# EXPERIMENTAL AERIAL APPLICATIONS OF PERMETHRIN FOR CONTROL OF CHORISTONEURA FUMIFERANA IN QUEBEC, 1976-1977


*by*

*R. F. DeBoo*

Forest Pest Management Institute

Sault Ste. Marie, Ontario



REPORT FPM-X-41

Canadian Forestry Service

Department of the Environment

August 1980



*Copies of this report may be obtained from:*

*Director*
*Forest Pest Management Institute*
*Canadian Forestry Service*
*Department of the Environment*
*P.O. Box 490*
*Sault Ste. Marie, Ontario*
*P6A 5M7*

TABLE OF CONTENTS

## ABSTRACT

Results of experimental aerial applications of permethrin, a synthetic pyrethroid insecticide, indicated that either a single treatment at 70 g AI/ha or two sprays at 18 g AI/ha, each timed vs. $L_3$ - $L_4$ larvae of the spruce budworm at population densities of 30-40/45-cm branch tip, will provide excellent protection of current year foliage. At higher population density (ca. 60/45-cm tip), 3 applications of 18 g AI/ha gave superior protection of foliage. Oil-based spray deposits of small droplets were 2-4 times better in terms of coverage on Kromekote® cards than sprays of aqueous emulsions emitted under similar weather conditions. Adjuvants such as an anti-drift, anti-evaporant agent are essential for aerial application of aqueous spray mixtures. Results of companion studies of impact on aquatic invertebrates by colleagues at this Institute indicate that significant mortality occurs to some species even after application at the lowest rate evaluated. These observations may limit the dosage in potential forest pest control situations to amounts below those already registered for suppression of agricultural pests in Canada.

## RÉSUMÉ

D'après les résultats de pulvérisations expérimentales de perméthrine, dérivé de synthèse de la pyréthrine, un seul traitement à la dose de 70 g de M.A./ha ou deux à la dose de 18 g/ha, coi'ncidant aux stades $L_3$ et $L_4$ de la tordeuse des bourgeons de l'épinette dont la densité est de 30 à 40 larves sur 45 cm de branche, protège le feuillage de l'année. Si l'infestations est plus dense (env. 60 larves sur 45 cm) 3 pulvérisations à la dose de 18 g de M.A./ha assurent une protection supérieure. Dans les mêmes conditions météorologiques, les dépôts huileux de petites gouttelettes couvrent 2 à 4 fois mieux les cartes Kromekote® que les pulvérisations d'émulsions aqueuses. Quant aux préparations aqueuses, il faut leur ajouter des adjuvants pour qu'elles ne soient pas entraînées par le vent et pour qu'elles ne s'évaporent pas. D'après plusieurs études parallèles des répercussions subies par les invertébrés aquatiques, réalises par des collègues de l'Institut, les mortalités sont notables même à la plus petite dose essayée, ce qui pourrait amener l'utilisation, contre les ravageurs ferestiers, de doses bien inférieures à celles qu'on utilise en agriculture au Canada.

## INTRODUCTION

Permethrin (3-phenoxybenzyl (±) - *cis, trans* -2, 2-dimethyl-3-(dichlorovinyl) cyclopropane carboxylate) is a relatively new synthetic pyrethroid insecticide which is known to be very effective against a wide variety of pest species. Unlike earlier pyrethroids and natural pyrethrins, permethrin belongs to a new group which has higher stability to degradation by sunlight with extended residual activity. Permethrin is particularly potent against lepidopterous species including *Choristoneura* spp. (DeBoo 1977, Hopewell 1975, 1977, Nigam 1975, Robertson *et al.* 1976).

As part of the Institute's role in the development and assessment of insecticidal treatments for forest insect pests, small-scale field experiments were conducted in Quebec during 1976 and 1977 to determine effective dosages of permethrin for control of the eastern spruce budworm, *C. fumiferana* (Clem.). These studies were also considered essential for future semi-operational evaluations and prerequisite to sequential studies (laboratory to field) of other compounds in the synthetic pyrethroid group.

In keeping with policies of the Canadian Forestry Service and the Forest Pest Management Institute, mention of trade names or proprietary products implies neither endorsement nor recommendation for operational use.

## MATERIALS AND METHODS

### *Research Study Areas*

The study areas selected for treatment during 1976 were located in the St. Maurice River Valley region of southwestern Quebec (Fig. 1). Known as the Grand'Mère Plantations (DeBoo 1975, Gagnon 1972), the area had been reforested mostly with white spruce, *Picea glauca* (Moench) Voss, by the owner. In 1977, the study was continued in natural forests comprised mostly of mixtures of balsam fir [*Abies balsamea* (L.) Mill.] and spruce near the north shore of the Gaspé Peninsula (Fig. 2). All areas were second-growth forests on or near abandoned agricultural lands.

Additional details of each study area have been summarized in Table 1.

*Populations of Spruce Budworm*

Estimates of population densities of fourth-instar larvae ($L_4$) at the Grand'Mère Plantations have indicated annual increases since 1968. Average numbers of $L_4$ per 45-cm branch tip were:

1968 - 16
1970 - 21
1974 - 55
1975 - 82

The continuous defoliation over an eight-year period, combined with unfavorable site conditions, had reduced many of the plantations to very low levels of vigor. In fact, top-killing and whole-tree mortality was evident in portions of most blocks by 1975. Expectations for 1976 were (1) continued stand deterioration and (2) reduced numbers of budworm larvae, possibly to those densities recorded 1968-70.

Conditions in the Ste. Anne des Monts area were quite different from those encountered at Grand'Mère. Damaging levels of the spruce budworm were recorded for the first time in 1976. All of the fir-spruce stands appraised for experimental purposes were vigorous despite the loss of 50-80% of the 1976 foliage. Continued severe defoliation (ca. 30 or more $L_4$/45 cm branch) was expected for 1977.

Larval development, based on collections at 3-4 day intervals from untreated check areas is depicted in Figures 3 and 4. Phenologically, shoot growth and occurrence of larval stadia was two weeks later in the Gaspé Region.

*The Insecticide Permethrin*

Permethrin[1] currently is registered in Canada for control of whiteflies in greenhouses, cutworms on field tobacco, cabbage looper, imported cabbage worm and diamondback moth larvae infesting cole crops, European corn borer and corn earworm on sweet corn, as surface spray for control of house and stable flies in dairies, feedlots, poultry houses, stables, and livestock barns, and as treatment for winter moth, eastern tent caterpillar, eyespotted budmoth, plum curculio, white apple leaf hopper, tentiform leafminer, green fruitworm, apple maggot, codling moth, pear psylla, oriental fruit moth, grape berry moth, and grape

---

[1]Permethrin is also known as NRDC 143, PP557, Ambush®, (Chipman Chemicals Ltd.) and FMC 33297, Pounce® (FMC Corp.).

leaf hoppers on a variety of fruit crops. Recommended application rates range from 35-210 g AI/ha or less. The insecticide also has been used extensively during recent experimental control studies of both agricultural and forest pests in Canada and many other countries. Technical data from Chipman Chemicals Ltd. and the Agricultural Chemical Division of FMC Corp. indicated permethrin to have low mammalian toxicity characteristic of natural pyrethrins:

| Acute Oral Toxicity - Technical Material | $LD_{50}$ - mg/kg |
|---|---|
| Rat | >4000 |
| Mouse | >4000 |
| Guinea Pig | >4000 |
| Rabbit | >4000 |
| Acute Dermal Toxicity | |
| Rat | >4000 |
| Rabbit | >2000 |

Permethrin has low toxicity to birds: The acute oral $LD_{50}$ for mallard duck, Japanese quail, starling, and ring-necked pheasant are greater than 9,900, 15,500, 38,000, and 13,500 mg/kg, respectively. Fish toxicities (48-hour tests) range from 1.8 (bluegill sunfish) to 38.5 μg (mirror carp) technical permethrin/ℓ. Figures for salmon and trout range from 1.8 to 18.5 μg/ℓ. Recent studies by Kingsbury (1976, 1977), Kingsbury and Kreutzweiser 1979, 1980a,b), Kingsbury and McLeod (1979), have indicated that the major environmental impact of concern for forest aerial spray application may be to aquatic ecosystems, particularly on the quantity and quality of insects and other invertebrates which serve as fish food.

Quantities of permethrin for field experimentation were supplied by Chipman (NRDC 143) and FMC (FMC 33297). Formulations used, and other pertinent information related to the insecticide as treatment are summarized in Table II.

*Spray Application Equipment*

Single-engine aircraft, each equipped with 4 Micronair® AU3000 rotary spray atomizers, were used for all spray applications. A Cessna Agtruck was contracted from Modern Airspray Ltd., St. Jean d'Iberville, for sprays at the Grand'Mère Plantations during 1976; the Institute's Cessna Skywagon was used for the applications near Ste. Anne de Monts in 1977. Mixing/loading equipment for spray preparations included a paddle-agitated ca. 900 ℓ mixing tank, ca. 5 cm diameter hose lines with quick-connection couplings, and a laboratory trailer for equipment storage, repairs, and for preliminary spray deposit analyses of droplet size and density during calibration trials.

*Experimental Design*

Single-spray treatments of aqueous permethrin emulsions were applied to white spruce plantations (Fig. 1) during 1976 as follows:

(i) NRDC 143 @35 g AI/ha - 3 replicates[1]
(ii) NRDC 143 @35 g AI/ha - 2 replicates
(iii) FMC 33297 @35 g AI/ha - 5 replicates
(iv) FMC 33297 @70 g AI/ha - 1 replicate

In addition, a single spray block for application of fenitrothion at 280 g AI/ha was selected as standard treatment for comparative purposes as were five additional plantation blocks as untreated check areas.

The study, continued and expanded during 1977, included the following treatments formulated with No. 2 fuel oil as diluent (Fig. 2):

(i) NRDC 143 @18 g AI/ha, single application - 3 replicates
(ii) NRDC 143 @18 g AI/ha, 2 applications - 2 replicates
(iii) NRDC 143 @18 g AI/ha, 3 applications - 1 replicate
(iv) NRDC 143 @35 g AI/ha, single application - 2 replicates
(v) NRDC 143 @70 g AI/ha, single application - 2 replicates

Two spray treatments of fenitrothion at 252 g AI/ha were applied as standard treatment to each of two forest blocks (2 replicates). Four additional representative balsam fir forests were reserved as untreated check areas.

---

[1]Replicate = forest spray block.

*Spray Applications*

All aerial sprays were applied during the period of $L_3$ to $L_5$ larvae, with optimum timing considered at peak $L_4$ (Fig. 3, 4). The aircraft, each carefully calibrated to emit a narrow size spectrum of small droplets at 4.7 ℓ/ha, flew 60 m swaths at ca. 160 km/hour. Where possible, corners of each spray block were marked by red and/or white meteorolgical balloons. All sprays were applied only under weather conditions considered suitable for aerial spray application (Table III, IV).

*Evaluation of Spray Treatments*

Population densities of larvae of the spruce budworm were sampled once before treatment and either 2 or 3 times after treatment in each spray block. The sample unit consisted of a 45-cm branch tip from the mid-crown region of representative host trees - white spruce during 1976 and balsam fir in 1977. Two such branches were obtained per collection at each sampling station located along transects at right angles to the direction of spray swaths. In most blocks two transects, each with 5 or 10 stations spaced at regular intervals, were established along roads, trails or fire guards, or were cut on compass bearings across spray blocks.

Indices of population development from $L_2$ to pupa (P) and natural mortality trends were obtained from untreated check areas at 3-4 day intervals throughout the larval feeding period. On each occasion a total of 10 branches were collected from each of five representative white spruce blocks during 1976; 20 branches were collected at regular intervals from each of 4 fir areas during 1977.

Kromekote® spray deposit cards (10 x 10 cm) were placed on staked platforms ca. 0.3 m above ground level in the centre of each sampling station clearing or along roadways near sampling sites in each spray block. Cards were placed out just prior to spray treatment and were collected within 2 hours afterwards. Droplet stains on cards were measured and counted for estimates of size (volume median diameter - VMD) and density (number/$cm^2$).

Finally, branch samples were again collected at each treated and untreated sampling station for estimates of defoliation. A total of 10 branches were collected per station. The branches were clipped into 5 to 10 cm lengths, mixed together at the field laboratory, and the first 100 shoots selected at random were visually appraised using the defoliation rating scheme developed by Fettes (1951) to provide estimates of foliage protection due to treatment.

Table I. Description of study areas near Grand'Mère (1976) and Ste. Anne des Monts (1977), Quebec.

| YEAR OF STUDY: | 1976 | 1977 |
| --- | --- | --- |
| LOCATION: | Grand'Mère Plantations | Ste. Anne des Monts Area |
| HOST SPECIES: | white spruce | balsam fir |
| STAND COMPOSITION: | 100% wS | 60% bF, 30% spruce, 10% hardwood |
| AGE OF STANDS: | 45-60 years | 25-40 years |
| HEIGHT OF TREES: | 10-20 m | 10-15 m |
| STAND VIGOR: | low to medium due to previous attack by spruce budworm and clay hardpan at many locations | good |
| SILVICULTURAL TREATMENT: | some selective thinning and insecticide application 1968-1975 | none |
| OWNERSHIP: | Consolidated-Bathurst Ltd. | private woodlots, crown forests |
| ACCESS: | primary and secondary roads, trails, fireguards | secondary roads, trails and hand-cleared transects |
| EXPECTED HARVEST: | pulpwood by clear-cut | pulpwood by clear-cut |

Table II. Formulations and spray mixtures of insecticides used for aerial applications in Quebec, 1976-1977.

| Year | Treatment formulation | Source | Application rate(s) g AI/ha[1] | No. spray applications | Vol. spray ingredients (%)[2] |
|---|---|---|---|---|---|
| 1976 | NRDC 143 (25% Ambush® EC) | Chipman | 18 | 1 | F - 1.6, W - 97.8, C - 0.1, R - 0.5 |
| | | | 35 | 1 | F - 3.2, W - 96.2, C - 0.1, R - 0.5 |
| | FMC 33297 (40% Pounce® EC) | FMC | 35 | 1 | F - 1.9, W - 97.5, C - 0.1, R - 0.5 |
| | | | 70 | 1 | F - 3.8, W - 95.6, C - 0.1, R - 0.5 |
| | Fenitrothion (97% Sumithion®) | Sumitomo | 280 | 1 | F - 6.0, E - 0.6, S - 0.6, W - 92.2, C - 0.1, R - 0.5 |
| 1977 | NRDC 143 (50% Ambush® OC) | Chipman | 18 | 1 | F - 0.8, O - 98.7 A - 0.5 |
| | | | 18 | 2 | F - 0.8, O - 98.7 A - 0.5 |
| | | | 18 | 3 | F - 0.8, O - 98.7 A - 0.5 |
| | | | 35 | 1 | F - 1.6, O - 97.9 A - 0.5 |
| | | | 70 | 1 | F - 3.2, O - 96.3 A - 0.5 |
| | Fenitrothion (97% Sumithion®) | Sumitomo | 252 | 1 | F - 4.3, O - 94.6, S - 0.6, A - 0.5 |

[1] Volume emission rate at 4.7 ℓ/ha/application.

[2] Legend: F - formulation; W = water; O = No. 2 fuel oil; E = Atlox® (emulsifier); C = Chevron spray sticker; R = Rhodamine B (liquid) dye; A = Automate Red B (liquid) dye; S = Arotex® (solvent)

Table III. Meteorological conditions and larval development during aerial applications of insecticides, Grand'Mère, Que., 1976.

| Treatment[1] | Replicate (Block No.)[2] | No. ha treated | Spray date(s) | | Larval development (%) | Meteorological conditions during spray | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Temp. (°C) | Stability | RH (%) | Wind[4] | Cloud cover (%) |
| Permethrin @ 18 g AI/ha | 1 | 118 | 4 June | (0605-0630) | $L_4$-70, $L_5$-15 | 4 | I | 95 | calm | 0 |
| | 2 | 36 | 4 June | (2030-2040) | $L_4$-70, $L_5$-15 | 17 | L | 60 | 5-7 W | 25 |
| | 3 | 37 | 4 June | (2040-2040_ | $L_4$-70, $L_5$-15 | 14 | S | 60 | 5-7 W | 25 |
| Permethrin @ 35 g AI/ha | 4 | 63 | 3 June | (2030-2045) | $L_3$-30, $L_4$-60 | 13 | S | 65 | calm | 20 |
| | 5 | 135 | 3 June | (0600-0620) | $L_3$-30, $L_4$-60 | 11 | I | 80 | 2-5 NW | 30 |
| | 6 | 36 | 2 June | (2020-2030) | $L_3$-45, $L_4$-45 | 16 | I | 72 | calm | 20 |
| | 7 | 60 | 2 June | (2030-2045) | $L_3$-45, $L_4$-45 | 14 | I | 72 | calm | 20 |
| Permethrin @ 70 g AI/ha | 8 | 108 | 3 June | (0750-0810) | $L_3$-30, $L_4$-60 | 16 | S | 54 | 2-5 SW | 80 |
| Fenitrothion @ 280 g AI/ha | 9 | 105 | 2 June | (0650-0710) | $L_3$-45, $L_4$-45 | 7 | I | 90 | 0-5 N | 0 |

[1]All treatments emitted at 4.7 ℓ/ha.

[2]Active ingredient NRDC 143 in spray blocks 1-5; FMC 33297 in blocks 6-8.

[3]S - stable temperature to height of 12 m
I - temperature inversion
L - lapse condition

[4]km/hr, direction

Table IV. Meteorological conditons and larval development during aerial applications of insecticides, Ste. Anne des Monts, Que., 1977.

| Treatment[1] | Replicate (Block No.)[2] | No. ha treated | Spray date(s) | Larval development (%) | Meteorological conditions during spray: Temp. (°C) | Stability[3] | RH (%) | Wind[4] | Cloud cover (%) |
|---|---|---|---|---|---|---|---|---|---|
| Permethrin @ 18 g AI/ha (1 application) | 1 | 36 | 15 June (0530-0540) | $L_3$-20, $L_4$-60 | 11 | S | 93 | 3-6 W | 30 |
| | 2 | 30 | 14 June (2000-2015) | $L_3$-30, $L_4$-50 | 13 | I | 75 | 0-3 NW | 50 |
| | 3 | 36 | 15 June (0545-0600) | $L_3$-20, $L_4$-60 | 12 | S | 82 | 3-8 WNW | 30 |
| Permethrin @ 18 g AI/ha (2 applications) | 4 | 30 | 14 June (1940-1955) | $L_3$-30, $L_4$-50 | 13 | I | 72 | 0-3 NW | 50 |
| | 4 | 30 | 17 June (1940-1950) | $L_3$-18, $L_4$-64 | 13 | I | 59 | 0-3 NW | 90 |
| | 5 | 35 | 14 June (2000-2015) | $L_3$-30, $L_4$-50 | 13 | I | 75 | 0-3 NW | 50 |
| | 5 | 35 | 17 June (2025-2040) | $L_3$-18, $L_4$-64 | 11 | I | 67 | 4-7 WNW | 90 |
| Permethrin @ 18 g AI/ha (3 applications) | 6 | 36 | 15 June (0630-0640) | $L_3$-30, $L_4$-60 | 12 | S | 89 | 4-7 W | 30 |
| | 6 | 36 | 17 June (2025-2040) | $L_3$-18, $L_4$-64 | 11 | I | 70 | 4-7 WNW | 90 |
| | 6 | 36 | 22 June (2000-2010) | $L_3$-60, $L_4$-25 | 12 | I | 70 | 0-3 NNE | 30 |
| Permethrin @ 35 g AI/ha (1 application) | 7 | 30 | 15 June (1955-2005) | $L_3$-20, $L_4$-60 | 12 | I | 69 | 4-7 SE | 75 |
| | 8 | 33 | 15 June (2010-2020) | $L_3$-20, $L_4$-60 | 12 | I | 72 | 0-3 S | 75 |
| Permethrin @ 70 g AI/ha (1 application) | 9 | 30 | 16 June (0515-0525) | $L_3$-20, $L_4$-62 | 7 | S | -1 | 4-7 NE | 25 |
| | 10 | 30 | 16 June (0530-0540) | $L_3$-20, $L_4$-62 | 7 | S | 65 | 3-8 ENE | 25 |
| Fenitrothion @ 252 g AI/ha (1 application) | 11 | 30 | 17 June (0620-0630) | $L_3$-18, $L_4$-64 | 10 | S | 53 | 2-4 WSW | 0 |
| | 12 | 30 | 17 June (0640-0645) | $L_3$-18, $L_4$-64 | 10 | S | 52 | 2-4 WSW | 0 |

[1] All treatments emitted at 4.7 ℓ/ha.

[2] See map, Figure 2; active ingredient is NRDC 143.

[3] S - stable temperature to height of 12 m
I - temperature inversion

[4] km/hr, direction

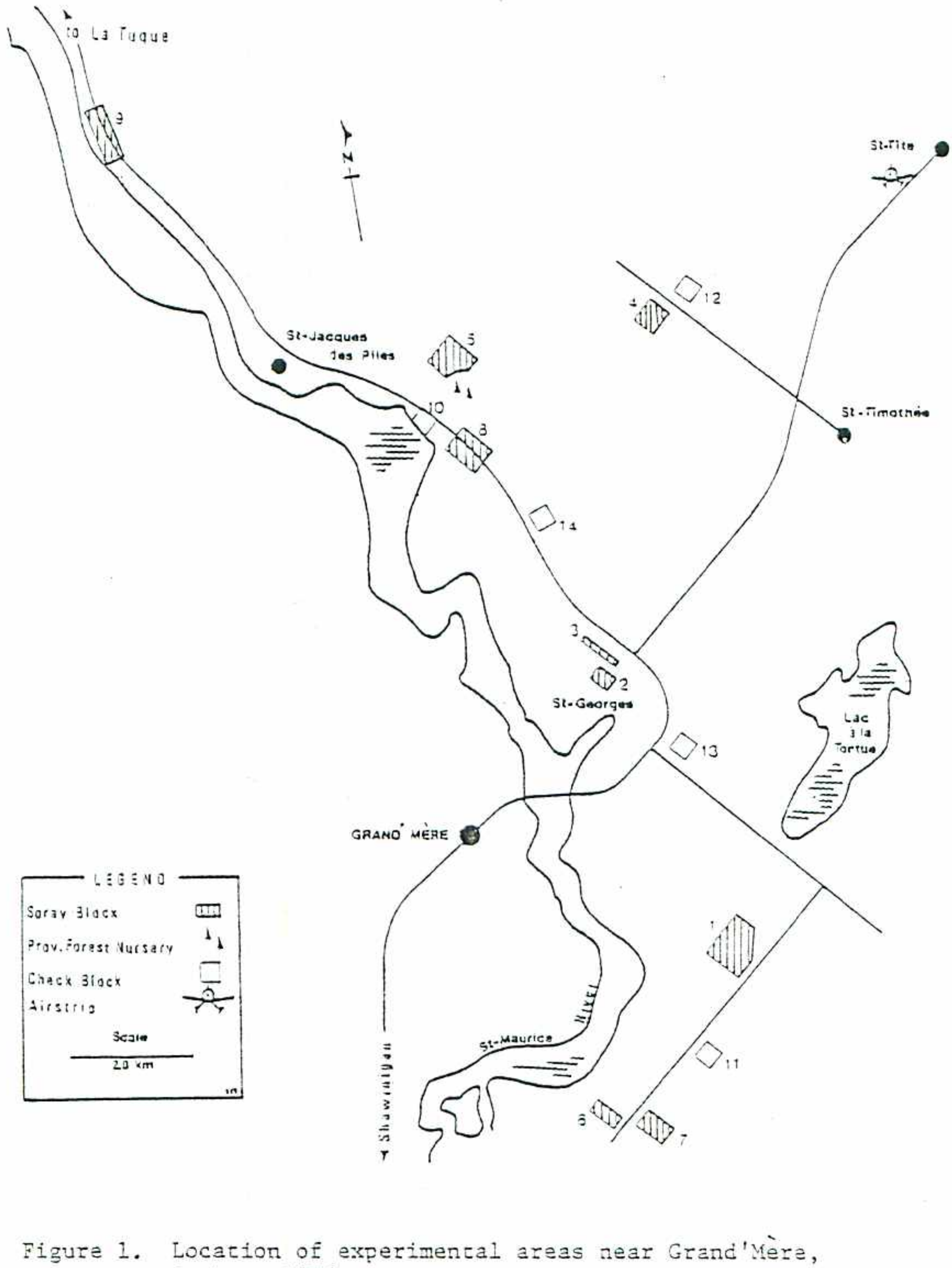


Figure 1. Location of experimental areas near Grand'Mère, Quebec, 1976.

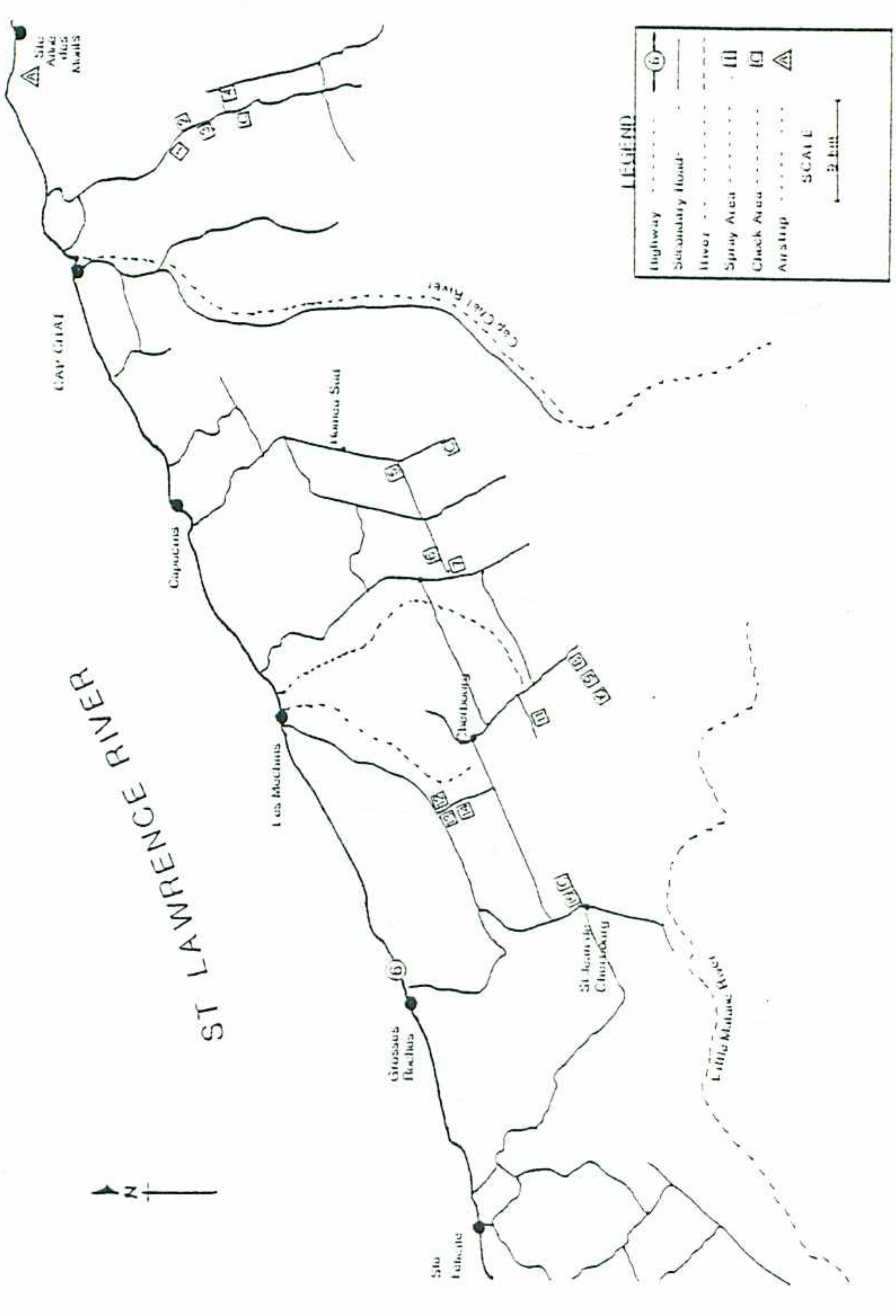


Figure 2. Location of experimental areas near Ste. Anne des Monts, Quebec, 1977.

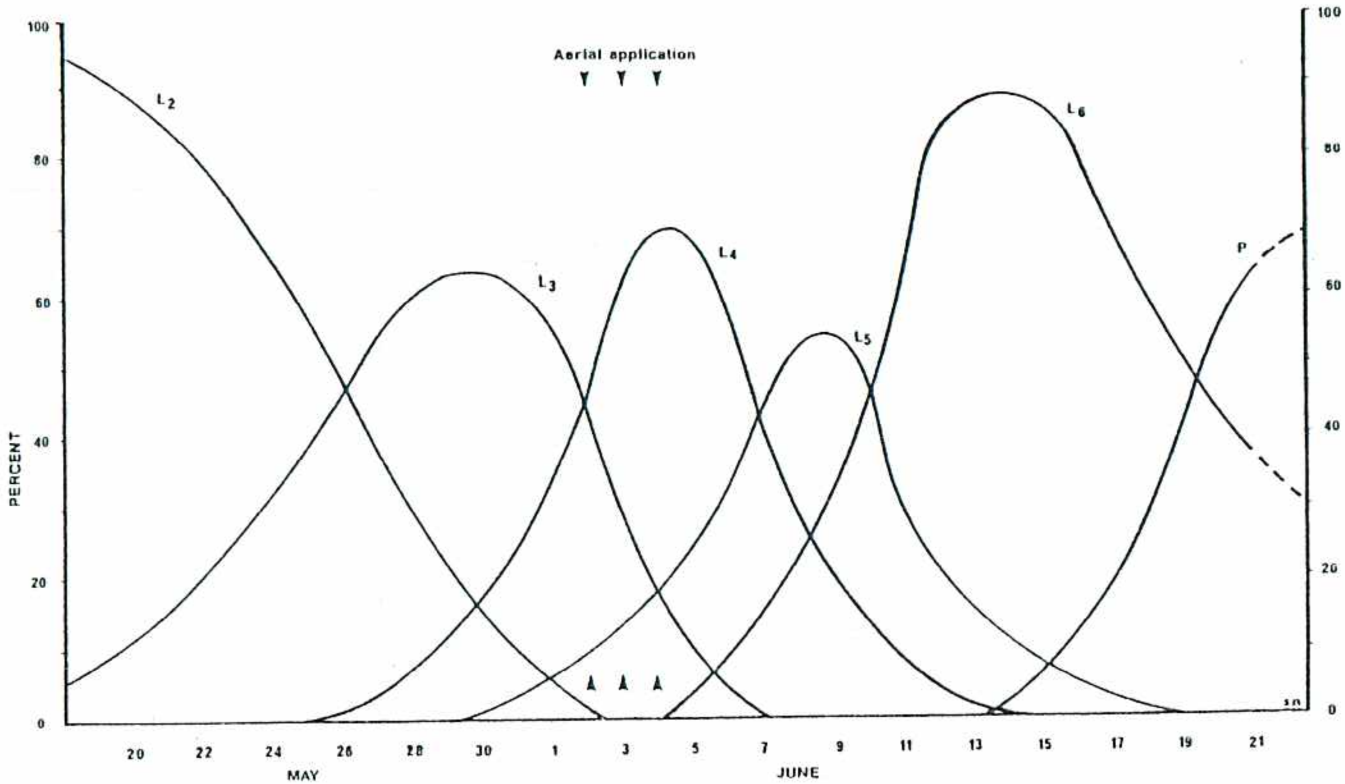


Figure 3. Trends in larval development of the spruce budworm – Grand'Mère Plantations, 1976

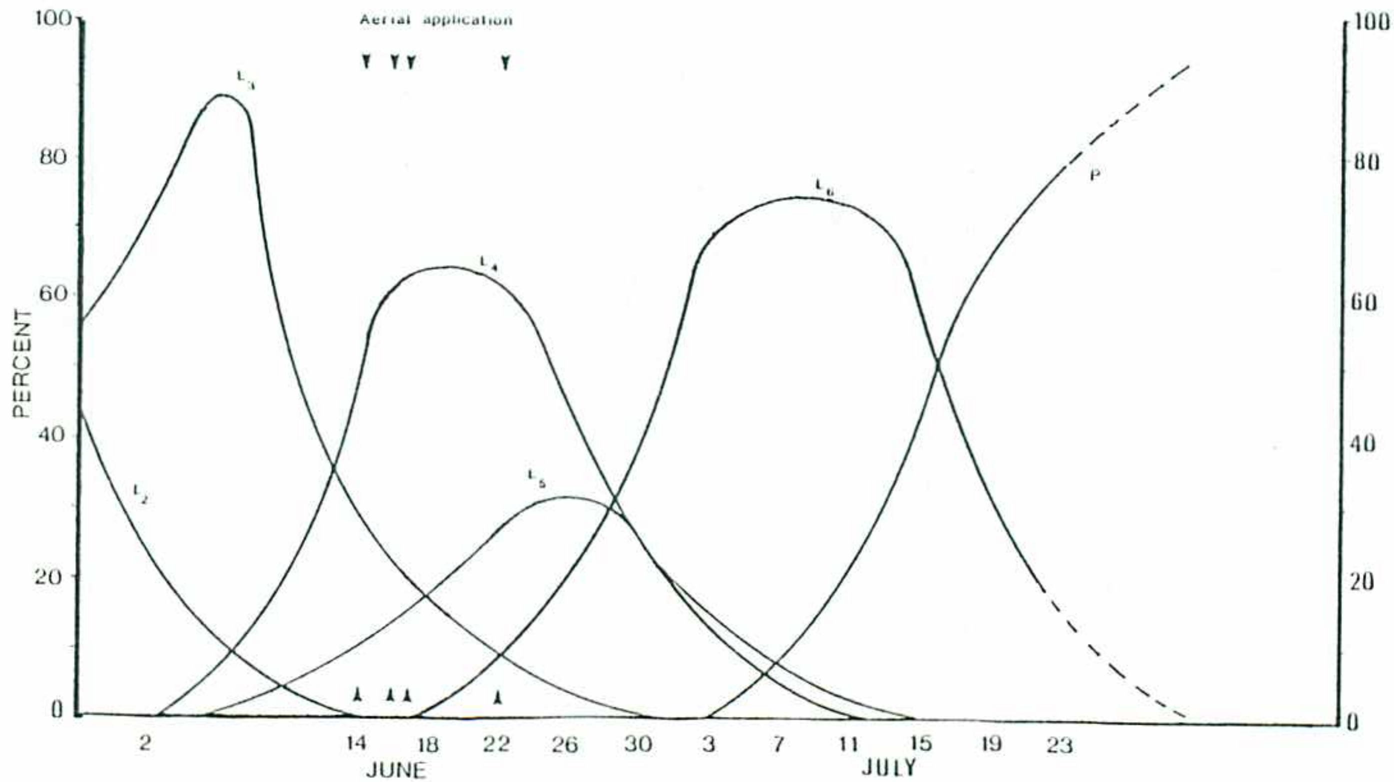


Figure 4. Trends in larval development of the spruce budworm – Ste. Anne des Monts, 1977

# RESULTS AND DISCUSSION

## *Permethrin as Treatment*

Preliminary sampling for larvae of the spruce budworm ($L_2$-$L_3$) at Grand'Mère indicated population densities of ca. 20/45-cm branch tip. However, subsequent sampling at time of $L_4$ showed only about half this density to be present. This level, with due consideration for vigor of host trees, was actually below the level of infestation warranting insecticidal treatment. The light defoliation for untreated check trees (Table V) is an accurate reflection of this unexpected situation and as a result efficacy of treatments was difficult to interpret and compare.

The younger infestations near Ste. Anne des Monts, on the other hand, provided excellent larval densities for experimentation. With the exception of Block 6 having a mean population density of about 60 larvae/45-cm branch just prior to spray treatment, populations at most of the other 15 experimental areas ranged from 30 to 40 $L_3$-$L_4$ larvae per branch. Accordingly, evaluation of results has been biased towards those treatments of 1977 near Ste. Anne.

Briefly, 1977 was the second year of severe attack in mostly vigorous second-growth balsam fir stands. Food supply was adequate (> 5 shoots/larva) to support larval feeding to pupation. The carefully applied spray treatments averaged more than 50 spray droplets ca. 80-90 $\mu$ VMD per $cm^2$ per application as measured on the deposit cards. Timing of treatments, including double and triple applications, was considered near optimum (Fig. 4).

Increased effectiveness of permethrin as treatment was evident both as (1) multiple application of 18 g AI/ha and (2) as increased quantity of active ingredient to 70 g AI/ha (based on 1977 results). At 70 g AI/ha the best level of foliage protection of the single applications was attained (Table VI); the highest percent larval mortality was achieved after 3 applications at 18 g AI/ha. It was of particular importance to note also that the triple application of this very low dose of insecticide provided excellent protection of foliage at an infestation level ($\sim$60 larval/branch) considered very severe. Only 25% defoliation occurred after treatment compared to 80% in the untreated blocks where population density was at about 40 $L_3$ and $L_4$ per branch.

Fenitrothion, the insecticide selected as standard for comparison, provided results (Table V, VI) very similar to those of previous years (Hildahl and DeBoo, 1975). Emitted at 250-280 g AI/ha, results were about 50% mortality of mostly $L_3$ and $L_4$ and a savings of 15-20% of the foliage. Similar results were attained also with single applications of permethrin emitted at 18 g AI/ha, a level of protection considered unsatisfactory particularly for conditions where fewer than 5 shoots (2-5 cm long) may be present per $L_4$. On this basis, permethrin appeared to be ca. 15 times as potent as fenitrothion for control of $L_3$ and $L_4$ larvae.

On a practical basis and in keeping with current application technology, 2 applications of permethrin at 18 g AI/ha gave excellent protection of balsam fir from attack by ca. 30 $L_3$ and $L_4$ larvae/45-cm branch (Fig. 6). Defoliation estimates of treated trees averaged less than 20%, whereas defoliation of untreated check trees having slightly higher populations was about 4 times this level. Results of the double applications of 18 g were superior to results of similar dosage (35 g AI/ha) emitted as a single spray (Table VI). About twice the amount of foliage was saved via the double application also. This level (40% foliage saved) can be expected only from superior spray treatments with other insecticides currently being used against budworm larvae (Auger *et al.* 1978, Blais *et al.* 1980, Trial and Thurston 1978).

Analyses of spray deposits on Kromekote® cards (Table VII) clearly demonstrated the superiority of oil-based mixtures vs. aqueous preparations: usually 2-4 times better coverage under similar weather conditions (Tables III, IV). The relatively poor deposits of aqueous sprays during 1976 also indicated the need for adjuvants such as an anti-evaporant. In fact, the erratic results as expressed by corrected percent population reduction during 1976 (Table V) could have been due to the inadequate spray coverage of the tree crowns.

*Environmental Impact*

Concomitant studies of environmental impact (i.e. to organisms other than spruce budworm larvae) have been conducted annually in eastern forests since 1976. The studies have been reported by Kingsbury (1976, 1977), Kingsbury and McLeod (1979), and Kingsbury and Kreutzweiser (1980a,b). In effect, the studies have shown the high toxicity of permethrin to aquatic invertebrates even at application rates as low as 17.5 g AI/ha. The effects of applications at up to 70 g AI/ha on stream- and lake-inhabiting fish have been nil; the impact has been most dramatic on fish food organisms. Ultimate implications of such non-target impacts are speculative only at present. However, these results no doubt will be of prime concern in the selection of operational dosages should permethrin be submitted for registration as treatment for control of spruce budworm and other forest insect pests in Canada.

## SUMMARY AND CONCLUSIONS

Experimental aerial treatments of permethrin were applied by agricultural-type spray aircraft in Quebec during 1976 and 1977. The studies indicated that this insecticide, representative of a new group of synthetic pyrethroids, was very effective for control of the spruce budworm. As summary, the following highlights, particularly from the 1977 study, are noted: (1) Two applications of permethrin, each at 18 g AI in 4.7 ℓ oil diluent/ha, was considered very effective and the most practical of the variety of dosages and spray mixtures evaluated for control of $L_3$ - $L_5$ larvae. (2) Three applications at 18 g AI were particularly effective in the protection of trees under very severe attack (> 60 $L_3$-$L_4$ larvae/45-cm branch). Only 25% of the new foliage was destroyed in treated blocks compared to 80% defoliation of new shoots in untreated blocks with fewer larvae (ca. 40) per branch sample. (3) As single spray treatment, the highest dosage evalueated, 70 g AI/ha, was the most effective (Fig. 5). (4) Spray coverage remains as one of the most important factors for consideration in the selection of spray mixtures: From 2-4 times better coverage as expressed by droplet densities on Kromekote® cards was attained with oil-based sprays. Suitable adjuvants would be required to improved deposit of aqueous mixtures. (5) Undesirable side effects, notably toxicity to aquatic (non-target) invertebrates, may limit application rates for forest protection to the lower rates of application evaluated. (6) However, as permethrin is one of the most effective insecticides yet evaluated for control of spruce budworm larvae, semi-operational evaluations of selected low dosages should be conducted. The experiments should include both appraisals of efficacy and intensive investigations of toxicity to certain non-target organisms. Only after such experimentation will the overall impact of permethrin as an operational treatment be determined. Such investigations have yet to be undertaken.

Table V. Results of experimental aerial applications of insecticides for control of spruce budworm on white spruce, 1976.

| Treatment | Replicate (Block No.) | Average No. larvae/45-cm branch tip | | | Percent population reduction[1] | Percent defoliation[2] |
|---|---|---|---|---|---|---|
| | | Prespray (-1 to 7 days) | 1st postspray (+3 to 6 days) | 2nd postspray (+8 to 12 days) | | |
| Permethrin @ 18 g AI/ha | 1 | 7 | 2 | 1 | | |
| | 2 | 8 | 3 | 2 | | |
| | 3 | 14 | 4 | 2 | | |
| | *Avg.* | *9* | *3* | *1* | *74* | *4* |
| Permethrin @ 35 g AI/ha | 4 | 6 | 1 | 1 | | |
| | 5 | 6 | 2 | 2 | | |
| | 6 | 18 | 4 | 3 | | |
| | 7 | 14 | 5 | 2 | | |
| | *Avg.* | *10* | *3* | *2* | *58* | *4* |
| Permethrin @ 70 g AI/ha | *8* | *12* | *3* | *3* | *47* | *3* |
| Fenitrothion @ 280 g AI/ha | *9* | *7* | *2* | *1* | *67* | *3* |
| Untreated check | 10 | 5 | 2 | 1 | | |
| | 11 | 6 | 1 | 1 | | |
| | 12 | 5 | 6 | 2 | | |
| | 13 | 9 | 6 | 4 | | |
| | 14 | 11 | 7 | 7 | | |
| | *Avg.* | *7* | *4* | *3* | -- | *7* |

[1] Corrected by Abbott's Formula (1925); population densities at prespray vs. final postspray.

[2] Using Fettes Method (1951).

Table VI. Results of experimental aerial applications of insecticides for control of spruce budworm on balsam fir, 1977.

| Treatment | Block No. | Average No. larvae/45-cm branch tip[1] Prespray (-1 to 4 days) | 1st Postspray (+3 to 5 days) | 2nd Postspray (+3 to 14 days) | 3rd Postspray (+6 to 15 days) | Percent population reduction[2] | Percent defoliation[3] |
|---|---|---|---|---|---|---|---|
| Permethrin @ 18 g AI/ha (1 application) | 1 | 43 | 27 | 22 | -- | | |
| | 2 | 33 | 24 | 13 | -- | | |
| | 3 | 37 | 12 | 9 | -- | | |
| | *Avg.* | *38* | *21* | *15* | -- | *46* | *62* |
| Permethrin @ 18 g AI/ha (2 applications) | 4 | 32 | 16 | 5 | 6 | | |
| | 5 | 28 | 24 | 16 | 11 | | |
| | *Avg.* | *29* | *20* | *10* | *9* | *59* | *19* |
| Permethrin @ 18 g AI/ha (3 applications) | *6* | *61* | *15* | *8* | *4* | *93* | *25* |
| Permethrin @ 35 g AI/ha (1 application) | 7 | 41 | 7 | 9 | -- | | |
| | 8 | 34 | 14 | 21 | -- | | |
| | *Avg.* | *38* | *11* | *15* | -- | *45* | *43* |
| Permethrin @ 70 g AI/ha (1 application) | 9 | 24 | 6 | 3 | -- | | |
| | 10 | 41 | 7 | 10 | -- | | |
| | *Avg.* | *32* | *7* | *6* | -- | *65* | *24* |
| Fenitrothion @ 252 g AI/ha | 11 | 53 | 30 | 17 | -- | | |
| | 12 | 25 | 15 | 32 | -- | | |
| | *Avg.* | *39* | *23* | *24* | -- | *15* | *65* |
| Untreated check | 13 | 40 | 24 | 20 | 24 | | |
| | 14 | 42 | -- | 32 | 30 | | |
| | 15 | 27 | 30 | 35 | 26 | | |
| | 16 | 48 | 36 | 29 | 49 | | |
| | *Avg.* | *39* | *30* | *29* | *32* | -- | *80* |

[1] In multiple application treatments, populations sampled once before and either once or twice after each spray.

[2] Corrected by Abbott's Formula (1925); population densities at prespray vs. final postspray.

[3] Using Fettes Method (1951).

Table VII. Summary and comparison of spray droplet deposits, 1976-1977: density, size and volume collected near ground.

| Treatment[1] | Year | No. replicates | No. drops/cm² Avg. | No. drops/cm² Range | Volume median diameter (μm) | Approx. % of vol. emitted collected near ground |
|---|---|---|---|---|---|---|
| Permethrin @ 18 g AI/ha | 1976 | 3 | 10 | 0- 41 | 110 | 9 |
| | 1977 | 10 | 50 | 1-125 | 86 | 25 |
| Permethrin @ 35 g AI/ha | 1976 | 4 | 16 | 0- 23 | 95 | 10 |
| | 1977 | 2 | 53 | 12-124 | 79 | 23 |
| Permethrin @ 70 g AI/ha | 1976 | 1 | 8 | 0- 11 | 102 | 7 |
| | 1977 | 2 | 78 | 5-154 | 80 | 31 |
| Fenitrothion @ 252 g AI/ha | 1977 | 2 | 29 | 1- 78 | 91 | 18 |
| Fenitrothion @ 280 g AI/ha | 1976 | 1 | 11 | 2- 16 | 117 | 11 |

[1]All mixtures in water during 1976, in oil during 1977; emitted at 4.7 ℓ/ha.

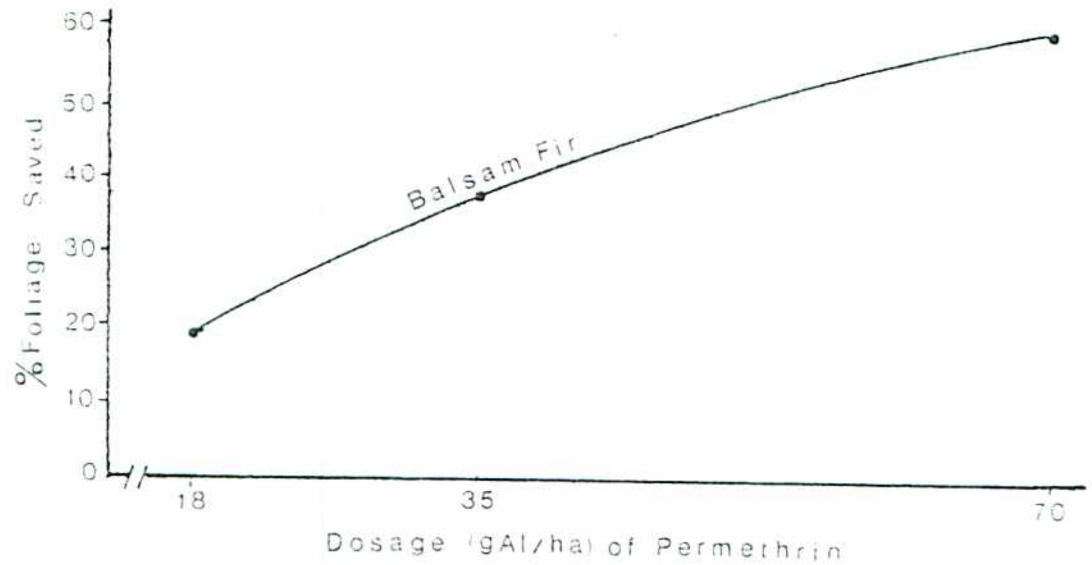


Figure 5. Indicated relationship: Dosage of active ingredient to quantities of foliage save, Ste. Anne des Monts area, 1977.

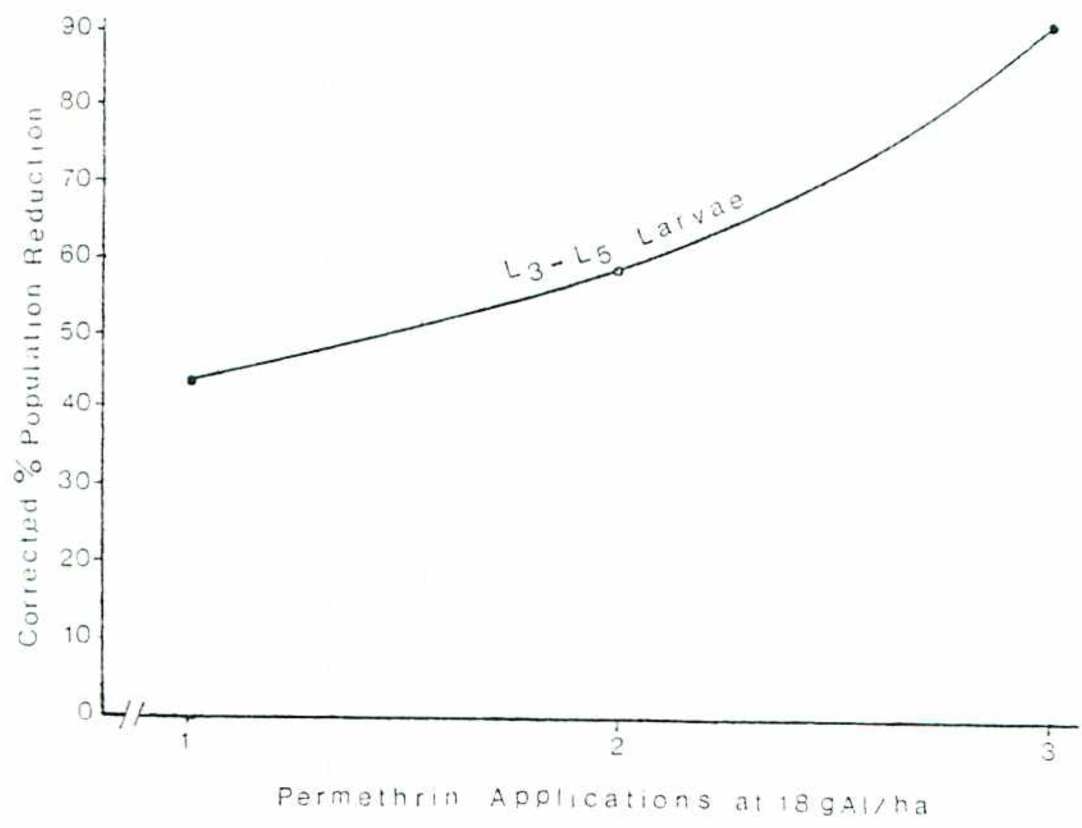


Figure 6. Indicated relationship: Number of applications of permethrin emitted at 18 g AI/ha to reduction in larval population density, Ste. Anne des Monts area, 1977.

## ACKNOWLEDGMENTS

The author acknowledges with sincere thanks the important contributions of the many people associated with the studies of 1976 and 1977: Areas suitable for spray treatment were suggested by staff of Consolidated-Bathurst Ltd. and the Quebec Department of Lands and Forests. Field laboratory facilities were provided by Mr. Marc Michaud, Superintendant of the Grands-Piles Nursery, during 1976, and Mr. Guy Fournier of Ste. Anne des Monts furnished utilities for the laboratory trailer during 1977.

The indispensable services of Mr. R.P. Gardiner, Chipman Chemicals Ltd., during mixing/loading operations at the airstrips and the conscientious aerial applications by Messrs. L.B. Pollock of the Institute and Jean Tardif of Modern Airspray Ltd. are much appreciated. Miss Alexa Morrison, with the technical assistance and advice of W.W. Hopewell and Wm. Haliburton, determined characteristics of spray depostion. J.A. Armstrong, G.W. Green, K.M.S. Sundaram of FPMI, R.S. Hodgkinson of the Great Lakes Forest Research Centre, and R.A. Costen of Chipman Chemicals Ltd. offered valuable comment during review of the manuscript. Illustrations were prepared by D.R. Dickson and L.B. Pollock of FPMI.

Finally, the role of the very essential technical and seasonal support staff during field operations is gratefully acknowledged: Thanks to S.A. Nicholson, D.F. Dyer, Bao Truong, Richard DeBoo, Susan and Louis Fulton, André Fortin, Brian Sergeant, Robert Gagnon, Luc Coté, André Beaulieu, Marc Lemieux, Guy Deshcênes, Laurent Letourneau, and Denis Thibault.

## LITERATURE CITED

Abbott, W.S. 1925. A method of computing the effectiveness of an insecticide. *J. Econ. Ent.* 18:265-267.

Auger, M., C. Bordeleau, M. Chabot, and L. Dorais. 1978. Expertises entomologiques reliées aux pulvérisations aériennes contre la tordeuse des bourgeons de l'épinette an Québec en 1977. Que. Min. Terres et For., Serv. d'Ent. et de Path. Rap. TFI-3294-4e, 306 p.

Blais, J.R., R.F. DeBoo, and M. Auger. 1980. Comparison of three spray regimes for control of spruce budworm in Quebec. *In Press*.

DeBoo, R.F. 1975. Plantation Research: XV. Experimental aerial applications of methomyl, phoxim and trichlorfon for control of *Choristoneura fumiferana* on white spruce in Quebec, 1975. Dep. Environ., Can. For. Serv. Inf. Rep. CC-X-105, 21 p.

DeBoo, R.F. 1980. Experimental applications of permethrin by mistblower for control of spruce budworm in Quebec, 1975-1978. Dep. Environ., Can. For. Serv. Bi-mthly. Res. Notes *In Press*.

Fettes, J.J. 1951. Investigations of sampling techniques for population studies of the spruce budworm on balsam fir in Ontario. Ph.D. thesis, Univ. of Toronto, 212 p.

Gagnon, J.D. 1972. Grand'Mère Plantations, an example for future reforestation. Dep. Environ., Can. For. Serv. Inf. Rep. O-X-30, 27 p.

Hildahl, V., and R.F. DeBoo. 1975. Aerial applications of chemical insecticides against the spruce budworm in Manitoba, 1973. *Man. Ent.* 7 (1973): 6-14.

Hopewell, W.W. 1975. Field evaluation of Orthene®, Phosvel®, FMC 33297 and TH 6040, against *Choristoneura fumiferana*, applied as a simulated aerial spray. Dep. Environ., Can. For. Serv. Rep. CC-X-115, 29 p.

Hopewell, W.W. 1977. Field evaluation of the pyrethroid NRDC-143, compared with fenitrothion, acephate and chlorpyrifos-methyl as simulated aerial spray deposit for control of the spruce budworm, *Choristoneura fumiferana* Clem. Dep. Environ., Can. For. Serv. Rep. CC-X-132, 31 p.

Kingsbury, P.D. 1976. Studies of the impact of aerial applications of the synthetic pyrethroid NRDC-143 on aquatic ecosystems. Dep. Environ., Can. For. Serv. Inf. Rep. CC-X-127, 111 p.

Kingsbury, P.D. 1977. Effects of an aerial application of the synthetic pyrethroid permethrin on a forest stream. *Man. Ent.* 10:9-17.

Kingsbury, P.D., and D.P. Kreutzweiser. 1979. Impact of double applications of permethrin on forest streams and ponds. Dep. Environ., Can. For. Serv. Rep. FPM-X-27, 42 p., appen.

Kingsbury, P.D., and D.P. Kreutzweiser. 1980. Environmental impact assessment of a semi-operational permethrin application. Dep. Environ., Can. For. Serv. Rep. FPM-X-30, 47 p., appen.

Kingsbury, P.D., and D.P. Kreutzweiser. 1980. Dosage-effect studies on the impact of permethrin on trout streams. Dep. Environ., Can. For. Serv. Rep. FPM-X-31, 51 p., appen.

Kingsbury, P.D., and B.B. McLeod. 1979. Terrestiral impact studies in forest ecosystems treated with double applications of permethrin. Dep. Environ., Can. For. Serv. Rep. FPM-X-28, 78 p.

Nigam, P.C. 1975. Summary of laboratory evaluations of insecicides against various species of forest insect pests during 1975. Dep. Environ., Can. For. Serv. Inf. Rep. CC-X-124, 9 p.

Robertson, J.L., N.L. Gillette, M. Look, B.A. Lucas, and R.L. Lyon. 1976. Toxicity of selected insecticides applied to western spruce budworm. *J. Econ. Ent.* 69:99-104.

Trial, H. Jr., and A.S. Thurston. 1978. Spruce budworm in Maine: The 1978 cooperative spruce budworm suppression project and expected infestation conditions for 1979. Maine For. Serv., Ent. Div. Tech. Rep. No. 8, 109 p.