducted in 1973.

The infestation occurred in a 16-year-old shelterbelt of Colorado blue spruce [*Picea pungens* Engelmann] consisting of 134 trees measuring 2.54–30.48 cm (1–12 in.) dbh and 1.8–7.9 m (6–26 ft) in height. When planted, the trees were 2.4 m (8 ft) apart in two rows 1.8 m (6 ft) apart; they had never been thinned. The spruce were protected on both sides by a dense, 2.44–3.66 m (8–12 ft) high caragana hedge mixed with mature Manitoba maple and ash, which now crowds the spruce. (This hedge enhanced the control application by restricting spray drift).

An experimental control test with the systemic insecticide Furadan® (carbofuran) was carried out in mid-August when most of the larvae were in the second instar and were feeding actively or migrating to unmined needles. The insecticide was mixed with water, 335 cm^3/454ℓ (12.5 oz active ingredient per 100 gal water), and applied with a hydraulic sprayer at a pressure of 50 kg/cm^2 (700 psi) to the drip stage. This pressure dislodged masses of dead needles and debris from the lower branches.

Material on ground sheets, previously set out below the trees, was examined soon after the application to evaluate the immediate larval mortality. Many dead larvae were found on the sheets or observed hanging by silken threads from the branches.

A branch 46-cm (18-in.) long was selected at random from the lower half of the two trees before and after treatment. Counts of the mined needles, living and dead larvae, and parasites are given in Table 1. Percentage control was calculated using Abbott's formula (J. Econ. Entomol., 18:265-267, 1925).

TABLE 1

Counts of *T. albolineana* and its parasites in branch samples before and after treatment with Furadan

Branch	Empty mined needles	No. of live larvae	No. of dead larvae	*No. of Parasites* *Hymenoptera* Alive	*Hymenoptera* Dead	*Diptera* Alive	*Diptera* Dead
			Pre-treatment				
1	68	284	13	2	0	0	0
2	105	155	30	0	0	0	0
			Post-treatment				
3	339	4	280	2	5	0	1
4	193	5	280	2	10	0	0

Results indicate that Furadan® 4.8 EC gave 98% control over the spruce needle miner. Spray application is probably most effective when larvae are in an early instar stage, because of their habit of feeding within the needles.—J. A. Drouin and D. S. Kusch, Northern Forest Research Centre, Edmonton, Alta.

Electrophysiological Evidence for a Humidity (Water) Receptor on the Antennae of Several Lepidoptera.—The antennae of Lepidoptera possess a wide array of sensilla that mediate responses to an equally wide range of environmental stimuli. Although most of these stimuli involve the olfactory modality an important environmental stimulus that also influences insect behaviour is relative humidity (water vapor). Antennal sensilla of some insects are involved in the detection of this stimulus (Wigglesworth, The Principles of Insect Physiology, 6th edition, Methuen, London 1965) but little behavioural or electrophysiological evidence is available for similar receptors in adult lepidopterans. This report provides some electrophysiological evidence for a water vapour (humidity) receptor on the antennae of several moths.

The electrophysiological response obtained form the antennae was the electroantennogram (EAG), which was recorded in the manner described previously (Grant, J. Econ. Entomol. 64:315-316, 1971; Grant, Ann. Entomol. Soc. Am. 64:1428-1431, 1971). The airstream source was a tank of compressed air. Humidity was adjusted by passing the airstream through gas wash bottles containing either desiccants (silica gel or activated alumina) or filter paper wetted with distilled water. Relative humidity (R.H.) was measured with a hygrometer (Abbeon, certified ± 2%) placed in a glass bottle at the emission port for the airstream. Between 20.6° to 22.2°C the moist airstream was between 70% and 82% R.H. while the dry airstream was between 21% and 28% R.H.

Typically in those insects which responded, the dry airstream evoked a hyperpolarizing EAG (i.e. recording electrode became positive relative to indifferent electrode) whereas the moist airstream induced a depolarizing (negative) EAG. Figure 1 illustrates a typical set of these responses from the antenna of the male cabbage looper [*Trichopulsia ni*] and demonstrates the change in polarity of the EAG response when the moisture content of the airstream was altered. Identical responses were obtained from the antennae of females.

Figure 1 also illustrates several characteristics of the response to dry air. With the initial successive stimulations by dry air, the positive component of the EAG increases in magnitude while the negative component, if present as in Figure 1, disappears. In addition, the time course of this EAG differs from the depolarization EAG in that the magnitude of the response increases slowly while the depolarization EAG reaches a peak quickly and then returns to a lower plateau. The characteristics of the hyperpolarization EAG are strikingly similar to the hyperpolarization generator potentials recorded by Boeckh (Int. Symp. Olfaction and Taste II. T. Hayashi (ed), pp. 721-735, Oxford, Pergamon Press, 1967) from single olfactory cells stimulated with inhibitory odors. Since EAGs are considered to be the summation of generator potentials along the antenna (Boeckh, *loc. cit.*), dry air can probably be considered as an inhibitory or repellant stimulus for adult moths.

The magnitude of the EAG responses to moist and dry air was dependent on the age and water balance of the insect. Moths that had free access to water showed a relatively small EAG deflection (0.1 to 0.5 mV) to either airstream but the response was usually largest in the oldest moths. When moths were deprived of water from emergence and tested at various times thereafter, very large responses (up to 1.5 mV) were obtained with both airstreams. The largest responses were obtained from those insects deprived of water for the longest period of time. Similar EAG responses were obtained from a number of other moth species including *Pseudaletia unipuncta, Mamestra configurata, Plodia interpunctella* and *Cadra cautella.* However, forest tent caterpillar moths, *Malacosoma disstria,* were much less responsive to moist and dry airstreams than those species and the white-marked tussock moth, *Orgyia leucostigma,* almost not at all. Possibly because these species do not feed as adults and have shorter life spans, they have fewer or less sensitive humidity receptors.

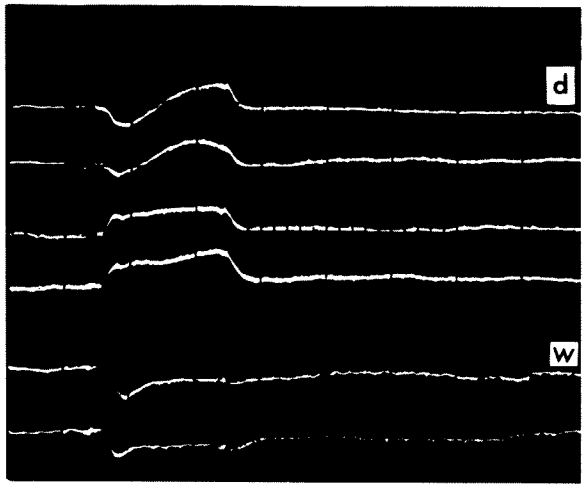

Figure 1. EAG responses from male *Trichoplusia ni* antenna to four successive stimulations with a dry airstream (d) and two with a moist airstream (w). Magnitude of first moist air response is approximately −0.5 mV.

Although the above results strongly suggest that the lepidopteran antenna possesses receptors that respond to relative humidity, it is also possible that the responses observed are due to temperature changes induced by changes in evaporation rates at the antennal sensilla. Conclusive proof of a humidity receptor will depend, therefore, on identification of the receptors involved and by careful single cell recordings with appropirate controls.—G. G. Grant, Insect Pathology Research Institute, Sault Ste. Marie, Ont.

Simplified Rearing of the Eastern Hemlock Looper.—The eastern hemlock looper [*Lambdina fiscellaria fiscellaria* (Guen.)] has been reared in large numbers for pathological and physiological investigations at this Institute since 1968. Other workers had reported that first instar larvae establish poorly on dormant foliage of balsam fir [*Abies balsamea* (L.)] therefore, during early rearings first instar, we reared larvae on an artificial food (McMorran, Can. Entomol. 97:58-62, 1965) in ¾ oz plastic creamer cups until they reached the second instar. At this stage they would accept the dormant foliage. Larvae could be reared through to pupation on the artifical food but it proved impractical as a very high incidence of cannibalism occurred after the second instar.

In 1972, rearing tests were carried out using the low cost CSM diet (Burton, J. Econ. Entomol. 63:1969-1970, 1970). The diet gave good results but dried out too quickly and was too viscous to be handled by our automatic dispenser. The diet was modified (Table 1) and proved excellent for

TABLE 1

Composition of a modified diet for hemlock looper. Quantities for 4.5 liters

Ingredient	Quantity
Water (tap)*	3377.0 ml
Granulated agar	75.0 g
CSM Powder**	422.0 g
Torula yeast	36.0 g
Ascorbic acid	14.4 g
Sorbic acid	2.7 g
Methyl paraben	5.4 g
Formalin (37% formaldehyde)	1.8 ml
Wheat embryo	50.0 g
Alphacel	9.0 g

* One half of the water used to dissolve agar, a small amount to blend dry ingredients and the balance (warm tap water) added after the CSM has been added to the melted agar solution.

** CSM (corn, soy flour and milk solids) produced by private companies in the United States under USDA specifications for shipment to protein deficient countries throughout the world. Purchased from Krause Milling Co., P.O. Box 1158, Milwaukee, Wisconsin.

looper rearings. Larvae complete development in approximately 1 month and rearing individually to avoid cannibilism was unnecessary. An average of 80% of the first instar larvae reach the pupal stage. Adults are well formed and produce a normal number of viable eggs.

The diet is prepared in a 17.5 imp gal (78.8ℓ), electrically heated kettle as described by Grisdale (Can. Entomol. 105: 1553-1557, 1973). When the agar is liquified, the mixing speed of the kettle is increased to 60 rpm and the CSM powder is slowly added to prevent the formation of lumps. The rest of the warm tap water is added followed by the rest of the ingredients, which were previously blended in a 1-gal (4.5ℓ) blender. When, depending on the temperature, the diet is too viscous for automatic dispensing 325 ml of warm tap water is added. The diet is dispensed into ¾ oz semi-translucent plastic creamer cups. An anti-fungal solution is not used (Grisdale, *op. cit.*) to avoid mortality of first instar larvae due to moisture on the inside of the cups.

Eggs that have been in cold storage for a minimum of 3 months are removed from storage, slightly moistened, placed in a plastic container vented with very fine mesh screening, and incubated at 22±1°C and 70% R.H. In low humidity environments the eggs should be moistened once or twice before hatching. Eggs hatch in approximately 11 days and most of the eggs hatch over a 3 day period following cold storage for 4 to 7 months.

Larvae are transferred to the diet with a camel's-hair brush at the rate of 20 per half cup of diet. Cups are placed in an upright position and exposed to 18 hours illumination, a temperature of 22±1°C, and a relative humidity of 60%. In about 2 weeks, when most larvae have attained the third instar, they are transferred to fresh diet at the rate of four per cup. They must be thinned at this stage as crowding will result in excessive cannibalism. Some of the larvae will pupate in the cups without transfer to fresh diet but others will require an additional change of food when food in the cups becomes too dry or the quantity is insufficient. Time from eclosion to pupation is 27 to 35 days.

At the time of the first transfer, larvae to be used in field tests are transferred to balsam-fir foliage to obtain individuals more physiologically compatible with an outdoor environment. For the same reason most of the larvae required for the maintenance of rearing stock are also reared on balsam-fir foliage.

Upon pupation, the pupae are sexed and placed on a piece of paper towel in a plastic dish fitted with a vented lid. To synchronize emergence, male pupae are initially held at a temperature 4°C lower than the female pupae. Adults emerge 14 to 21 days.

One-gallon (4.5ℓ) cardboard ice-cream cartons are used as mating and oviposition chambers, which can accommodate up to 40 pairs. The central portion of the lid is removed and the circular rim retained. The bottom of the carton is lined with paper towelling and a hole 25 cm in diameter is cut mid-way up the side; this hole is plugged with an appropriately sized vial. A piece of cheesecloth (at least three layers thick) is placed over the top of the carton and held in place by forcing the rim from the lid over it. As eclosion occurs moths are transferred to the carton through the hole in the side. For ease in handling, moths are placed in a refrigerator for a few minutes. Adults are transferred to the mating chamber by clasping the wing with featherweight forcepts. Cartons of adults are held at 20±1°C and relative humidity of 90-95%. Adults are given a liberal amount of water daily by wetting the cheesecloth cover. Eggs are laid in the cheesecloth and after 2 or 3 weeks the cloth is removed and placed in a sealed plastic bag. Approximately 5 weeks after eggs were first deposited a few drops of water is added to the cloth, the bag resealed and storaged at a temperature of 0° to 1°C for future use.—D. G. Grisdale, Insect Pathology Research Institute, Sault Ste-Marie, Ont.

Introduction of Parasitoids of the Birch Leafminer into Newfoundland.—The birch leafminer [*Fenusa pusilla* (Lepeletier)], a pest of birch species [*Betula* spp.], was accidentally introduced from Europe into mainland North America about 1920 (Cheng and LeRoux, Ann. Soc. Ent. Quebec 10: 173-188, 1965). This leafminer was first recorded in Newfoundland in 1954 (Reeks, et al., *In* Annu. Rep., For. Insect Dis. Surv., Can. Dep. Agric., Div. For. Biol., 1954), and has since spread throughout the Island. Although not a major pest of forest stands in Newfoundland, the insect tends to be abundant on white birch trees [*Betula papyrifera* Marsh.] on exposed mineral soil or on grassy sites where it can cause severe browning of foliage. Therefore, trees along roadsides, in camp sites, and those used as ornamentals, are often severely attacked and their aesthetic value impaired.

In 1970 the Newfoundland Forest Research Centre, in cooperation with the Commonwealth Institute of Biological Control, initiated a biological control program against the birch leafminer by introducing parasitoids into Newfoundland. Introductions into Newfoundland were terminated in 1973. This report presents data on the Newfoundland introductions and on the recovery of parasitoid progeny.

In August 1972 two species of ichneumon parasitoids, *Lathrolestes* (= *Priopoda*) *nigricollis* (Thompson) and *Gryocentrus albipes* (Ruthe) were introduced from Austria and released onto caged white birch trees at Pasadena, Newfoundland. The cages placed over the trees were 1.2 m x 1.2 m and 2.3 m high, with sides and top of 26 strands-per-inch nylon screening. The ground of each cage was covered with 8 cm of sifted soil. A total of 99♂♂, 114 ♀♀ *L. nigricollis* were released on three trees on August 10, August 16 and August 23, and 4♂♂, 9 ♀♀ *G. albipes* on one tree on August 10. The tree used for *G. albipes* had about 400 and the other three trees about 600 susceptible host larvae.

In 1972 mating, host searching and oviposition were observed in the cages for *L. nigricollis*, but not by *G. albipes*. The following year relatively small numbers of progeny, about 10 *P. nigricollis* and 40 *G. albipes*, emerged into the cages by July 11, 1973. A few males were collected for positive identification and then the cages were opened on July 17 to allow dispersal of these parasites.

On 30 Aug. 1973, additional 12 ♂♂, 13 ♀♀ *L. nigricollis* and 8 ♂♂, 9 ♀♀ *G. albipes* were introduced from Austria and released in the open at Pasadena.

Ground emergence traps of 930 cm^2, which consisted of plywood cubes with a glass jar attached to them, were used to recover parasitoid progeny in 1974. Three traps were placed under the tree used for *G. albipes* release, and a total of 6 traps under the three trees used for *L. nigricollis* release. In addition, 10 traps were placed under infested white birch trees within 10 m of the caged trees. Traps were placed in mid-June and checked for parasitoid emergence at about weekly intervals. A total of 2 ♂♂, 4 ♀♀ *L. nigricollis* was obtained from these traps, but no *G. albipes*.

It appears that *L. nigricollis* has become established in Newfoundland, but no decision can be made regarding *G. albipes*. Future monitoring will estimate effectiveness of these parsitoids in the control of the birch leafminer.—A. G. Raske and J. M. Jones, Newfoundland Forest Research Centre, St. John's, Nfld.

FIRE

Convection Temperatures above Low Intensity Forest Fires.—It is sometimes of interest to know what temperatures can be expected at various heights above forest fires. For example, the question may arise during the design of a power line running through forested country. For present purposes, a forest fire is considered to be a simple line heat source. The simplest expression for convection temperature is, then, one adapted from Thomas (Proc. Ninth Int. Symp. Combust., p. 844-859, Academic Press, 1963):

$$\Delta T = I^{2/3}/h \qquad (1)$$

where ΔT is temperature rise above ambient, °C
I is line-fire intensity, kcal/sec-m
h is height above ground, m

There is no easy way of calculating the proportionality constant k, which is best determined from field measurement. This note presents estimates obtained in two different ways.

The first determination was made during a study of crown scorch height following the passage of low intensity fires (Van Wagner, Can. For. Res. 3:373-378, 1973). No temperatures were measured, but crown scorch was assumed to occur at the 60 C temperature level above ground. Based on data from 13 experimental fires ranging up to 300 kcal/sec-m in intensity, a value of 11.6 was obtained for k (Eq. 9, Van Wagner op. cit.). Consideration of wind is omitted in the present exercise, but a possible way of accounting for light wind is discussed in that same article.

The second determination is based on measured temperatures above six fires, two of them common to the set of 13 mentioned above. The data were obtained by hanging a vertical set of 20-gauge thermocouples above the ground and running a line of fire underneath it. Temperatures were recorded at 0.1, 0.3, 0.9, 2.1, and 4.6 m above ground, occasionally higher.

According to the structures of Eq. 1, the product $\Delta T \cdot h$ should be constant for each fire at given intensity I. For each fire, therefore, height h was plotted over the inverse of maximum temperature rise ΔT. As the theory anticipates, these graphs turned out to be reasonably straight lines with slope $b = \Delta T \cdot h$. Four of the lines are shown in Fig. 1, two being omitted to avoid clutter. Dividing slope b by the 2/3 power of I then yields k.

TABLE 1

Evaluation of constant k in Eq. 1 for six fires

Fire Description	Intensity (kcal/sec-m)	Slope b* ($\Delta T.h$)	Constant k ($b/I^{2/3}$)
Jackpine slash #1	1487	1300	10.0
Jackpine slash #2	578	383	5.5
Aspen	112	120	5.2
Red-white pine #1	87	273	14.2
Red pine	76	126	7.0
Red-white pine #2	21	86	11.3

* From Figure 1.

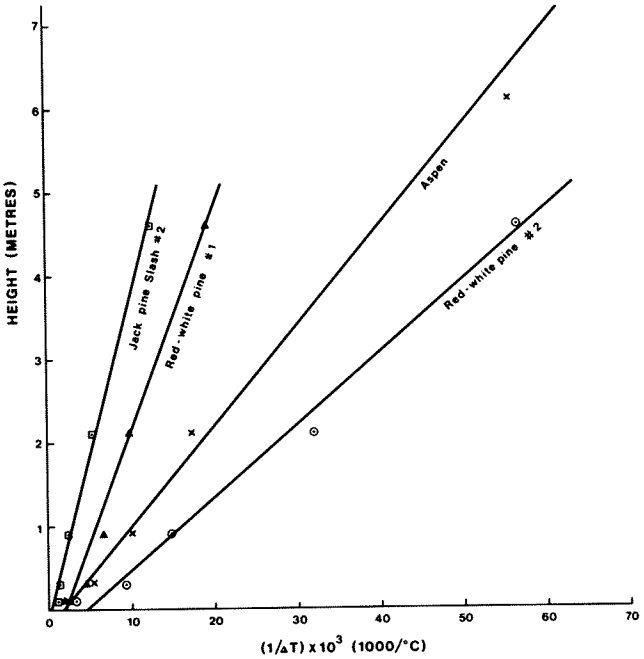

Figure 1. Graphs of height against inverse temperature rise in the convection columns above four experimental fires.

The estimated intensities of these six fires ranged from 21 to 1487 kcal/sec-m, calculated from the measured average rates of spread and quantities of fuel consumed, with an assumed constant heat of combustion of 4500 kcal/kg. Intensity I is simply the product of these three factors. Note that this is a gross intensity, no allowance being made for radiation, incomplete combustion, etc. Table 1 shows I, b, and k for the six fires. The average value of these k's is 8.9.

There are three points worth noting. First, the intensity range of the fires involved is about 100-fold, but there is no sign of any trend of k throughout the range. Second, while extrapolation is always dubious, both the theory and the graphed results suggest that this temperature-height relationship should hold for considerably greater height than those actually measured. Third, some of the variation in k in Table 1 is no doubt due to the difficulty of specifying the exact intensity while each fire was passing under the thermocouple station. The best that could be done was to calculate average intensities for the whole fires. If the gross intensities of Table 1 were reduced substantially to account for radiation and incomplete combustion (say by one-third), then the average k from Table 1 (8.9) would approach the value obtained from crown scorch measurements (11.6). However, in view of all the uncertainties involved in both determinations, the best value of k is probably the rough average of the two, namely 10. (The unit system is m-sec-kg-kcal-°C). Then, if the ambient temperature is known and the line fire intensity can be estimated, the expected temperature at any height can be calculated from Eq. 1.—C. E. Van Wagner, Petawawa Forest Experiment Station, Chalk River, Ont.

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