VIRUS TRIALS TO CONTROL RED-HEADED PINE SAWFLY IN QUEBEC PLANTATIONS

(A report on a field demonstration program conducted by the Canadian Forestry Service in cooperation with officers of the Quebec Department of Lands and Forests).

CANADIAN FORESTRY SERVICE
INFORMATION REPORT DPC-X-1

DEPARTMENT OF FISHERIES AND FORESTRY
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1. INTRODUCTION

At a meeting of the Interdepartmental Committee on Forest Spraying held in Ottawa in November 1969, the Quebec Department of Lands and Forests reported on plans for chemical spraying of young pine plantations heavily infested with the red-headed pine sawfly, Neodiprion lecontei (Fitch). The proposal was advanced that a sawfly virus material, isolated and produced by the Insect Pathology Research Institute of the Canadian Forestry Service, be tested and demonstrated as an alternative control method. Plans were developed in consultation with various provincial and federal agencies and this report outlines the results of trials conducted in the St. Jovite area of southern Quebec.

The various sections of the report were authored by officers most intimately involved in the field operations and the composite report was compiled and edited within the Directorate of Program Coordination, with assistance from Dr. R.F. DeBoo of the Chemical Control Research Institute.

Copies of the report are available in both French and English at the following establishments:

Protection Services, Conservation Branch,
Quebec Department of Lands and Forests,
Parliament Building,
Quebec, Quebec.

Forest Research Laboratory,
Department of Fisheries and Forestry,
1080 Route du Vallon,
P.O. Box 3800,
Ste. Foy, Quebec.

Chemical Control Research Institute,
Department of Fisheries and Forestry,
25 Pickering Place,
Ottawa, Ontario.

Insect Pathology Research Institute,
Department of Fisheries and Forestry,
P.O. Box 490,
Sault Ste. Marie, Ontario.

Directorate of Program Coordination,
Canadian Forestry Service,
Department of Fisheries and Forestry,
Ottawa 4, Ontario.

2. THE PROBLEM

R. Martineau[1] and R. Desaulniers[2]

Reforestation programs were started in Quebec around 1930 but the most extensive plantings were carried out during the last decade. Red pine, Pinus resinosa Ait., the preferred host of the red-headed pine sawfly, Neodiprion lecontei (Fitch), was one of the main tree species used in reforestation and plantings now cover an area of approximately 30,000 acres. Each year this increases by approximately 2,000 acres, which represents 6% of the total acreage planted annually in Quebec. Jack pine, Pinus banksiana Lamb., and Scots pine, Pinus sylvestris Linn., are also damaged by the sawfly if planted in association with red pine, but to a lesser degree.

Surveys have been carried out annually in Quebec since 1938 and the red-headed pine sawfly has been recorded in all major areas of red-pine plantations (Fig. 1). Highest numbers have been recorded on trees under 15 feet in height. Infestations have been reported periodically and have usually persisted for about 3 years.

The sawfly has one generation a year and overwinters within a cocoon in the ground. The adult emerges from mid-June to early July and eggs are laid in pine needles throughout July. The larvae hatch and feed on the foliage (Fig. 2), completing their development in about 25 days. Damage is most conspicuous in late August and early September.

[1] Forest Research Laboratory, Department of Fisheries and Forestry, Ste. Foy, Quebec.

[2] Conservation Branch, Quebec Department of Lands and Forests, Quebec, Quebec.

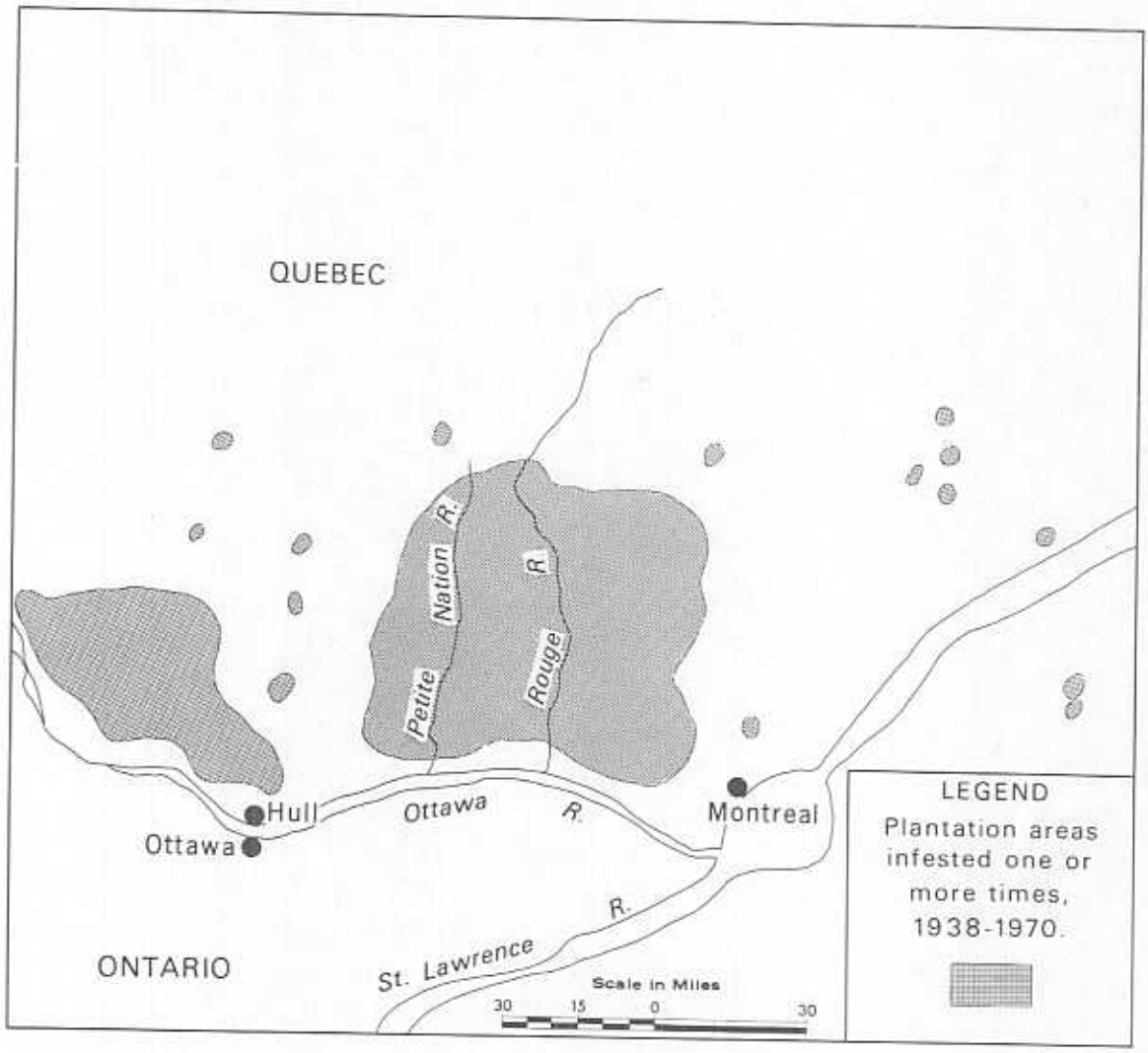

Figure 1. Map depicting areas of defoliation by the red-headed pine sawfly since 1938.

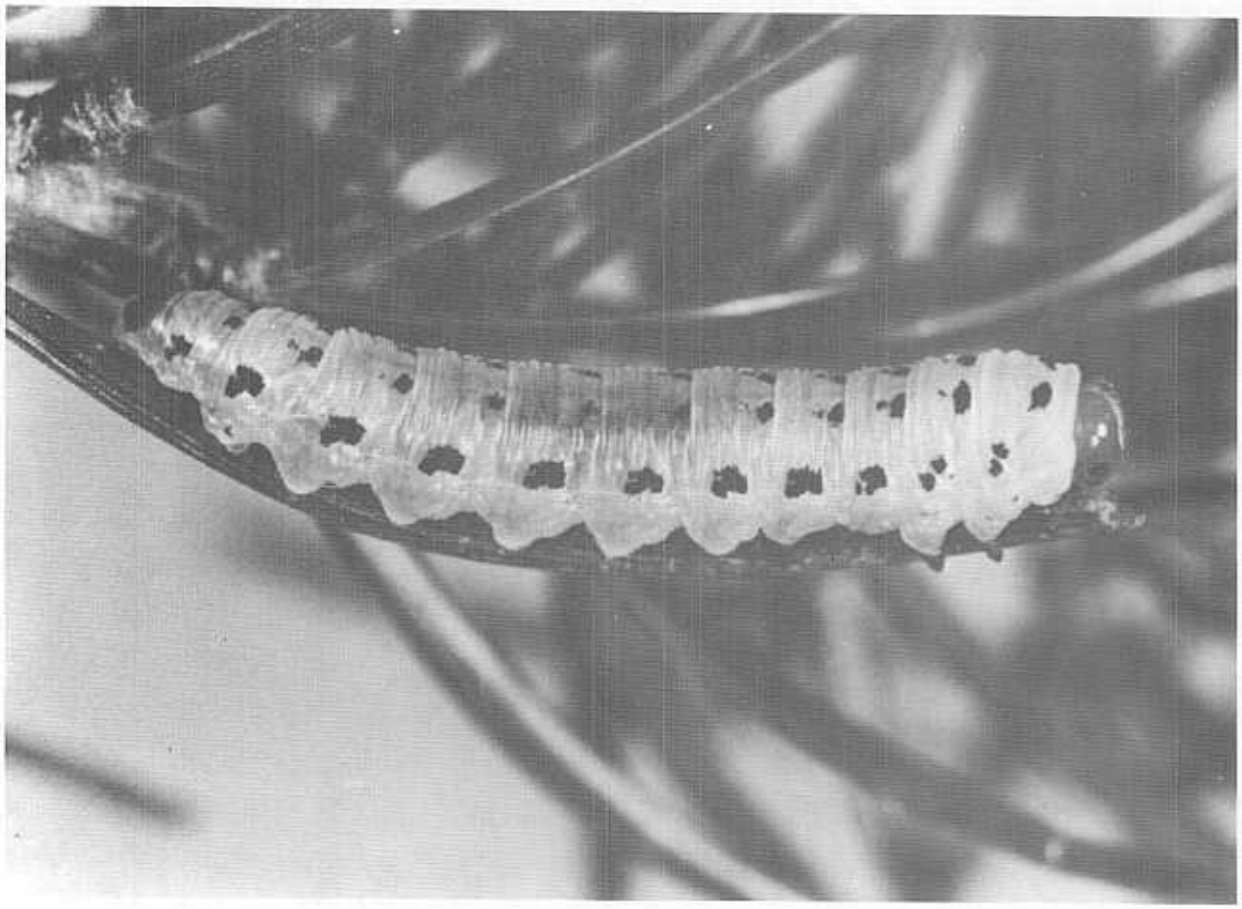

Figure 2. Larva of the red-headed pine sawfly.

The Quebec Department of Lands and Forests has supported chemical control programs against the red-headed pine sawfly for a number of years. In 1941, for example, extensive spraying with calcium arsenate prevented the complete loss of 3-to-10 year old plantings in the Maholey Creek and Lac Chateau areas in Argenteuil County. Since 1966 the Department has carried out intensive surveys of young pine plantations and now provides trained technician services for the inspection of plantations, as well as materials and equipment for chemical control of the sawfly. A total of approximately 450 plantations were examined from 1966 to 1969 and 62 of these have been treated with insecticides (primarily DDT).

Surveys were intensified in 1969 by the Department of Lands and Forests when it became obvious that the sawfly posed a serious threat to plantations throughout the central part of the Province. Aerial surveys were carried out over an area of 2,300 square miles in Argenteuil, Terrebonne, Labelle, Papineau, Gatineau and Pontiac counties and 216 of a total of 417 pine plantations showed signs of sawfly damage. The following table shows the areas involved and the degree of infestation in plantations affected by the sawfly.

Table I. Infestations of red-headed pine sawfly in southwestern Quebec during 1969.

Sector	Area in acres	Percent of area showing defoliation[1]		
		Light	Moderate	Severe
Shawville	2070	17.5	30.0	48.0
Hull	220	14.8	3.6	0
Chénéville	220	37.3	9.1	15.5
St. Jovite	910	49.3	9.6	13.1
Labelle	150	65.2	0	0
Total or mean	3570	28.7	20.7	32.4

[1] Light - defoliation of a few isolated trees. Moderate - defoliation of groups of trees. Severe - as in moderate but with apparent mortality.

The results of the survey clearly showed the importance of the problem in Quebec and the need for control action if serious losses were to be avoided. The problem was discussed at the Interdepartmental Committee for Forest Spraying held in Ottawa, November 26, 1969, and the Committee recommended that a virus, occurring naturally in other

parts of Canada and propagated from infestations in Ontario, be tested in Quebec. Collaborative arrangements were made between workers in the Canadian Forestry Service and the Quebec Department of Lands and Forests for field testing in Quebec in 1970.

Surveys during July 1970 indicated that there had been a substantial decline in sawfly numbers in many of the plantations in Quebec because of an egg parasite but populations remained sufficiently high in the St. Jovite and Chénéville areas to permit the carrying out of meaningful trials. These are outlined in the following sections of this report.

3. THE VIRUS

F. T. BIRD [1]

The virus disease of the red-headed pine sawfly was discovered in 1950 in larvae collected and reared by the Forest Insect and Disease Survey, Ontario Region, Canadian Forestry Service. It is very similar to a disease that controlled large outbreaks of the European spruce sawfly, Diprion hercyniae (Htg.), in eastern Canada about 30 years ago, and also to a disease introduced into Canada from Sweden over 20 years ago and very effective against the European pine sawfly, Neodiprion sertifer (Geoff.). Each of these diseases is specific in that it affects only its own host and has no effect on other insects, animals, or plants.

Description of the Virus

The virus is a nuclear polyhedrosis virus, so-called because of the formation of polyhedra-shaped inclusion bodies in the nuclei of infected cells. Following infection, a dense mass of viroplasm is formed in each infected cell. Rod-shaped virions appear on the exposed surfaces of these viroplasms and are later occluded by protein to form the polyhedra.

The polyhedra are the resistant form of the virus and remain infectious for many years when stored in the laboratory. They are about one micron in diameter and can be observed under the light microscope. The virus rods are about 0.21 micron in length and only 0.05 micron in width and must be observed under the electron microscope.

[1] Insect Pathology Research Institute, Department of Fisheries and Forestry, Sault Ste. Marie, Ontario.

Action of the Virus

The sawfly larvae become infected when they consume polyhedra. These dissolve in the gut fluids liberating the infectious virus rods which then, presumably, attach to a cell wall and inject nucleic acid into the cell which in some way, not understood, takes over the function of the cell to produce viral nucleic acid.

The disease is confined to the midgut of the larva and this turns from a greenish translucent to milky white in color. The incubation period varies in the cold-blooded insect with development being more rapid at the higher temperatures. In laboratory experiments at a constant temperature of 72°F, 87% of larvae fed 10 polyhedra died in 11.6 days and 98.2% of larvae fed 1000 polyhedra in 11.1 days. The period of mortality ranged from 9 to 16 days. In field experiments 99.9% of larvae feeding on foliage sprayed with a suspension of 10,000 polyhedra per ml of water died after 11.8 days and all larvae on foliage sprayed with 50,000,000 polyhedra per ml of water after 8.6 days. It is not necessary, however, to spray virus directly on the foliage and in most cases an advantage can be gained by spraying a mist into the air over the trees and allowing wind to carry the virus-laden mist into a plantation. Experiments in Ontario have shown that a cone-shaped path of mortality extending 300 ft. into a plantation of Scots pine infected with European pine sawfly resulted when 4000 ml of virus containing 1,000,000 polyhedra per ml was sprayed with a mist blower from one position on the windward edge of the plantation. Similarly, rapid and complete mortality over 10 rows of infested Scots pine was obtained from virus-laden mist sprayed from a mist blower mounted on a truck and driven slowly through a plantation. There are, of course, gradations in rate of mortality depending on the amounts of virus deposited on the foliage, with mortality occurring first on the rows of trees nearest the spray source and therefore receiving the greatest amount of virus.

Virus Transmission

Virus appears to be transmitted from one year to another chiefly through the contamination of eggs of infected females. Larvae infected shortly before they spin cocoons survive and develop into adults and these adults transmit virus to their progeny. The infection of 10% of the egg cluster of European pine sawfly is sufficient to initiate a severe virus epizootic. Similar data are not available for the red-headed pine sawfly. However, severe epizootics have occurred the year following artificially induced virus epizootics of the red-headed pine sawfly. In fact populations which survive spraying have in some instances been totally destroyed by virus the following year.

The virus of the red-headed pine sawfly is transmitted rapidly from one area to another either by the infected females or by parasites and predators which become very numerous. In one experiment all red-headed pine sawfly infestations within a 5 mile radius of a plantation sprayed with virus contained diseased larvae the following year. Natural virus epizootics do occur but these are rare and unpredictable.

Preparation of Virus Sprays

To obtain polyhedral suspensions, the bodies of diseased larvae are allowed to rot in water for several months. The polyhedra settle out as a white precipitate on the bottom of the container which is purified by centrifugations and washings. A great many polyhedra are lost during this process and polyhedra also disintegrate. Recently a freeze drying process has been developed whereby the diseased larvae are frozen, freeze dried, and pulverized. None of the virus is lost and preservation of the polyhedra and infectivity is good. This material is simply weighed, macerated in water and large particles which might clog a sprayer are removed.

4. VIRUS TRIALS IN QUEBEC, 1970

R.F. DeBoo[1] and J.R. McPhee[2]

Introduction

In years past successful control operations against the red-headed pine sawfly included the application of any one of several synthetic organic insecticides. The recent development of production and field application techniques of a highly infectious and host-specific polyhedral virus as outlined in the preceding section by F.T. Bird afforded an excellent opportunity to demonstrate an alternative method for control of this important plantation pest.

Population levels of the sawfly had been high at many locations for several years, and preliminary surveys during 1969 indicated a continuation of this trend. Intensive surveys during June and July, 1970, however, showed an abrupt reduction in egg deposition and high parasitism of viable eggs by a small wasp[3]. As a result the expected widespread and serious sawfly infestations were reduced to only light to moderate levels at a few locations. The field program was intended originally to be larger in scope and included helicopter applications, however, the program was later revised with the following objectives:

[1] Chemical Control Research Institute, Department of Fisheries and Forestry, Ottawa.

[2] Insect Pathology Research Institute, Department of Fisheries and Forestry, Sault Ste. Marie, Ontario.

[3] Tetrastichus sp.; Hymenoptera:Eulophidae (identified by C.M. Yoshimoto, Entomology Research Institute, Ottawa).

1. To demonstrate efficacy of the virus spray preparations and to determine dosage rates for ground application.
2. To introduce, with the intention to establish, virus by random spot-treatments to individual sawfly colonies within an area of approximately 400 square miles.
3. To demonstrate a propagation technique for the production of a virus supply.

Materials and Methods

Sawfly Populations and Red Pine Plantations

The pre-treatment sawfly population survey extended from June 23 to July 14, 1970. Of the many plantations visited, only eight in the Petite Nation-Rouge River areas were selected for virus spray application (Fig. 3). Populations of the red-headed pine sawfly in these areas were under heavy attack by the egg parasite. However, many trees at each of these locations were seriously weakened by previous defoliation (Fig. 4) and viable unparasitized sawfly eggs on them were sufficiently numerous to warrant control trials with virus.

One plantation at Rockway Valley was selected for control demonstration and dosage evaluation. The plantation was sub-divided into treatment blocks with one small corner reserved as an untreated check plot (Fig. 5). As apparently is characteristic of this species, the sawfly was distributed unevenly with major concentrations in the check plot and in the western quarters of treatment blocks V and VI. Colonies occurred randomly throughout most of the remainder of the plantation. Each colony was identified by an orange ribbon for later reference. Colonies numbered from 1 to 8 per infested tree and averaged approximately 1 per 8 trees throughout the plantation.

Six other plantations, all with lower population levels (range - 1 colony/20 to 100 trees), were selected for virus introduction.

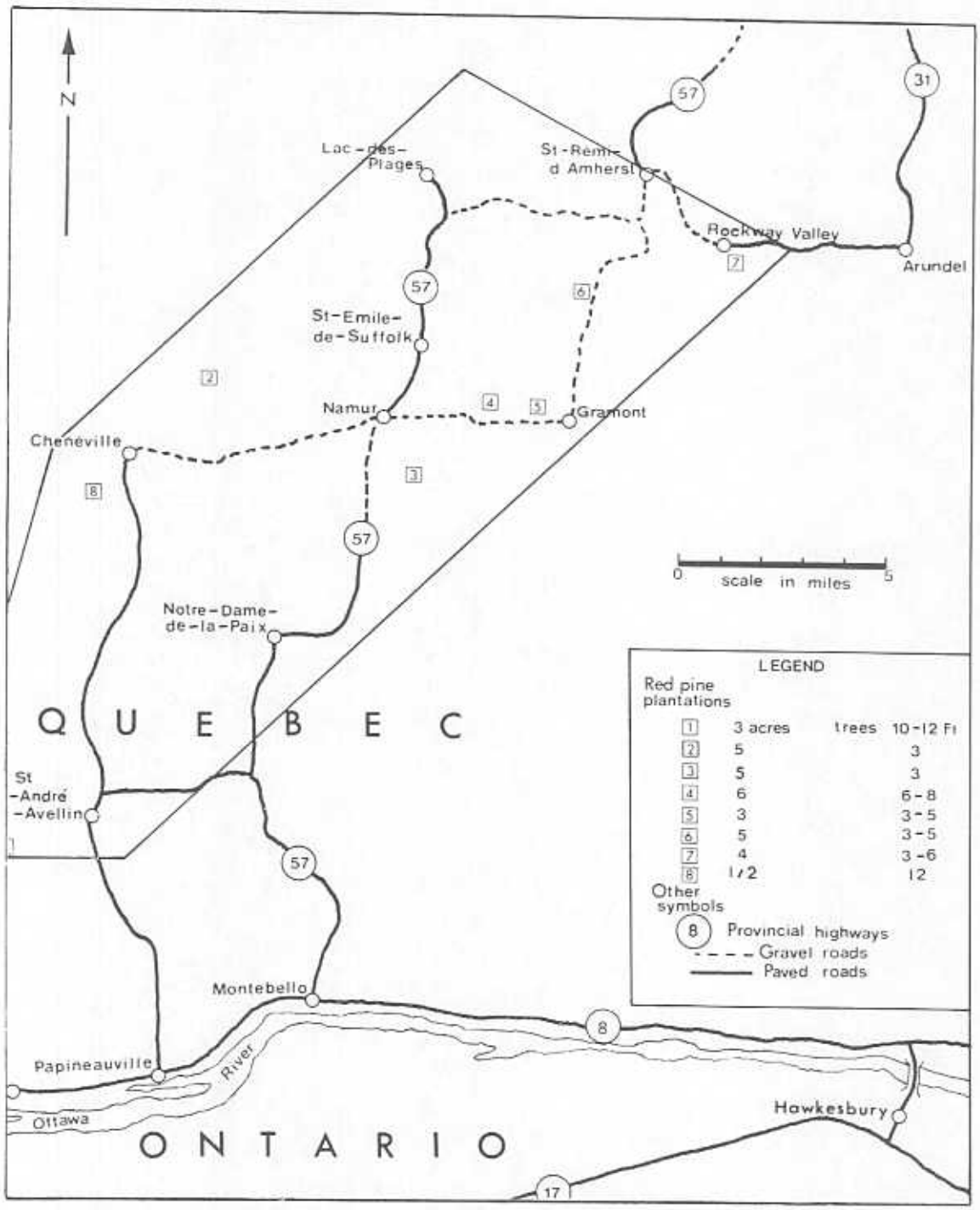

Figure 3. Location of red pine plantations treated with sawfly virus sprays in southwestern Quebec 1970.

Figure 4. A red pine severely defoliated by the red-headed sawfly in 1969.

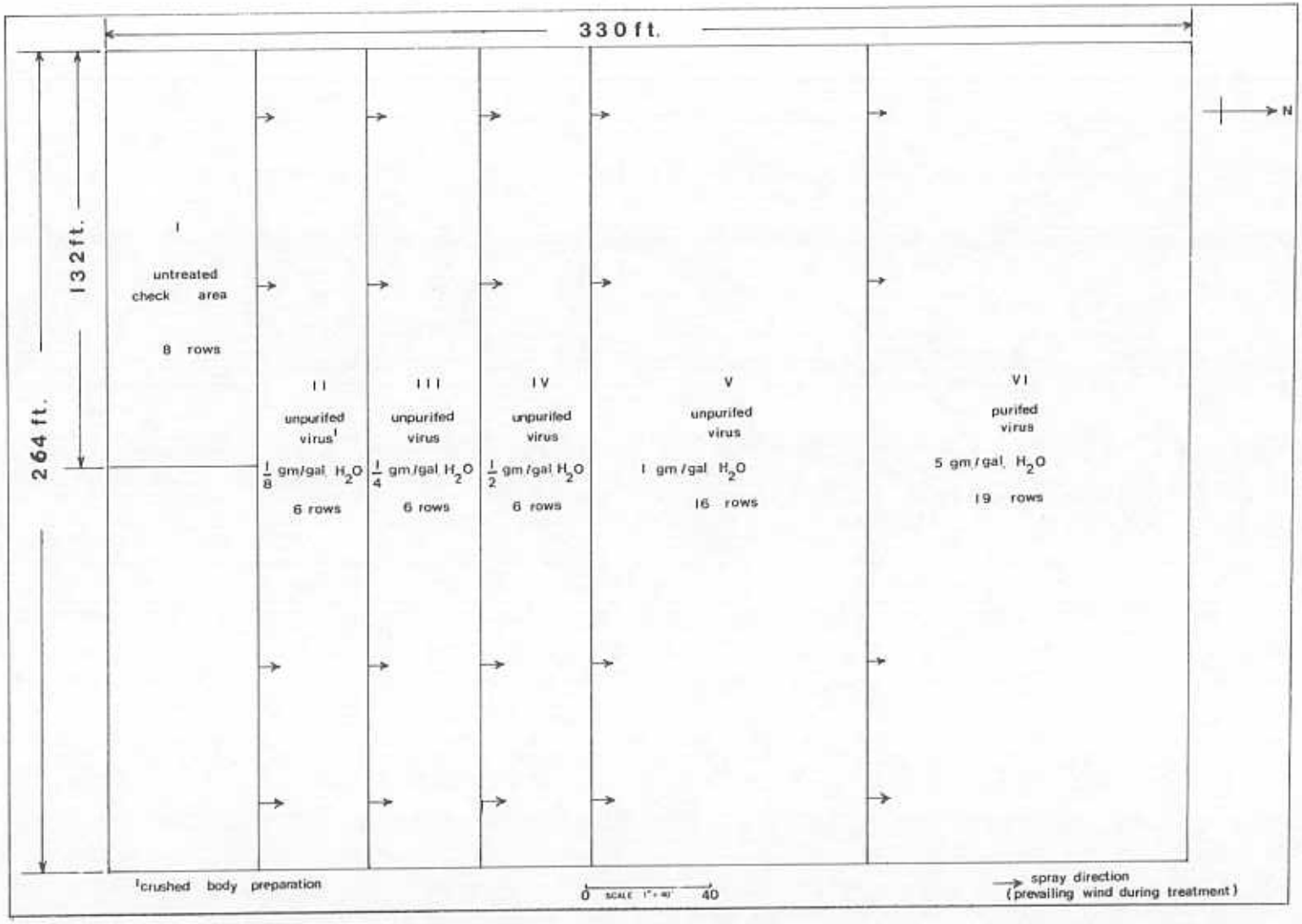

Figure 5. Schematic diagram of the Rockway Valley virus demonstration plantation.

Note: no buffer strips.

Colonies again were labeled with ribbon for spray treatment.

Virus propagation was undertaken at a plantation near Chéneville, and a laboratory trailer at Lac-des-Plages was utilized for field processing of diseased larval collections.

Egg Parasitism. Parasites were reared at the Lac-des-Plages field laboratory to determine percent parasitism in seven different plantations and to determine the cause of low larval populations within the region. Records were kept on observations of more than 5,000 eggs to obtain information on the number of eggs deposited per pine needle, the number of viable eggs, and the number of parasitized eggs.

Virus Application Techniques. Spray applications commenced July 16 (when larvae were in the third instar) at Rockway Valley and terminated at the Chéneville propagation plot on July 28 (peak fourth instar). Treatments in the six plantations selected for virus introduction were made on July 22 and 23 (third and fourth instars). A summary of the techniques, equipment and rates of application is given in Table II.

Sawfly Population Control Assessment Methods. From two to seven examinations of infested trees were made in demonstration and introduction plots, depending upon the mortality rate of larvae at individual locations. The percentage mortality was calculated as:

$$\frac{\text{no. dead colonies}}{\text{no. living + no. dead colonies}} \times 100$$

Table II. Applications of virus sprays in red pine plantations

Plantation location	Treat-ment	Virus prep. used	Type of sprayer	Dosage (amt./ gal. water)	No. trees treated	Approx. amt. spray mixture/acre
1. St. André-Avellin	B	CB	CA	1 gm	12	15 gal.
2. Chéneville	B	CB	T	1 gm	25	1 gal.
3. Namur SE	B	CB	T	1 gm	17	1 gal.
4. Namur	B	CB	CA	1 gm	12	10 gal.
5. Gramont	B	CB	CA	1 gm	70	15 gal.
6. Brookdale	B	CB	CB	1 gm	approx. 200	17 gal.
7. Rockway Valley	A	CB,P	MB	(see Fig. 5)	approx. 3,000	4 gal.
8 Chéneville	C	CB	MB	4 gm	approx. 400	6 gal.

A - control demonstration; B -Virus introduction; C - Virus propagation.

CB - crushed-body preparation (concentration of virus polyhedra variable).

P - purified virus preparation (1 million polyhedra/gm).

MB - Kiekens knapsack mist blower (2 gal. capacity).

CA - Knapsack compressed air sprayers (1 and 2 gal.).

T - Turbair Mark I ULV sprayer (2 litres).

The cumulative mortality rate in percent was tabulated up to 48 days after treatment (Sept. 2). Records were kept also of the occurrence of larval infection in the check plot and in rows 7-16 of Treatment V and rows 7-19 in Treatment VI at Rockway Valley.

Virus Propagation. The procedure for obtaining a supply of virus for spray formulation was as follows:

1. Trees in the plantation at Chénéville were sprayed on July 28.
2. Branches with colonies were clipped from the trees as disease symptoms and mortality of larvae occurred. Clipping commenced after an initial incubation period of 13 days and extended to the seventeenth day after treatment.
3. Diseased (and dead) larvae were transported in paper bags to the field laboratory and removed individually from the branches (Fig. 6).
4. Larvae then were placed in petri dishes and frozen immediately.
5. The frozen collections were transported by picnic cooler to the Environmental Health Laboratory at Ottawa on Aug. 13 and 17, and were freeze-dried on Aug. 28-31 (Fig. 7). Dried larvae were placed in small bottles for storage at the Insect Pathology Research Institute, Sault Ste. Marie.

Results and Discussion

Egg parasitism. Based on an examination of 266 red pine needles (5,106 sawfly eggs) at seven plantations, parasitism by Tetrastichus sp. accounted for 80% mortality of the 1970 sawfly population (Table III). Coupled with probably high 1969 larval parasitism and predation, natural control factors accounted for the sharp reduction in sawfly populations throughout southwestern Quebec this year.

Virus spray efficacy and dosage assessment. Mortality of larvae was first observed 14 days after treatment at the Rockway Valley demonstration area (Table IV). An average of 98% mortality was not achieved, however, until after 48 days. Although larvae continued feeding for

Figure 6. Sorting of diseased red-headed pine sawfly larvae from foliage for virus propagation.

Figure 7. Freeze-drying of diseased larval collections.

Table III. Parasitism of Neodiprion lecontei by Tetrastichus sp. in southwestern Quebec, 1970.

Location	No. needles examined	Total No. eggs	Avg. no. eggs /needle	No. viable eggs	No. parasitized eggs	Percent Parasitized
Demonstration Area						
Rockway Valley	50	831	16.6	228	603	72.6
Virus Introduction Areas						
Namur SE	50	862	17.2	171	691	80.2
St. Andre-Avellin	50	1007	20.1	162	845	83.9
Brookdale	5	75	15.0	35	40	53.4
Cheneville	11	246	22.4	91	155	63.1
Propagation Area						
Cheneville	50	1112	22.2	160	952	85.6
Additional Plantation						
(near) St. Adele	50	973	19.5	169	804	82.6
TOTALS	266	5106	19.2 (range 2-40)	1016	4090	80.1

Table IV. Cumulative mortality of sawfly larvae at the Rockway Valley control demonstration plantation[1].

	Treatment	DAYS AFTER TREATMENT 19	23	27	31	36	48
I	1/8 gm (6 rows)	28%	57.1%	79.7%	90.9%	94.4%	100%
II	1/4 gm (6 rows)	31.8	61.9	76.4	90	100	100
III	1/2 gm (6 rows)	41.9	78.1	96.9	96.9	100	100
IV	1 gm (rows 1-6)	51.9	70.9	94.5	96.4	100	100
V	1 gm (rows 7-16)	13.1	32.8	66.6	81.4	88.7	96.9
VI	Purified (rows 1-6)	79.8	94.7	94.7	97.4	97.4	97.4
VII	Purified (rows 7-19)	24.4	53.2	64.6	84.8	91.1	94.9

Summary - All Treatments
(Days after Treatment)

14	19	23	27	31	36	48
7.8%	29.2%	53.3%	76.1%	87.8%	93.1%	97.8%

[1]Treated July 16/70 vs. peak third instar (50% egg hatch on July 8); mortality (percent) expressed as

$$\left(\frac{\text{no. dead colonies}}{\text{no. living + no. dead colonies}}\right) \times 100$$

a considerable period of time, the rate of foliage consumption was greatly reduced (Table V), suggesting good spray coverage and infection of the sawfly populations. Similarly, at the six plantations sprayed for virus introduction, mortality commenced 9-13 days after treatment (Table VI).

The virus spray was very effective in affording protection of current-year foliage: Only one or two shoots were defoliated per sawfly colonly on treated trees while up to eight shoots were defoliated per colony on untreated check trees (Figs. 8 and 9). As a result of the protective virus treatments, good refoliation occurred on many trees injured by sawfly larvae in 1969.

The crushed-body preparation was as effective as the purified virus formulation in preventing defoliation (one or two shoots defoliated/colony in each case). Mortality of larvae, however, was more rapid with the purified preparation (Table IV); consequently, the amount of defoliation was least with this preparation (Table V). In terms of shoot protection (i.e., no. of shoots defoliated/colony), the crushed-body virus stock applied at 1.8 gm/gal. of water provided protection equivalent to higher dosages of the same preparation and to the purified virus preparation.

The various types of application equipment used showed that spray efficacy increased with droplet deposit concentration. Most rapid mortality occurred with heavy applications by compressed air sprayer. Applications with the Turbair sprayer (droplet spectrum 60-70 µMMD) provided good protection, but because of the very fine deposit the mortality rate was considerably slower (Table VI).

The knapsack mist blower gave good coverage for six rows (approx. 40 ft.) of trees. Considerable spray drift occurred beyond the 6-row spray blocks but deposit was not recorded.

Virus spread (e.g., possibly by larval parasites, ants) was recorded in the untreated check block at Rockway Valley. Diseased

Table V. Defoliation comparisons for sawfly colonies on treated and untreated trees at Rockway Valley, October 19, 1970[1].

Treatment plot	No. shoots defoliated	Cumulative length of defoliation (inches)	Avg. shoot defoliation/ colony (inches)
Untreated Check	18	59	11.8
1/8 gm	7	26	5.2
1/4 gm	7	18	3.6
1/2 gm	5	14	2.8
1 gm	6	9	1.8
Purified	5	6.5	1.3

[1] Based on examination of 5 trees/plot, each having one colony only; partially defoliated shoots included in measurements.

Table VI. Cumulative mortality of sawfly larvae at the six plantations selected for virus introduction[1].

Treatment	Location	DAYS AFTER TREATMENT																												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
I	St. André-Avellin							0			100																				
II	Chéneville[2]							0		0			17			39										94					100
III	Namur NE[2]							0		14			60			65										90					100
IV	Namur							0		92					100															
V	Gramont						0			30				90		95								100							
VI	Brookdale							0		0				55		60								100							

[1]Mortality of sawfly colonies on trees selected for treatment (other infested trees in these plantations not treated); cumulative mortality (percent) expressed as $\left(\frac{\text{no. dead colonies}}{\text{(no. living + no. dead colonies)}}\right) \times 100$

[2]Applications at these plantations made with the Turbair Mk. I sprayer; virus applied by compressed-air sprayers at other locations.

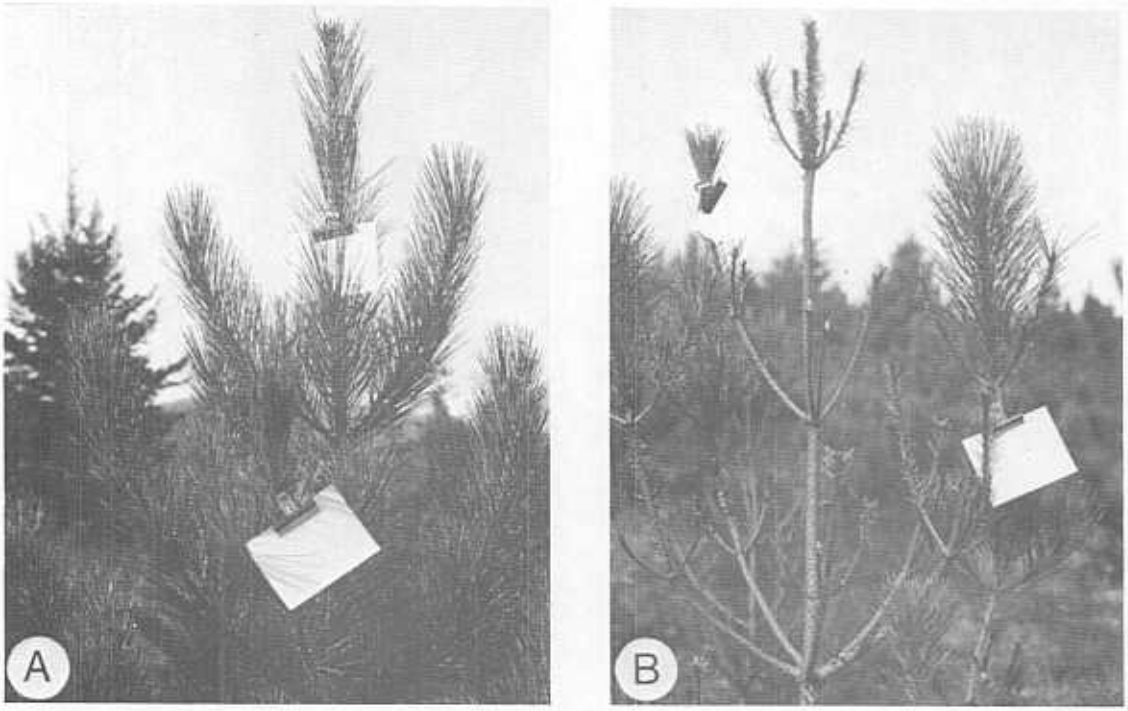

Figure 8. Defoliation by two sawfly colonies on a virus treated tree (A) and on an untreated check tree (B).

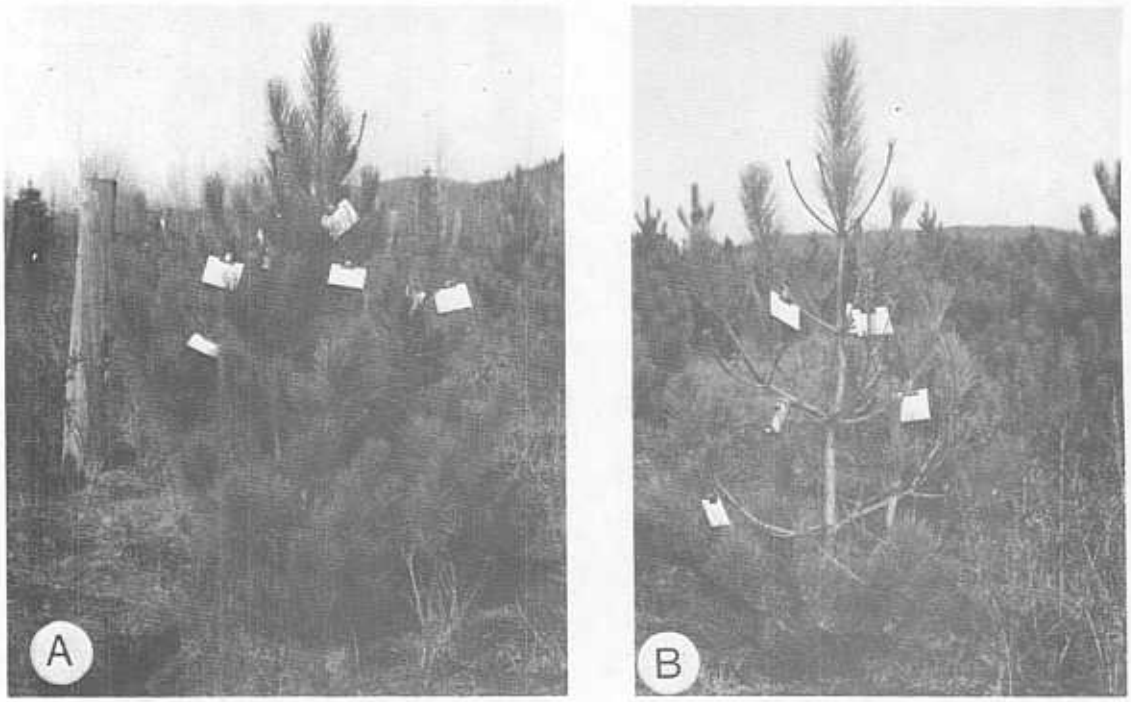

Figure 9. Defoliation by seven sawfly colonies on a treated tree (A) and on an untreated check tree (B).

and dead larvae were found throughout the block and on trees at the southern edge of the plantation about 50 ft. from the nearest treated tree. In addition, most larvae on trees in rows 7-16 of block V and rows 7-19 of block VI were infected and dead.

Virus Propagation. Thirty-eight grams of virus stock were obtained from the diseased larval collections at Chénéville. This amount would be sufficient to treat about 150 acres at a dosage of 1/8 gm/gal.

Summary

1. The control demonstration using a polyhedrosis virus for protection of trees from attack by the red-headed pine sawfly was successful. A crushed-body suspension in water applied at 1/8 gm/gal afforded protection equivalent to those levels obtained either with higher concentrations of the same preparation or with a purified formulation.

2. Until more critical assessments can be made, an application of the virus preparation by compressed air (or hydraulic) equipment may be considered superior to applications by other types of sprayers. However, the the differences in efficacy were mainly in mortality rates; differences in protection levels achieved were not noticeable.

3. Propagation of the virus is simple when a large supply of diseased larvae is available. The 38 grams of freeze-dried material collected would be sufficient to treat approximately 150 acres at a dosage of 1/8 gm/gal.

4. Timing of the virus application to coincide with peak egg hatch would have resulted in early mortality of larvae and consequently less feeding injury.

5. CONCLUSIONS, RECOMMENDATIONS, AND FOLLOW-UP

F. T. Bird [1]

The results presented in this report were similar to those results obtained from earlier experiments in Ontario; that is, virus sprays for control of the red-headed pine sawfly are as effective as chemical insecticides. It is expected that the results may be duplicated wherever and whenever the need for control arises and that they are not entirely dependent on certain climatic or stress conditions which might be considered particularly favorable for the virus or unfavorable for the host insect. All populations are susceptible and it is only necessary to determine what the particular need is. If trees must be saved from serious defoliation, entire populations can be destroyed by selecting a virus concentration and method of application which assures complete coverage and quick mortality. A higher concentration to produce more rapid kill would be required for insects that are half grown than those newly hatched. It is not advisable, however, to spray virus on foliage long before hatching because most of it will be inactivated by solar radiation. Also, virus cannot be used effectively if the larvae are nearing pupation as it is thought that the infection process stops soon after cocoons are formed. A knowledge of the sawfly's life history is essential, therefore, for optimum effect of spray applications.

A great deal of work could be done with regard to the quantitative aspects of virus spraying to produce the greatest amount of infection and mortality with the least amount of virus at the most favorable time. These are considered as refinement in technique which, although perhaps desirable, are not necessary for the immediate and effective use of the virus. The virus is relatively inexpensive for the small plantation owner to obtain by simply collecting cadavers

[1] Insect Pathology Research Institute, Department of Fisheries and Forestry, Sault Ste. Marie, Ontario.

from sprayed areas, and a small overdose of virus is not expensive or wasteful. It will simply hasten the development of an epizootic. Moreover, mortality resulting from spraying is not entirely due to primary infection but to transmission of virus from diseased to healthy larvae and this will depend not only on population density but on the relative position of colonies on a tree. Thus there may be rapid transmission from an infected colony in a strategic position at the top of a tree but very slow and sometimes no transmission if the infected colony is at the bottom of a tree.

Virus is transmitted from one generation to another via the egg. This is not simply due to contamination of virus from a previous epizootic, but by a true infection of the egg-laying adult. There will be little or no transmission of virus if larvae are sprayed as they are spinning cocoons. To obtain viral transmission there must be active infection of the larvae. It is therefore necessary to spray virus early enough to produce a severe epizootic before cocoon spinning occurs and late enough to ensure partial survival. Foliage contaminated with virus from an epizootic is quite thoroughly cleansed by solar radiation, wind, and rain, and little if any remains viable overwinter and is not important in the development of infections the following year. Such virus as does remain viable might, however, constitute a source of infection years following an epizootic when populations reach a high level. It would be necessary for only a single individual to pick up the virus to initiate the epizootic.

When population levels are low and general spraying impractical, spraying those colonies detected during a rapid survey might be sufficient to prevent population increases. This will have to be determined by trial and error, keeping careful records on population density and proportion of colonies infected. The timing of such an operation, and manipulation of virus dosage, could produce partial infection and some survival.

The general trend in a red-headed pine sawfly outbreak is the apparently complete collapse of the outbreak chiefly by egg and larval parasites and occasionally by the natural development of the virus disease. The introduction of virus will destroy populations much earlier and prevent tree defoliation and mortality. It would be very interesting and important to determine what proportion of infestations would have to be sprayed with virus to cause the collapse of an outbreak over a wide area. The current outbreak in the St. Jovite area appears to be collapsing chiefly from egg parasites and it is perhaps too late to do much more than accelerate the collapse and save a few trees by spraying virus. It is recommended that a program of virus introductions be considered at the beginning of an outbreak, and that careful records be kept now and in the future of places of virus introductions. Special metal tags similar to those used for parasite introductions could be used for marking points of virus introductions. It is also recommended that every opportunity for virus propagation be used.

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