# PLANTATION RESEARCH: XII. EXPERIMENTAL APPLICATIONS OF INSECTICIDES BY MISTBLOWER FOR CONTROL OF *Choristoneura fumiferana* ON WHITE SPRUCE IN QUEBEC, 1974

by

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## ABSTRACT

Experimental applications for control of spruce budworm on white spruce indicated that good protection of foliage can be obtained with aqueous spray mixtures of acephate, carbaryl, methomyl or phoxim. Good protection of foliage also was attained with combination treatments of Dipel(R) WP and chlordimeform and with Thuricide(R) 16B in combination with either acephate, carbaryl or methomyl. Applications of commercial preparations of Bacillus thuringiensis at up to 8 BIU per acre did not provide significant levels of foliage protection when timed against peak third-instar larvae.



## RÉSUMÉ

Une bonne protection du feuillage de l'épinette blanche est obtenue contre la tordeuse en utilisant un mélange de vaporisation aqueuse d'acephate de carbaryl de methomyl ou de phoxim. Une bonne protection est aussi observeé en combinant le Dipel(R) WP et le chlordimeform et le Thuricide(R) 16B avec soit l'acephate, le carbaryl ou le methomyl. Des préparations commerciales de Bacillus thuringiensis appliquées jusqu à 8 BIU par âcre ne donnent pas la protection voulue au feuillage contre la troisième stade larvaire.

## INTRODUCTION

A previous report in this series summarized preliminary experimentation on the protection of white spruce (*Picea glauca* (Moench) Voss) from defoliation by the spruce budworm (*Choristoneura fumiferana* (Clem.)) through application of insecticides using a truck-mounted mist-blower (DeBoo and Campbell, 1972). It was noted that only one insecticide - dimethoate - had federal registration for commercial application by ground spray equipment against the budworm up to 1972. Since then, two formulations of the microbial insecticide *Bacillus thuringiensis* (B.t.) have been registered for commercial use whereas one other chemical insecticide, malathion, has been registered for domestic use in the protection of ornamental trees (Chemical Control Research Institute, 1975). The choice of spray treatments remains limited to date (1974), and it is expected that 1-2 years of additional experimentation will be required to obtain the research documentation necessary for federal acceptance of several other potentially effective and environmentally acceptable insecticides for groundspray application.

It is the major objective of the plantation studies on the spruce budworm to ultimately provide a selection of safe, effective and practical spray ingredients and application techniques for the protection of high-value host trees. Since 1972, the study on groundspray treatments has included experimental applications in parks and plantation tree farms, to ornamental trees, nursery shelterbelts, and along roadsides to minimize larval feeding damage for both silvicultural and aesthetic purposes. Research during 1973 was restricted primarily to the evaluation of B.t. sprays in Manitoba (DeBoo and Campbell 1974). During 1974, the study

was continued to:

(1) determine the efficacy of selected dosages of acephate (Orthene(R)), carbaryl (Sevin(R)), methomyl (Lannate(R)), and phoxim (Volaton(R)) for control of fourth-instar larvae ($L_4$),

(2) determine the efficacy of three different dosages for each of two commercial preparations of B.t. (Dipel(R) WP, Thuricide(R) 16B) for control of third-instar larvae ($L_3$),

(3) evaluate the effectiveness of several B.t. plus chemical insecticide combinations for application when larval development was mostly $L_3$ and $L_4$.

As experienced during the 1972 field study, time and staff available for this work were major factors limiting the selection and scope of insecticide treatments. Rates of application were based on either previous experimental results obtained by the authors or on suggestions from technical representatives of the manufacturers. Mention of proprietary trade names, therefore, implies neither endorsement nor recommendation by the Canadian Forestry Service. Also, this report should not be construed as the basis for the selection of insecticide dosages for operational use until the experimental results have been verified by additional experimentation.

## MATERIALS AND METHODS

### Field Research Study Area

Arrangements were made with Mr John Conway, Plantation Forester for Consolidated-Bathurst Limited, to conduct spray experiments along roadsides and hydro rights-of-way in portions of the Grand'Mère Plantations. Gagnon (1972) has described the historical aspects of these predominantly white spruce stands and their associated growth rate/site relationships. He states, "Among the oldest and largest in Canada, the Grand'Mère plantations, established between 1913 and 1932, totalling 9,600 acres, are located in the St. Maurice River Valley, near the city of Grand'Mère, Quebec". The plantation blocks which were selected for peripheral spray treatment by mistblower were located along a 10-mile stretch from the Grandes-Piles provincial tree nursery and St. Timothée to the Proulx block of plantations south of Lac-à-la-Tortue (Fig. 1). Trees selected for treatment were half to fully crowned white spruce ranging from 20 to more than 60 feet in height and growing on the variety of sites described by Gagnon (1972).

### Spruce Budworm Population Density

Historically, populations of the spruce budworm have occurred in the Grand'Mère Plantations at injurious levels since 1946 (Daviault 1946). Chemical control operations were initiated by the Quebec Dept. of Lands and Forests in 1968 and repeated in 1970 in an attempt to reduce the spread and subsequent feeding impact of spruce budworm larvae in the plantations (Martineau and Smerlis 1968, Martineau and Lavallee 1970). Population densities, based on the number of larvae per 18-inch branch tip, averaged 15.5 in 1968 and 20.8 in 1970 (Desaulniers and Martineau 1970).

A total of 3,350 acres were treated with a single application of phosphamidon (4 oz A.I. in 0.5 U.S. gal spray mix/acre) during 1968, and 4,500 acres were sprayed in 1970 (fenitrothion at 3.5 oz A.I. in 0.4 gal spray mix/acre, single application). Bell G-4 helicopters equipped with boom and nozzles were used to apply the insecticides during both years.

Although successful in reducing defoliation impact during the years of spray application, the treatments did not contain the spread or intensity of the infestation. By 1973 tree mortality was evident (especially in the low-vigor stands) and population densities of the budworm had continued to increase. Pre-treatment sampling in 1974 indicated that an average of approximately 50 larvae per 18-inch branch tip occurred throughout the plantations. Gagnon (1972), in discussing the research value of the plantations, stated "As all white spruce plantations ... are still infested by the spruce budworm, every effort should be made to bring the infestation under control. It is my opinion the 1946 budworm infestation ... affected growth far more on all sites than any other reported factor".

## Insecticides

Two formulations of B.t. and five chemical insecticides were selected for experimental application. Names and mammalian toxicities are given in Table I; selected treatment dosages and guidelines for the timing of spray applications are indicated in Table II.

## Application Equipment

A John Bean(R) Rotomist Model 100HT, acquired by C.C.R.I. for experimental spray applications, was utilized exclusively in the study.

The sprayer (title page) was equipped with a Ford 4-cylinder 172 cu. in., 68 h.p. engine, John Bean Royalette 10 plunger-type pump, 3 Micro-Mist nozzles, 300 gal. (U.S.) stainless steel tank, and a 10-bladed axial-flow fan capable of producing air velocities and volumes up to 100 mph and 28,000 cu. ft./min., respectively. The sprayer was operated at 300-350 p.s.i. pump pressure and from half to full throttle (depending upon tree height, proximity to target trees, branch density, tree spacing and direction of prevailing wind) to obtain the desired coverage of spray droplets (ca. 100-300 microns MMD).

Preliminary calibrations using dyed water indicated that the average condition along the borders of plantation blocks at Grand'Mère would permit effective spray penetration (20 droplets/$cm^2$ or more) for approximately 2 chains (132 ft.) from the nozzles at heights of up to 50 ft. Time studies and records of simulated spray volumes indicated also that about 15 gal. of spray would be required to treat an acre of trees (with dimensions of 2 chains in depth x 5 chains in length).

Experimental Design

Nineteen treatment blocks were established along roadsides and hydro transmission lines at the Grand'Mère Plantations (Fig. 1); six B.t. sprays, four chemical insecticide sprays, four combination sprays, and five untreated checks were subsequently assigned by random numbers. Each spray block was designed to approximate as closely as possible the selected standard of one mile in length and 16 acres in area (i.e. 80 x 2 chains). Because of stand openings and/or the inaccessibility of some trees, actual spray block areas varied from 15.4 to 18 acres (Table III).

In effect, then, the treatment blocks were established in non-replicated design, but with each block sufficiently large to permit the acquisition of representative budworm population density and post-treatment defoliation data required for detailed appraisal of treated/untreated trees.

Spray Applications

The B.t. treatments were applied June 4-6 when most larvae were in the third instar ($L_3$). Combination B.t. + chemical insecticide sprays were applied June 6-7 when the larval population was primarily $L_3$ and $L_4$, and the chemical spray treatments were applied June 9-12 near the peak occurrence of $L_4$ (Table III, Fig. 2).

All sprays were mixed (U.S. measure) at central facilities at either St-Georges-de-Champlain or at the Grandes-Piles tree nursery (Fig. 3,4). Water (slightly acid) was obtained from the municipal supply at St-Georges or from the nursery. Mixed spray batches were then moved immediately to the designated blocks.

Two-man crews (vehicle operator, spray applicator) operating in 4 to 8 hour shifts were used during periods of optimal meteorological conditions (wind $\leq$ 5 mph, high relative humidity). Spray applications at night were made using a system of truck and mistblower-mounted lights. Each tree along the outside borders of the treatment blocks was sprayed as thoroughly as possible. Rate of travel along the borders was below 1 mph (from 60 to 90 min./treatment).

Treatment Assessment Methods

Five 18-inch branch tips from the mid-crown section were collected at random from trees along the border of each treatment block as the basic

sampling unit to obtain indices of larval population density. The branch samples were collected twice before treatment and four times afterwards to permit the construction of population survival curves from $L_2$ to $L_6$. The technique developed by DeBoo, Campbell and Copeman (1973) and the apparatus developed by Martineau and Benoit (1973) were used during post-treatment branch sampling operations; population densities from pre-treatment samples (i.e. mostly $L_2$ and $L_3$) were obtained by the conventional detailed examination technique. Data from the survival curves were then selected for estimations of treatment impact. Population density data for each spray treatment were adjusted by Abbott's formula (1925):

$$P_o = \left[ 1 - \frac{(CbxTa)}{(CaxTb)} \right] x \ 100$$

where $P_o$ = Percent population reduction

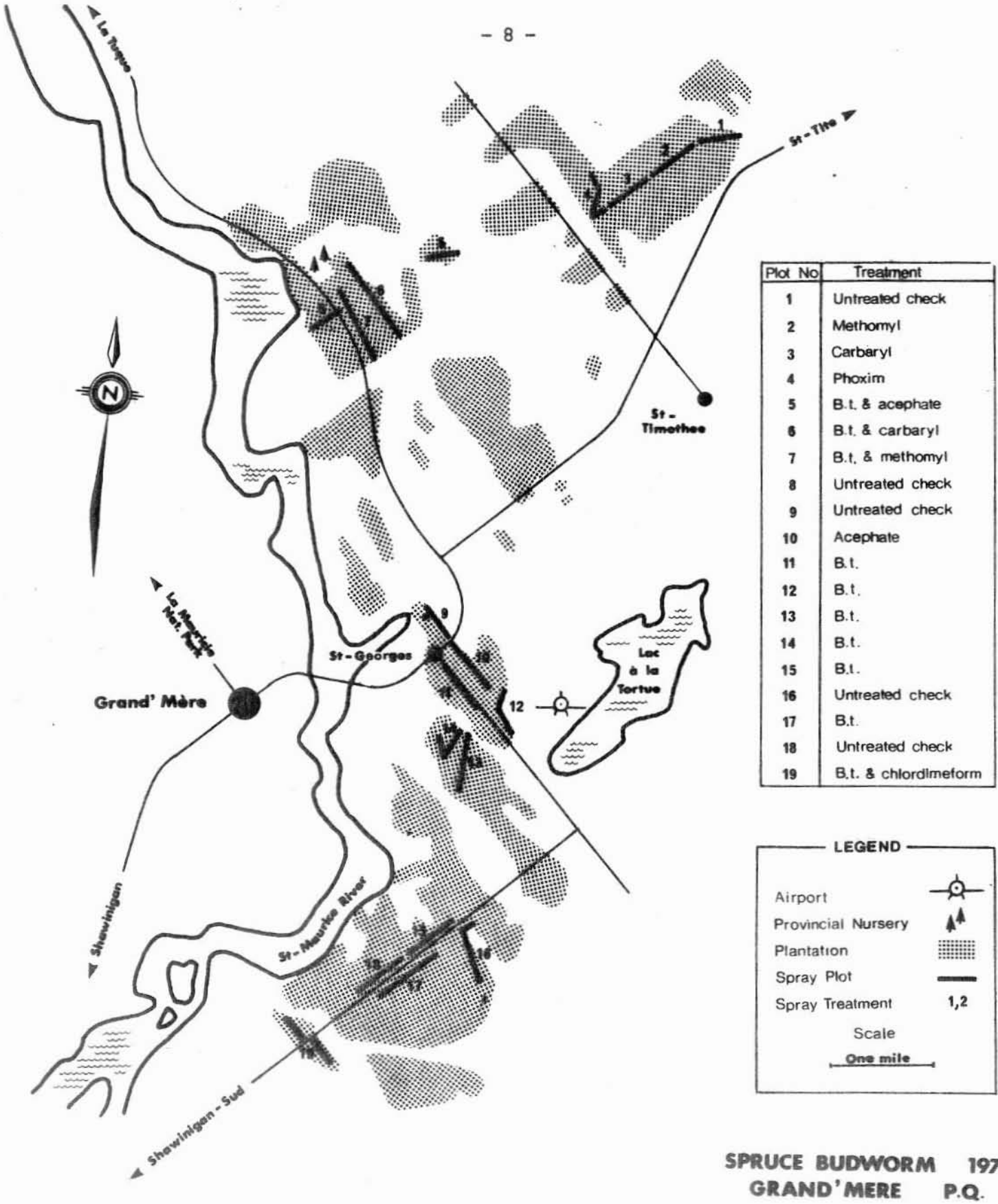
Cb = Avg. no. living larvae, pre-spray - untreated check

Ta = Avg. no. living larvae, post-spray - treated

Ca = Avg. no. living larvae, post-spray - untreated check

Tb = Avg. no. living larvae, pre-spray - treated

Estimates of defoliation of current year branch growth were based on 1,000 shoot samples (collected August 1-2) randomly selected from a total of 10 mid-crown branches per treatment. Each shoot was examined visually using the method developed by Fettes (1951). In addition, overall tree crown condition was appraised by binocular estimation of foliage retention on new shoots.




| Plot No | Treatment |
|---|---|
| 1 | Untreated check |
| 2 | Methomyl |
| 3 | Carbaryl |
| 4 | Phoxim |
| 5 | B.t. & acephate |
| 6 | B.t. & carbaryl |
| 7 | B.t. & methomyl |
| 8 | Untreated check |
| 9 | Untreated check |
| 10 | Acephate |
| 11 | B.t. |
| 12 | B.t. |
| 13 | B.t. |
| 14 | B.t. |
| 15 | B.t. |
| 16 | Untreated check |
| 17 | B.t. |
| 18 | Untreated check |
| 19 | B.t. & chlordimeform |



Figure 1. Location of experimental spray areas Grand'Mère, P.Q., 1974.

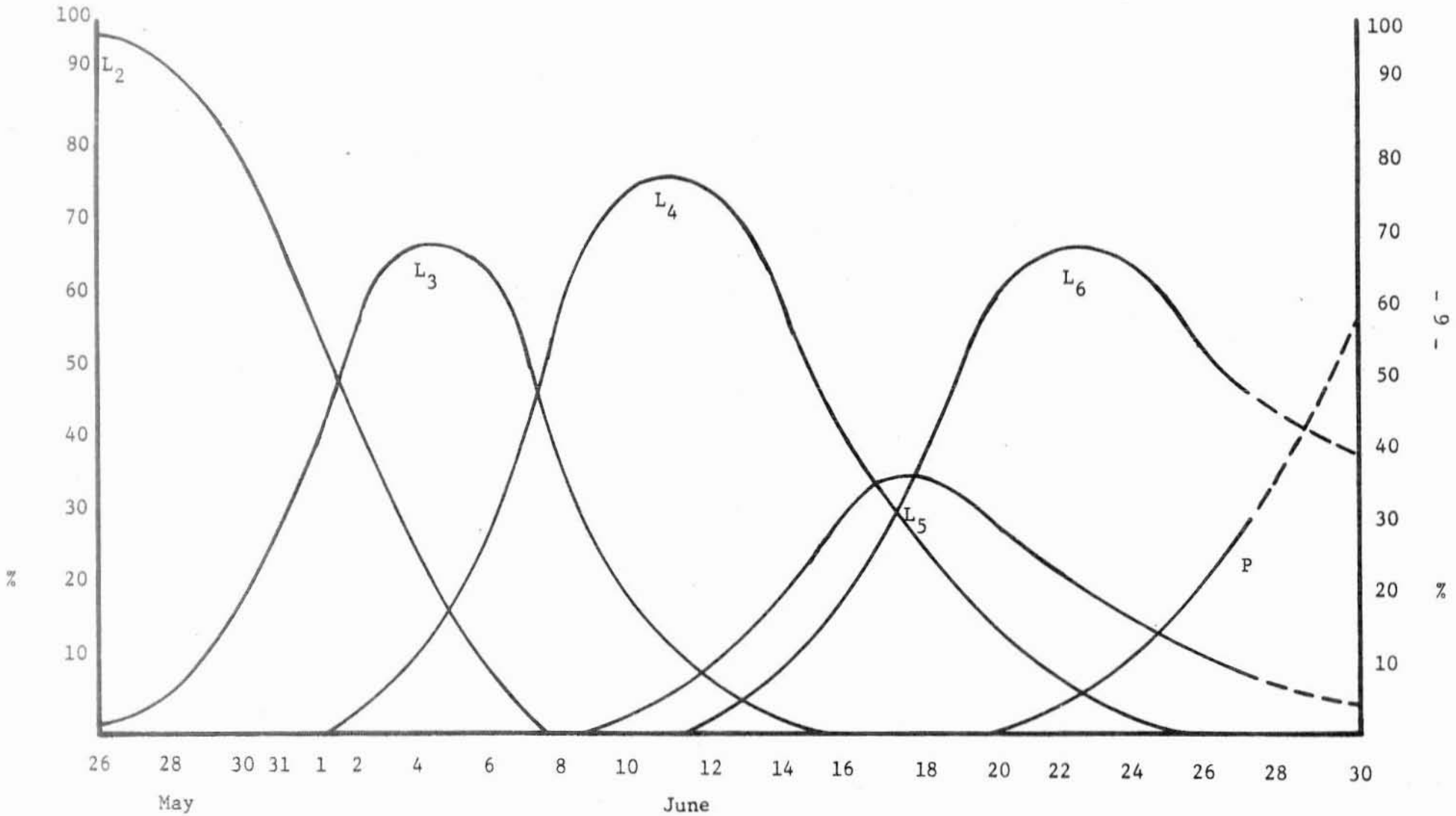



Figure 2. Larval development patterns for the spruce budworm at Grand'Mère, Quebec during 1974.

Figure 3. Spray mixing facility at St-Georges-de-Champlain.

Figure 4. Spray mixing facility at the Grandes-Piles Forest Nursery.

Table I

Insecticides applied experimentally for control of spruce budworm, Grand'Mère Plantations, Quebec, 1974

| Common Name | Trade Name & Formulation | Chemical/A.I. Designation | Mammalian Toxicity[1] |
|---|---|---|---|
| acephate | Orthene(R) 90 WP | *O,S-dimethyl acetylphosphoramidothioate* | Rb > 2000 |
| B.t. | Dipel(R) WP | *Bacillus thuringiensis* Berliner | - |
| B.t. | Thuricide(R) 16B | *Bacillus thuringiensis* Berliner | - |
| carbaryl | Sevin(R) 80S | *1-naphthyl methylcarbamate* | Rb > 2000 |
| chlordimeform | Fundal(R) | *N'-(4-chloro-o-tolyl)-N,N-dimethylformamidine* | - |
| methomyl | Lannate(R) 20L | *methyl N-[(methylcarbamoyl)oxy] thioacetimidate* | Rb > 1000 |
| phoxim | Volaton(R) 47SC | *phenylglyoxylonitrile oxime O,O-diethyl phosphorothioate* | R > 1126 |

[1] After Kenaga and End (1974): acute dermal toxicity $LD_{50}$ in mg/kg where Rb = rabbit, R = white rat.

Table II

Selected insecticide treatments, dosages, and timing of spray applications for control of spruce budworm, Grand'Mère Plantations, Quebec, 1974

| Spray Treatment | Calculated Amt. (A.I.)/Acre | Equivalent Spray Concentration (% A.I. wt./vol.) [1] | Proposed Timing of Spray (Target larval instar) |
|---|---|---|---|
| | | B.t. Treatments | |
| Dipel | 4, 6 & 8 BIU | 0.0145, 0.0218, 0.0390 | $L_3$ |
| Thuricide | 4, 6 & 8 BIU | 0.0145, 0.0218, 0.0390 | $L_3$ |
| | | Combination Treatments | |
| Dipel + chlordimeform | 4 BIU + 4 oz. | 0.0145 + 0.2 | $L_3 + L_4$ |
| Thuricide + acephate | 4 BIU + 2 oz. | 0.0145 + 0.1 | $L_3 + L_4$ |
| Thuricide + carbaryl | 4 BIU + 2 oz. | 0.0145 + 0.1 | $L_3 + L_4$ |
| Thuricide + methomyl | 4 BIU + 1.5 oz. | 0.0145 + 0.08 | $L_3 + L_4$ |
| | | Chemical Insecticide Treatments | |
| Acephate | 8 oz. | 0.4 | $L_4$ |
| Carbaryl | 10 oz. | 0.5 | $L_4$ |
| Methomyl | 4 oz. | 0.2 | $L_4$ |
| Phoxim | 4 oz. | 0.2 | $L_4$ |

[1] - Based on calibration trials indicating requirement of 15 gal. spray mix/acre; for B.t. and B.t. + chemical insecticide sprays:

Dipel WP contains 7.26 BIU/lb. (3.2% A.I.)

Thuricide 16B contains 16 BIU/gal. (0.69% A.I.)

## RESULTS AND DISCUSSION

The selected insecticide treatments were applied June 4-12 with only minimal actual deviations in timing, spray dosages and volumes from the experimental work plan (Tables II, III). Short periods of inclement weather, time for equipment maintenance and repair, travel to and from the mixing/loading areas, and the careful cleaning of equipment required between treatments were major reasons for the extension of treatment time to 9 days for the applications to approximately 230 acres requiring 11.5 miles of operating travel.

Results of spray treatments in terms of impact on larval population densities and foliage protection (Table IV) indicated the following descending order of efficacy:

*Chemical Insecticides* > *B.t. + Chemical Combinations* > *B.t. alone.*

Interestingly, the grouping of treatments indicated that although only slight differences in budworm population decline occurred between the B.t. alone vs B.t. + chemical treatments, trees treated in this latter group of treatments were strikingly superior with regard to foliage quality. Comparatively, the insecticide-alone sprays induced both high larval mortality and foliage retention. The following tabulation summarized these relationships between corrected larval mortality and foliage protection:

| Treatment | Approximate % Population Reduction (+ 10 days) | Approximate Percent Defoliation |
|---|---|---|
| Chemicals alone | 90 | 10 |
| Combination sprays | 40 | 20 |
| B.t. alone | 20 | 40 |
| Untreated check | - | 50 |

Visual appearance of trees, as well as the supporting data, indicated that there was little difference between those treatments grouped as chemicals (alone) and those as B.t. + chemical insecticide combinations. Similarly, only slight difference was noted between trees treated with B.t. alone and those in the untreated check blocks. These experimental mistblower sprays indicated that:

(1) The chemical spray treatments selected provided excellent protection of foliage due to their immediate toxicological impact inducing cessation of feeding in a significant percentage of the larval populations on the branches;

(2) B.t. sprays applied alone, at up to 8 BIU/acre vs mostly $L_3$ and $L_4$ larvae, had only slight impact on budworm density and feeding. Trees treated with B.t. alone did not differ greatly in foliage retention from those trees examined in unsprayed check blocks;

(3) The addition of low dosages of several chemical insecticides, however, significantly increased the amount of foliage saved when mixed with the lowest dosage of B.t. evaluated (ca. 4 BIU/acre).

Examinations of branches during spray applications indicated that approximately 50% of the new shoots still had bud caps present. Although some caps were blown off by the high velocity airblast produced by the mistblower, many caps harbouring larvae remained. Accordingly, it was assumed that a large percentage of larvae protected beneath the bud caps

may not have consumed B.t.-covered foliage. Conversely, the contact and/or fumigation effect of the chemical insecticide treatments apparently was sufficient to overcome larval feeding in these protected locations. Similarly, the B.t. + chemical combination sprays were sufficiently potent to influence the normal feeding patterns of larvae under bud caps, but without causing high mortality (Fig. 5).

Table III

Results of experimental spray applications by mistblower for control of spruce budworm at Grand'Mère, Quebec, 1974: Actual spray timing, dosages and volumes emitted

| Treatment | Date Sprayed (June) | Larval Development at Spray Date | Spray Block Size | | Dosage Applied[1] (Actual AI/acre) | Volume Spray Mix Applied[1] US gal/Spray Block |
|---|---|---|---|---|---|---|
| | | | Length (ch) | Area (ac) | | |
| Dipel WP* | 6 | 63% $L_3$ | 88 | 17.6 | 3.7 BIU | 255 |
| Dipel WP* | 6 | 63% $L_3$ | 78 | 15.6 | 6.1 BIU | 226 |
| Dipel WP* | 6 | 63% $L_3$ | 82 | 16.4 | 7.8 BIU | 216 |
| Thuricide 16B | 5 | 65% $L_3$ | 89 | 17.8 | 3.7 BIU | 274 |
| Thuricide 16B | 5 | 65% $L_3$ | 78 | 15.6 | 6.1 BIU | 226 |
| Thuricide 16B | 4 | 68% $L_3$ | 81 | 16.2 | 7.9 BIU | 228 |
| Dipel + Chlordimeform* | 7 | 50% $L_3$; 40% $L_4$ | 78 | 15.6 | 4.1 BIU + 4.1 oz | 250 |
| Thuricide 16B + acephate | 7 | 50% $L_3$; 40% $L_4$ | 80 | 16.0 | 4.0 BIU + 2.0 oz | 250 |
| Thuricide 16B + carbaryl | 7 | 50% $L_3$; 40% $L_4$ | 90 | 18.0 | 3.6 BIU + 1.8 oz | 270 |
| Thuricide 16B + methomyl | 6 | 63% $L_3$; 30% $L_4$ | 80 | 16.0 | 4.0 BIU + 1.5 oz | 250 |
| Acephate* | 12 | 75% $L_4$ | 82 | 16.4 | 7.8 oz | 250 |
| Carbaryl* | 9 | 70% $L_4$ | 84 | 16.8 | 9.5 oz | 273 |
| Methomyl* | 10 | 72% $L_4$ | 86 | 17.2 | 3.7 oz | 293 |
| Phoxim* | 10 | 72% $L_4$ | 77 | 15.4 | 4.3 oz | 251 |
| Untreated check 1 | - | - | 80 | 16.0 | - | - |
| Untreated check 2 | - | - | 80 | 16.0 | - | - |
| Untreated check 3 | - | - | 80 | 16.0 | - | - |
| Untreated check 4 (water) | 7 | 50% $L_3$; 40% $L_4$ | 80 | 16.0 | - | ca. 200 |
| Untreated check 5 (water) | 8 | 45% $L_3$; 42% $L_4$ | 80 | 16.0 | - | ca. 200 |

* Chevron Spray Sticker added at 8-24 oz. per 100 gal. spray mixture.

[1] Varying amounts of insecticide and spray volume applied due to physical differences between plantations and final size of treatment blocks.

Table IV

Results of experimental spray applications by mistblower for control of spruce budworm at Grand'Mère, Quebec, 1974: Larval mortality and foliage protection

| Treatment & Amount A.I./acre | Average No. Larvae/18-in. branch tip | | | | % Population Reduction[1] | Percent Defoliation |
|---|---|---|---|---|---|---|
| | Prespray | Postspray | | | | |
| | -1 day | +3 days | +5 days | +10 days | (+10 days) | |
| Dipel WP 3.7 BIU | 50 | 50 | 47 | 44 | 0 | 49 |
| Dipel WP 6.1 BIU | 67 | 62 | 56 | 43 | 21 | 20 |
| Dipel WP 7.8 BIU | 56 | 50 | 48 | 40 | 14 | 40 |
| Thuricide 16B 3.7 BIU | 50 | 45 | 40 | 38 | 8 | 47 |
| Thuricide 16B 6.1 BIU | 73 | 67 | 62 | 42 | 31 | 64 |
| Thuricide 16B 7.9 BIU | 88 | 81 | 77 | 65 | 50 | 35 |
| Dipel WP 4.1 BIU + chlordimeform 4.1 oz | 40 | 37 | 33 | 24 | 29 | 20 |
| Thuricide 16B 4.0 BIU + acephate 2.0 oz | 27 | 23 | 20 | 12 | 43 | 12 |
| Thuricide 16B 3.6 BIU + carbaryl 1.8 oz | 51 | 42 | 29 | 18 | 56 | 25 |
| Thuricide 16B 4.0 BIU + methomyl 1.5 oz | 42 | 37 | 27 | 18 | 45 | 23 |
| Acephate 7.8 oz | 47 | 10 | 5 | 0.5 | 98 | 6 |
| Carbaryl 9.5 oz | 37 | 15 | 7 | 3 | 89 | 13 |
| Methomyl 3.7 oz | 42 | 23 | 14 | 4 | 85 | 11 |
| Phoxim 4.0 oz | 55 | 41 | 20 | 8 | 79 | 8 |
| Untreated check 1 | 80 | 78 | 78 | 65 | 19* | 61 |
| Untreated check 2 | 65 | 60 | 47 | 38 | 42* | 42 |
| Untreated check 3 | 45 | 41 | 36 | 31 | 31* | 60 |
| Untreated check 4 (water) | 42 | 41 | 40 | 37 | 12* | 57 |
| Untreated check 5 (water) | 50 | 48 | 46 | 40 | 20* | 29 |

[1] Population reductions corrected by Abbott's formula (1925) in all sprayed areas; * indicates uncorrected natural population decline from June 8-18.

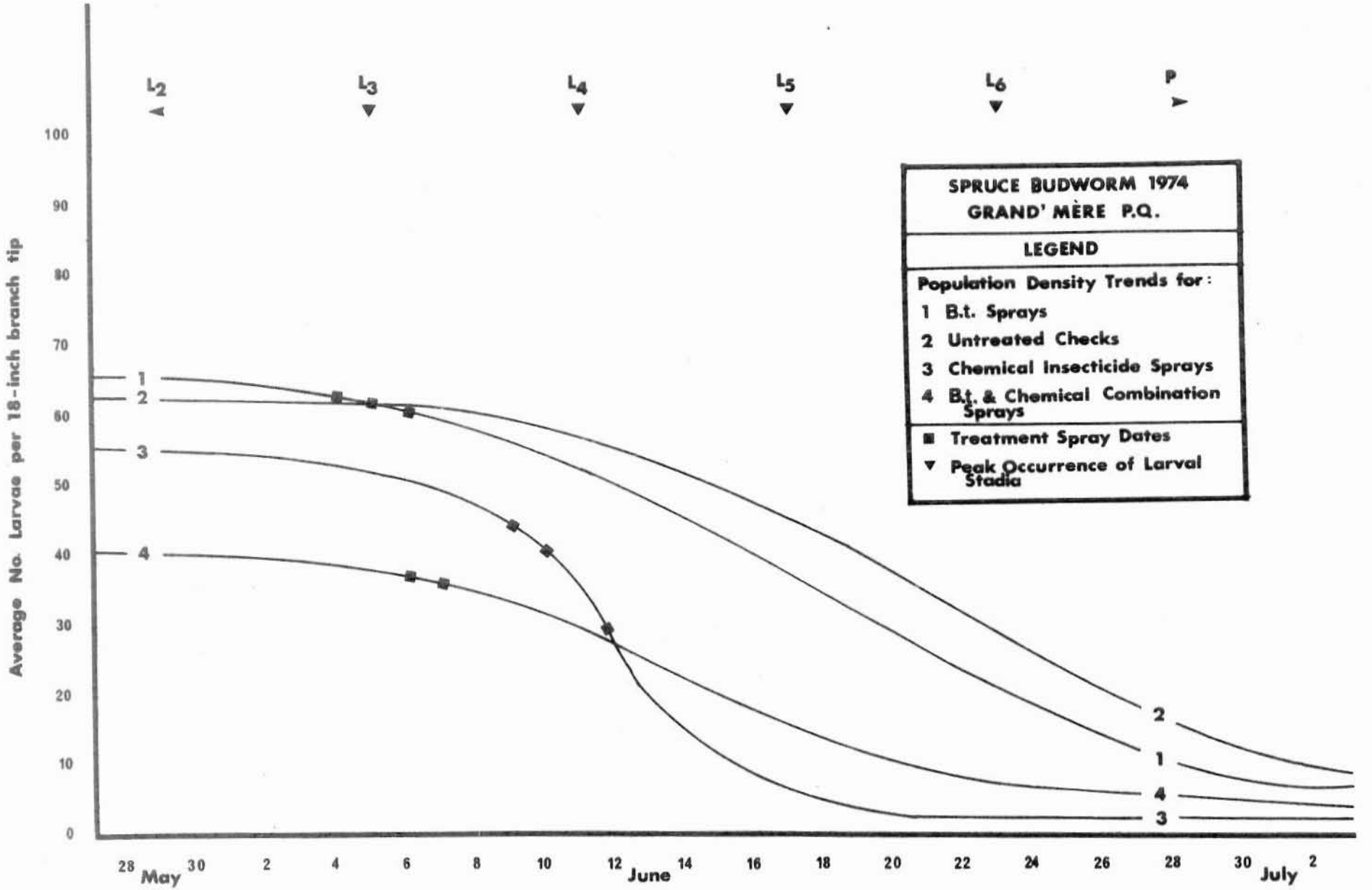



Figure 5. Spruce budworm larval population decline trends based on grouping of treatments, Grand'Mère, Quebec, 1974.

## SUMMARY AND CONCLUSIONS

The experimental spray study at Grand'Mère during 1974 indicated that:

(1) Applications of dilute concentrations of acephate, carbaryl, methomyl or phoxim can provide excellent protection of white spruce trees under conditions of severe infestation by the spruce budworm. The results also substantiated similar experimentation using acephate (Armstrong and Nigam 1975) and carbaryl (DeBoo 1974, Dimond 1974, Hildahl and DeBoo 1973) by aerial application. The mistblower application of methomyl was as effective as at Shawville during 1972 (DeBoo and Campbell 1972), whereas the application of phoxim was more effective than indicated by Hopewell and Nigam (1974) using an apparatus for simulating aerial sprays.

Because of the accelerated accumulation of data on the efficacy of these chemical spray treatments during recent years, it is expected that new registered insecticide treatments may be available to the resource manager in the near future. More information is needed, however, on the range of effective dosages required as well as on the corresponding potential for undesirable side effects.

(2) Carefully timed applications of *Bacillus thuringiensis*

at up to 8 BIU/acre did not provide satisfactory protection of new branch shoots. Research conducted by staff of CCRI during recent years indicates that B.t. spray applications may be effective against coniferous defoliators such as the spruce budworm only when combined with a low (1-4 oz A.I.) to sub-lethal (< 1 oz A.I.) quantity of chemical insecticide or with other potency-activating adjuvants (Chemical Control Research Institute 1974, Morris and Armstrong 1973, 1974). The results of the study at Grand'Mère clearly indicated this synergistic effect, and such combination treatments may be particularly important for the success of applications to bud-capped white spruce shoots.

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Limited, Toronto, Ontario. By virtue of their active participation at Grand'Mère, Messrs C.G. Keefer, C.D. Byrd and D.F. Lindgren of Sandoz, Messrs R. and S. Woodhouse of Abbott, and Mr J.E. Steffel of Nor-Am, completed their apprenticeships in control of the spruce budworm.

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## LITERATURE CITED

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

ARMSTRONG, J.A. and P.C. NIGAM 1975. The effectiveness of the aerial application of Orthene(R) against spruce budworm at Petawawa Forest Experiment Station during 1974. Environ. Can. Forest Serv. Rept. CC-X-82, 29 pp. In press.

CHEMICAL CONTROL RESEARCH INSTITUTE 1974. Evaluation of commercial preparations of *Bacillus thuringiensis* with and without chitinase against spruce budworm. Environ. Can., Forest Serv. Rept. CC-X-59, 261 pp.

CHEMICAL CONTROL RESEARCH INSTITUTE 1975. Compendium on pesticides registered for use in Canada against pests of forests, trees and shrubs. Environ. Can., Can. For. Serv. Rept. CC-X-19 (revised 1975), 147 pp.

DAVIAULT, L. 1946. Province of Quebec. In Ann. Rep. Forest Insect Survey, Div. Entomol., Sci. Service, Can. Dept. Agric., pp 20-21.

DEBOO, R.F. 1974. Plantation pest control research: spruce budworm. Environ. Can., Rept. Can. Insect Pest Control Forum, Nov., 1974, 2 pp.

DEBOO, R.F. and L.M. CAMPBELL 1972. Plantation research: V. Mistblower applications of dilute insecticide solutions for control of *Choristoneura fumiferana* on white spruce in Quebec, 1972. Environ. Can., Forest Serv. Inf. Rept. CC-X-21, 17 pp.

DEBOO, R.F. and L.M. CAMPBELL 1974. Evaluation of commercial preparations of *Bacillus thuringiensis* with and without chitanase against spruce budworm. Part C. Assessment of effectiveness by mistblower and aerial application, Spruce Woods, Manitoba. Environ. Can., Forest Serv. Inf. Rept. CC-X-59, 31 pp.

DEBOO, R.F., L.M. CAMPBELL and A.G. COPEMAN 1973. A sampling technique for estimating numerical trends in larval populations of insect defoliators on conifers. I. Development and experimental evaluation of the technique. Phytoprotection 54: 9-22.

DESAULNIERS, R., and R. MARTINEAU 1970. Summary statement on the 1970 spruce budworm aerial operations in Quebec and forecast for 1971. Environ. Can., Rept. of Meet. of the Interdept. Comm. on For. Spray. Oper., 25 pp.

DIMOND, J.B. 1974. Field tests of Sevin, Thuricide and Zectran against spruce budworm in Maine, 1974. Me. Life Sci. and Agric. Exp. Sta., Orono, Me., Prelim. Rept., 7 pp.

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 pp.

GAGNON, J.D. 1972. Grand'Mère Plantations, an example for future reforestation. Environ. Can., Forest Serv. Inf. Rept. Q-X-30, 27 pp.

HILDAHL, V. and R.F. DEBOO 1973. Aerial applications of chemical insecticides against the spruce budworm in Manitoba, 1973. Manitoba Ent. 7: 6-14.

HOPEWELL, W.W. and P.C. NIGAM 1974. Field evaluation of Orthene(R), phoxim and fenitrothion against spruce budworm (*Choristoneura fumiferana*), applied as simulated aerial spray. Environ. Can., Can. For. Serv. Rept. CC-X-83, 14 pp.

KENAGA, E.E. and C.S. END 1974. Commercial and experimental organic insecticides. Ent. Soc. Amer. Special Publ. 74-1, 77 pp.

MARTINEAU, R. and P. BENOIT 1973. A sampling technique for estimating numerical trends on larval populations of insect defoliators on conifers. II. Modification and operational use of the technique for extensive sampling of spruce budworm populations in Quebec. Phytoprotection 54: 23-31.

MARTINEAU, P. and A. LAVALLEE 1970. Quebec Region. In Annual report of the forest insect and disease survey. Can. Dept. Fish. and Forest., Can. For. Serv., p.34.

MARTINEAU, R. and E. SMERLIS 1968. Quebec Region. In Annual report of the forest insect and disease survey. Can. Dept. Fish. and Forest., Can. For. Serv., p.37.

MORRIS, O.N. and J.A. ARMSTRONG 1973. Aerial application of *Bacillus thuringiensis* - fenitrothion combinations against the spruce budworm, *Choristoneura fumiferana* (Clem.). Environ. Can., Can. For. Serv. Inf. Rept. CC-X-61, 24 pp.

MORRIS, O.N. and J.A. ARMSTRONG 1974. Aerial application of *Bacillus thuringiensis* - Orthene(R) combinations against the spruce budworm, *Choristoneura fumiferana* (Clem.). Environ. Can., Forest. Serv. Inf. Rept. CC-X-71, 25 pp.