THE EFFECTIVENESS OF THE AERIAL APPLICATION OF ORTHENE®
AGAINST SPRUCE BUDWORM AT PETAWAWA FOREST EXPERIMENT STATION DURING 1974.

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Chemical Control Research Institute

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Abstract

Orthene® (O,S-dimethyl acetylphosphoramidothioate) was applied at 0.21, 0.42 and 0.63 kg/ha (3.0, 6.0 and 9.0 oz AI/acre) in aqueous solution emitted at 2.34, 4.67 and 9.35 l/ha (0.25, 0.50 and 1.0 gpa) to balsam fir and white spruce trees infested with the spruce budworm. Analysis of the results showed that budworm population reduction and foliage protection of white spruce was possible with a deposit of 0.21 kg/ha (3.0 oz AI/acre) in a volume of 4.67 l/ha (0.5 gpa). Population reduction and foliage protection was possible on balsam fir with a deposit of 0.19 kg/ha (2.75 oz AI/acre) Orthene emitted at a single application of 4.67 l/ha (0.5 gpa) or a double application at 2.34 l/ha (0.25 gpa).

Résumé

Orthene® (O,S-dimethyl acetylphosphoramidothioate) était appliqué à 0.21, 0.42 et 0.63 kg/ha (3.0, 6.0 et 9.0 once IA/acre) dans une solution aquée émise à 2.34, 4.67 et 9.35 l/ha (0.25, 0.50 et 1.0 gpa) aux sapins baumiers et aux épinettes blanches. Un analyse des résultâts a démontré qu'une réduction des populations des tordeuses et une protection des feuilles des épinettes blanches étaient possible avec une déposition de 0.21 kg/ha (3.0 once IA/acre) d'Orthene émis à 4.67 l/ha (0.5 gpa). Une réduction de la population et une protection aux feuilles des sapins baumiers étaient possible avec une déposition de 0.19 kg/ha (2.75 once IA/acre) d'Orthene émis à une application unie de 4.67 l/ha (0.5 gpa) ou à une application double de 2.34 l/ha (0.25 gpa).

INTRODUCTION

The insecticide Orthene® (O,S-dimethyl acetylphosphoramidothioate) is at present registered and marked in the United States for control of shade tree insects. Nigam (1972) and Nigam and Hopewell (1973) have shown this material to be effective against the spruce budworm larva (Choristoneura fumiferana Clem.), and Lyon (1973) has shown that Orthene has systemic qualities which may be considered to be an advantage in extending the life of the insecticide. In laboratory trials, Nigam (1974) has shown that Orthene is effective in terms of combined stomach and contact toxicity to V instar larvae of spruce budworm to the same extent as fenitrothion although in terms of contact toxicity alone fenitrothion is 4 times as effective at the LD_{50} level and 8 times as effective at the LD_{95} level. One of the major criteria used in assessing the usefulness of a candidate material for spruce budworm control is its residual toxicity. If an insecticide does not retain its toxicity for a minimum of about 3 days it is considered to have too short a life to be useful on a large spray operation. Nigam (1974) has shown that Orthene applied to potted trees at 0.56 kg/ha (8 oz AI[1]/acre) will produce a 50-60% mortality in spruce budworm larvae after 3 days exposure to weathering; after 5-10 days weathering the mortality is in the range of 25-35 percent.

Field applications of Orthene and fenitrothion on individual white spruce (Picea glauca (Moench Voss)) in the area of Shawville,

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1 AI Active Ingredient

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Quebec at an application rate of 0.36 kg/ha (5.2 oz AI/acre) resulted in a 76% mortality with Orthene and a 60% mortality with fenitrothion (Nigam and Hopewell, 1973). Ground applications of Orthene were carried out on white spruce plantations in 1973 (DeBoo 1974). At the dosages applied, 0.56 kg/ha (8 oz AI/acre) a population reduction of 98% was achieved 10 days after application. The percentage defoliation on these trees was only 6 percent.

Orthene has been shown to be safe material. The oral toxicity to white rats shows that Orthene is 1.5 to 3 times as safe as fenitrothion, e.g., Orthene oral LD_{50} is 945 mg/kg and fenitrothion oral LD_{50} is 250 - 670 mg/kg; Orthene dermal LD_{50} is 2000 mg/kg and fenitrothion dermal LD_{50} is 200-300 mg/kg, (Chevron Chemical Co., 1973; Kenaga and Allison 1971). Studies by the Chevron Chemical Company and the Fisheries and Marine Services, Environment Canada indicate that Orthene is 300 times safer to rainbow trout than fenitrothion. The only indication of Orthene being more harmful than fenitrothion to non-target organisms is with respect to bird toxicity. Data from Chevron Chemical Company and Tucker and Crabtree (1970) show an acute oral toxicity to mallard ducks of 350 mg/kg for Orthene and 1190 mg/kg for fenitrothion.

The general safety of Orthene to the environment, coupled with its apparent effectiveness against spruce budworm larvae as indicated by the laboratory tests, individual tree applications and ground applications indicated that Orthene should be considered as a candidate insecticide for aerial application against the spruce budworm.

The present spruce budworm epidemic in eastern Canada has been cause for concern at the Petawawa Forest Experiment Station since 1970. Survey reports by the Forest Insect and Disease Survey (1973) indicated a continuing high budworm population in the area and at a meeting of representatives of Chevron Chemical Company and the Chemical Control Research Institute (CCRI), it was planned to apply Orthene to the prime plantation areas in 1974.

MATERIALS AND METHODS

1. Plan of Operation

The Petawawa Forest Experiment Station (PFES) is located about 110 miles (175 km) northwest of Ottawa between the towns of Chalk River and Petawawa. Within the station limits are about 200 ha (500 acres) of high value white spruce and balsam fir (*Abies balsamea* L. Mill) plantations that have been used for experimental studies for many years. Within this same area are stands of lesser importance and areas of non-susceptible trees and cleared areas. Fenitrothion sprays applied by the Chemical Control Research Institute in 1972 and 1973 at Petawawa Forest Experiment Station demonstrated that to achieve effective control of the spruce budworm and to provide adequate protection against defoliation it was necessary to spray more than the minimum target area and the spray must be applied at an emission rate of at least 4.67 l/ha (0.5 gpa).

Orthene studies by DeBoo (1974) and Nigam (1973) had indicated that an application of 0.56 kg/ha (8 oz AI/acre) would control spruce budworm on white spruce and it was decided to use dosage rates at PFES which would bracket this rate. The spray area was subdivided into blocks and plots which would be treated with a range of concentrations and volumes of emitted material. The map in Fig. 1 shows the layout of the spray areas and in Table I is shown the different treatments used.

The sequential treatment of blocks B-W, B-E and C was planned as follows: on the first application the whole of each block (all three plots in each) were to be treated at the selected treatment rate. Then at the time of the second application, two-thirds of each block was to be treated and at the third application only one-third of each block was to be treated. Thus, taking B-W as an example the first application resulted in plots A, B and D being treated, the second application resulted in B and D being treated and on the third application only plot D was treated.

Table I

Orthene Treatment Rates

Block	Plot	No. of applications	Conc. %	Total AI kg/ha	Total AI oz/acre	Total Volume l/ha	Total Volume gpa
B-W	A	1	2.25	0.21	3	9.35	1.0
	B	2	2.25	0.42	6	18.70	2.0
	D	3	2.25	0.63	9	28.05	3.0
B-E	E	1	4.5	0.21	3	4.67	0.5
	F	2	4.5	0.42	6	9.35	1.0
	G	3	4.5	0.63	9	14.02	1.5
C	H	1	9.0	0.21	3	2.34	0.25
	J	2	9.0	0.42	6	4.67	0.5
	K	3	9.0	0.63	9	7.0	0.75

Table I Cont'd

Block	Plot	No. of applications	Conc. %	Total AI kg/ha	Total AI oz/acre	Total Volume l/ha	Total Volume gpa
Plantations							
(PFES No.)							
	42	1	13.5	0.63	9	4.67	0.5
	101	1	9.0	0.42	6	4.67	0.5
	126	1	6.75	0.63	9	9.35	1.0

2. Formulation of Insecticide

Orthene was received in the technical form (90% active ingredient) in 4.53 kg (10 lb) bags in drums, each drum containing 20 bags of insecticide. The plan was to spray the Orthene in water dyed with Rhodamin B (0.5% dye concentration) which was added to facilitate droplet and deposit analysis. Since a water formulation was being used, concern was expressed over the problem of evaporation of the formulation at the time of application. Laboratory trials at CCRI and Chevron Company Laboratories indicated that the addition of ethylene glycol to give a 10% glycol-water solvent system would act as an anti-evaporant. Tests in the laboratory at CCRI on the biological activity of an Orthene:water:glycol formulation showed that there was no change in effectiveness compared to a formulation without glycol, and it was therefore decided to add 10% by volume ethylene glycol to the formulation.

The insecticide was formulated in a 1140 l (300 gallon) stainless steel tank fitted with a paddle agitation system. A meter system fitted onto the plumbing of the tank enabled accurate quantities

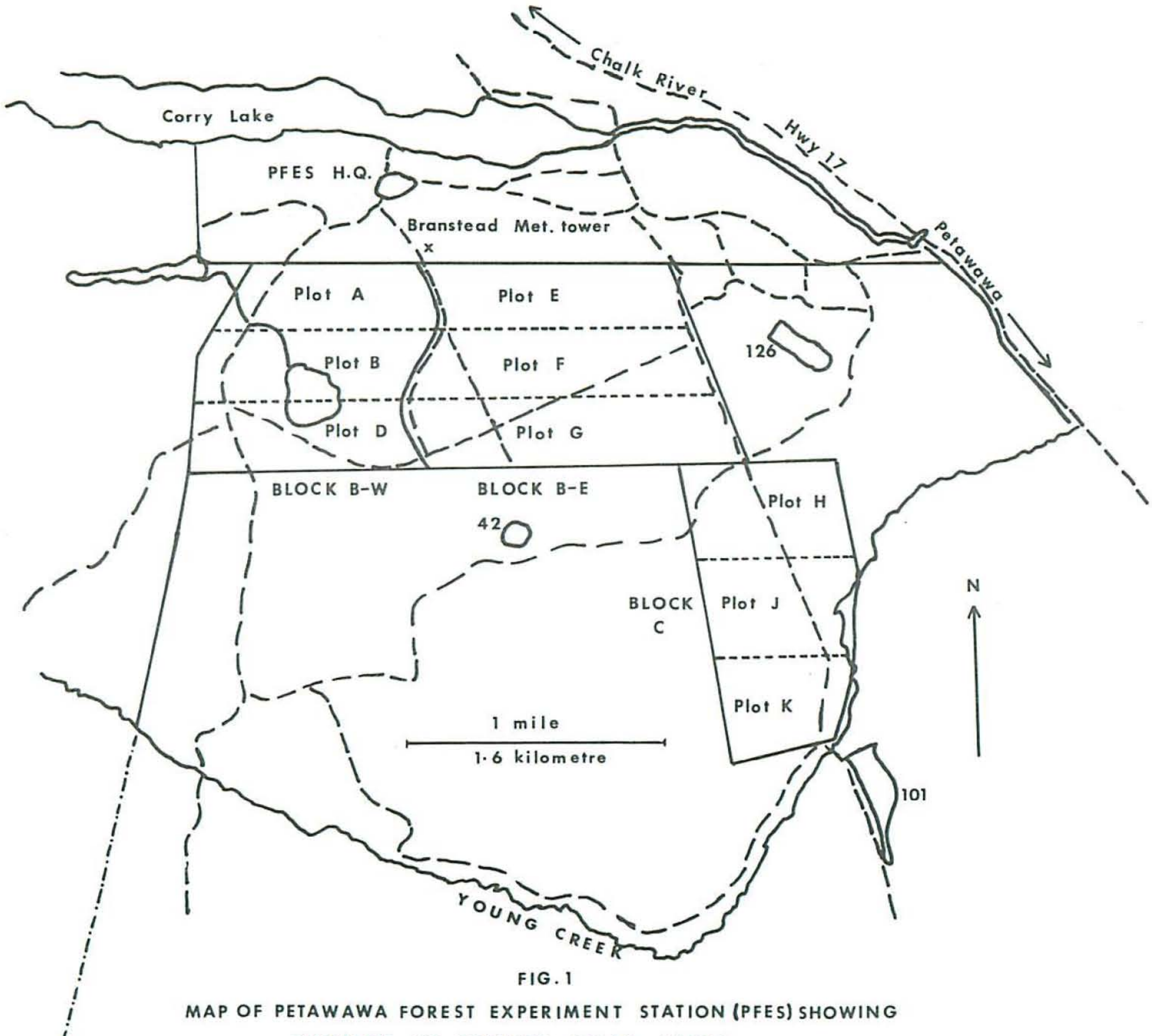

FIG. 1

MAP OF PETAWAWA FOREST EXPERIMENT STATION (PFES) SHOWING POSITION OF ORTHENE SPRAY PLOTS of water and glycol to be metered into the tank. With the Orthene prepacked in 4.53 kg (10 lb) packs, each formulation batch was prepared to the proper concentration by adjusting the amount of water used such that the addition of the required number of bags of Orthene would give the desired concentration. Through the co-operation of PFES, a truck-mounted 7560 l (2000 gallon) tank was parked at the Pembroke airstrip beside the mixing tank. A hose connection between the bulk water tank and the formulating tank provided a means for quickly filling the mixing tank (Fig. 2). At the time each batch of insecticide was formulated, a 118 ml (4 fluid ounce) sample of the fully formulated material was taken and returned to the laboratory in Ottawa to be used as the standard for colorimetric and drop analysis of the spray deposit.

3. Spray Application Equipment

The Orthene sprays were applied using a Cessna Agtruck[1] and a Cessna 185[2] fitted with a Sorensen spray system. Both aircraft were fitted with Micronair[3] AU 3000 spinning cages. Prior to spray application each aircraft was calibrated to determine the proper setting of the variable restrictor units to permit a rapid and accurate change of delivery rate. The Cessna Agtruck was used to deliver the two high volume applications (Blocks B-W and B-E) and the Cessna 185 was used for the applications to Block C and the plantations.

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1 Cessna Agtruck. Leased from Modern Airsprays, St. Jean, Quebec

2 Cessna 185 - belonging to CCRI

3 Micronair AU 3000. Micronair (Aerial) Ltd, Benbridge Fort, Isle of Wight, England.

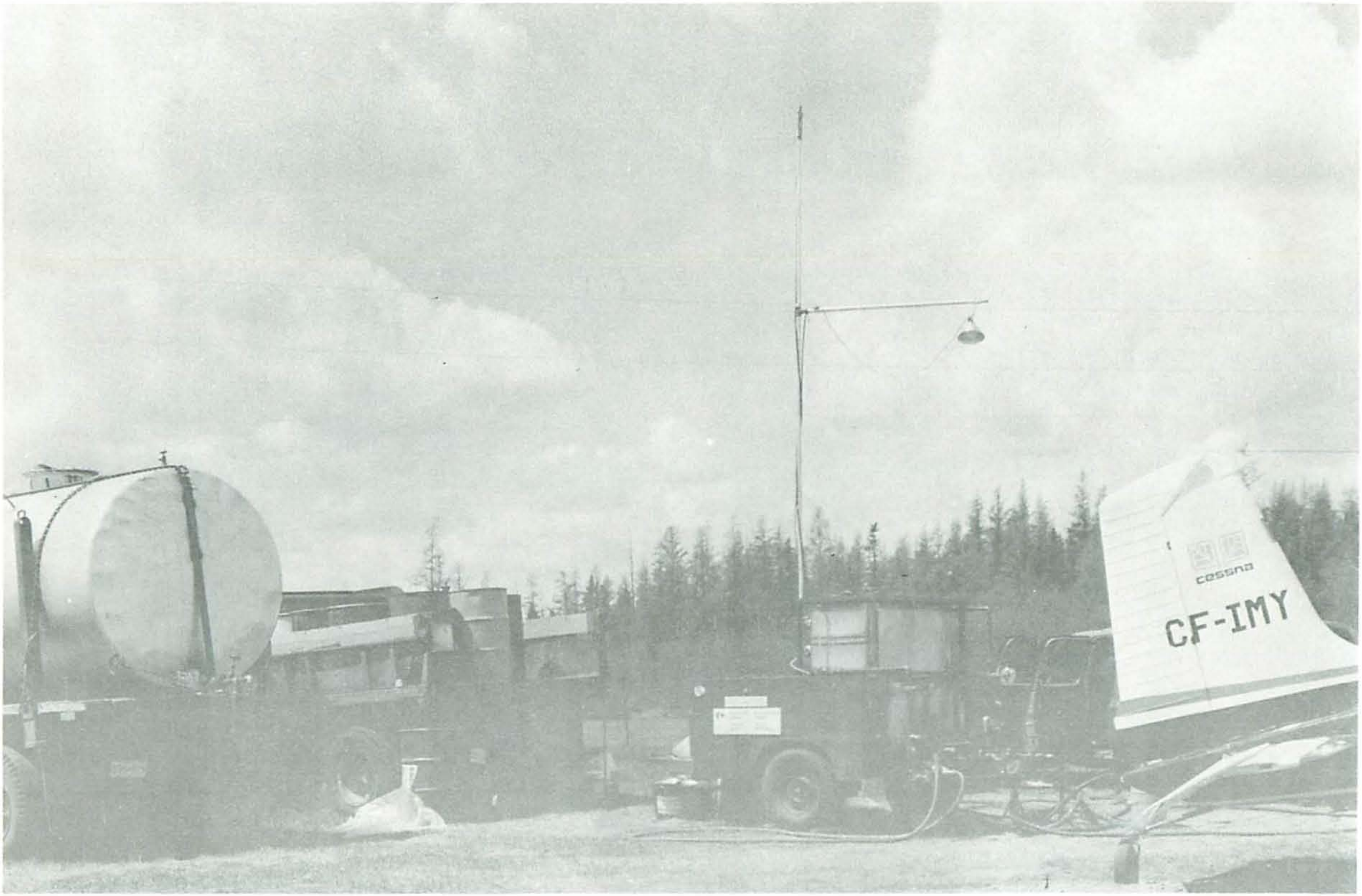

FIG. 2

INSECTICIDE MIXING AND LOADING SITE

4. Control of the Spray Operations

The criteria for suitability of spray conditions were a mean wind speed of 3.6 m/s (8 mph) or less and a temperature differential between two heights indicating inversion conditions. The wind speed and direction were determined from anomometers at the Branstead weather station (Fraser and Farr, 1965) and from sensors mounted on a 30 m (97 foot) tower. At the Branstead site, wet and dry bulb temperatures and relative humidities were also recorded using standard sensing equipment. Temperature differentials were determined using probes mounted at 2 m (6 feet) and 6 m (20 feet) on the Branstead tower. The mean wind speed and temperature differential were used to calculate a stability ratio (S.R.) which gives a positive number under stable (inversion) conditions and a negative number under unstable (lapse) conditions. The larger the numerical value of this number the greater the degree of stability or unstability. This factor has been shown to be a good means of determining the suitability of spray conditions and it also has the advantage of giving a numerical value which permits a comparison of the meteorological conditions under which the different sprays were applied (Armstrong, 1973).

Communication between the airstrip and the spray blocks (a distance of about 18 km (11 miles) was by telephone. There was no radio link between the spray aircraft and the ground crews in the spray blocks and to permit the transmission of important last minute messages a visual signal system was used. On a spray morning the telephone was used to signal the time to start or stop the spray application. With each spray load the pilots made a visual check of a predetermined ground point prior to spraying the particular load. If the weather was still good, an arrow made of strips of orange cloth approximately 5 m x 1 m was laid out on the ground in the direction of the wind. If the conditions were not good and the spray was to be cancelled, a cross was laid out. If there was some necessity to delay the application, i.e. ground sample crews not ready, a rectangle was laid out which indicated "hold".

The plan was to apply the sprays at 3-4 day intervals with the first spray being applied when the majority of the larvae were II and III instar with about 1-2% of IV instar larvae. Population development was monitored by a biological assessment crew (Morris and Armstrong, 1973).

5. Assessment of the Spray Results

Three factors were considered in assessing the effectiveness of each application of Orthene. They were:

a) The amount of material deposited in terms of active ingredient per unit area and number of drops per square centimetre.

b) The population reduction of spruce budworm on white spruce and balsam fir corrected to allow for the normal population reduction.

c) The percentage defoliation on white spruce and balsam fir.

(a) Deposit

Insecticide sample units were set out in clearings along a line at right angles to the flight line of the spray aircraft. Each sample unit was made up of aluminum plates to which were fastened two 75 x 50 mm glass microscope slides and a 10 x 10 cm (4 x 4 inch) square of Kromekote paper[1]. A minimum of 10 sample units were set out in each spray plot just prior to application and they were left in position for 40 minutes after the spray was completed. After the sample period the units were collected and returned to the laboratory where the glass plates and the Kromekote cards were first labelled and then removed. A piece of waxed hamburg paper was placed over the face of each card to prevent smearing of the spots. At the Ottawa laboratory a colorimetric assessment technique was used to determine the amount of spray deposited on each sample unit (Armstrong and Randall, 1969). With this amount known, the volume of material deposited on the spray block could be calculated and hence the amount of active ingredient which hit the target area ascertained. The Kromekote cards were sent to the National Aeronautical Establishment for a droplet spectrum analysis (Slack, 1972). This analysis indicated the number of droplets per square centimetre on the target area, the number, mass and volume mean diameter of the spray cloud and a calculation of the volume of spray on the target area. For this particular spray, the most important measurements were the number of drops per square centimetre and the volume of spray deposited.

(b) Population Reduction

In the original design of the experiment it was hoped to have a minimum of 10 white spruce and 10 balsam fir sample trees per plot.

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1 Kromekote Paper. Kruger Pulp and Paper Ltd, Montreal, Quebec.

This did not prove feasible in all cases and white spruce and balsam fir sample trees were selected at positions to give an assessment of the population across the plot at right angles to the line of flight of the spray aircraft. The selection of sample trees and the method of assessing the population has been described by Armstrong and Randall (1969). In this study the population density per 45 cm (18 inch) branch was averaged to give a plot average per branch tip. Limitations on number of staff were such that instead of making the normal three pre-spray counts and three to four post-spray counts, it was only possible to have one pre-spray and two post-spray population fixes. To make this minimum number of counts more valid, a detailed population assessment was carried out on an untreated check block which had a population about equal to that of the treated blocks. These counts gave data indicating the normal decline in population density which was used to correct the counts in the treated blocks and also indicated the development of the population to provide information for the timing of the operation.

(c) Defoliation

The effectiveness of aerial sprays is evaluated not only by the percentage reduction of the target insects but also the amount of protection given to the foliage. This protection is determined as the percentage defoliation; the less defoliation the more protection the tree has received. The method for assessing the defoliation used by CCRI was that described by Fettes (1951). In this method a count is made of the number of needles and buds destroyed by the budworm larvae, this is related to the number that would have been present with no insect damage and from this a numerical value of percentage defoliation can be calculated. Branch samples from mid and upper-crown were taken from each tree at intervals prior to and after the spray; defoliation rates from the untreated control checks were also made and from these two values, a percentage protection was calculated.

RESULTS AND DISCUSSION

1. Spray Application

The application of Orthene started the 27th May with the budworm population on balsam fir being 7.1% L_2, 91.5% L_3 and 1.4% L_4 and that on white spruce being 2.5% L_2, 97% L_3 and 0.5% L_4. This development met the desired plan of initiating spray application when the budworm population indicated 1-2% L_4 with the rest L_2 and L_3. The original plan had been to apply the Orthene at 3-4 day intervals to give the required accumulation of insecticide. Weather, budworm development and unforeseen factors resulted in necessary alterations to this program (Table II).

Table II

Dates of Spray Application of Orthene

Date of spray	Plots sprayed	Application	No. of days interval after previous spray
27/5 am	A,B,D,H,J,K	1st	0
27/5 pm	E,F,G	1st	0
30/5 pm	42, 101, 126	1st	0
30/5 pm	J,K	2nd	3
31/5 am	B,D	2nd	4
1/6 am	F,G	2nd	5
2/6 pm	D	3rd	2
2/6 pm	G	3rd	1
2/6 pm	K	3rd	3

All sprays were applied under the desired weather conditions with the exception of the applications to Plot K and the plantations. In Table III are listed the weather conditions at the time of each application. Referring to the map shown in Figure 1, it can be seen that the meteorological sensing equipment was positioned about 4.0 km (2.5 miles) from Block C. There is also a change in topography with the land sloping down to the stream at the southern end of Block C. The results of these two factors (distance and topography) were such that on occasion the weather as indicated at the Branstead tower site was not the same as existed in Block C and in fact during the time of the application to plot K and the plantations, a weak weather front with an associated short sharp rain shower moved through the PFES area to the east of Block C. Associated with this was an increase in wind speed and an increase in turbulence which was noticed by the pilot but which was not recorded at the Branstead site.

Table III

Meteorological Conditions at the Time of Spray Application

Plot Sprayed	Wind (m/s)	Speed (mph)	Wind Direction	S.R.[1]	R.H.(%)	Suitability of Spray Conditions
A,B,D,H,J,K	1.	2.3	NW	+ 7.9	90-95	1
E,F,G	1.9	4.3	W to NW	+ 0.4	90-95	4
J,K,42,101,126	0.9	2.1	N to NE	+15.5	70-90	2
B,D	3.4	7.6	SE	+ 0.1	90	5
F,G	1.6	3.6	W	+ 2.1	95	3
D,G,K	1.2	2.6	SE	very large	50-70	6

1 S.R. - Stability Ratio

2. Spray Deposit Assessment

The amount of formulated spray deposited on each plot was determined by colorimetric assessment and from this the amount of active ingredient on the target area was calculated. The droplet assessment completed by NAE indicated the number of droplets per square centimetre. In Table IV is shown the total spray emitted on each plot in terms of active ingredient and the deposit of active ingredient, the drop density and the percentage of spray deposited on the target area.

Table IV

The Deposit of Orthene on Spray Plots

Plot	Total emitted		Actual deposit		Drops/cm^2	Percentage Spray Deposited
	kg/ha	oz/acre	kg/ha	oz/acre	(total)	
A	0.21	3.0	0.15	2.13	> 100*	70.9
B	0.42	6.0	0.11	1.56	> 86.3	25.9
D	0.63	9.0	0.26	3.76	>135.4	41.7
E	0.21	3.0	0.21	3.0	52.8	100
F	0.42	6.0	0.23	3.22	42.5	53.6
G	0.63	9.0	0.41	5.96	> 76.1	66.2
H	0.21	3.0	0.03	0.40	> 25.6	13.3
J	0.42	6.0	0.05	0.68	> 38.8	11.4
K	0.63	9.0	0.19	2.76	55.6	30.6
42	0.63	9.0	0.03	0.48	14.1	5.3
126	0.63	9.0	0.02	0.36	3.8	5.0
101	0.42	6.0	0.01	0.25	13.0	4.2

* Where more than the number of drops is indicated (i.e. >100) some of the spray cards in the sample had such a heavy deposit that it was impossible to count the number of drops per square centimetre; in these cases the drop density was determined from the cards that could be counted and the deposit was then indicated as more than this number.

The percentage spray deposited ranged from a theoretical 100 percent of emitted spray to 4.0%. This variation existed within the plots and from plot to plot. With reference to the suitability of meteorological conditions at the time of application and the percentage spray deposited, there are apparent anomolies which seem to be contrary to the theory of relationship of weather conditions to spray application. Hurtig et al (1953) have shown that there is close agreement between the spray deposited on ground sample units with that deposited at the tree crown. In the spray plots at PFES the sample units were set out along the roads running through each plot. The road clearance in plots A,B, D,E,F and G were generally wide varying from about 12 to 60 m (40 to 200 feet) and the trees bordering the roads ranged from 6 to 15 m (20 to 50 feet) high. In plots H,J and K the road clearance was much narrower (6 to 7 m - 18 to 20 feet) and bordered by very tall trees (18 to 24 m - 60 to 80 feet). The plots 42, 101 and 126 were characterized by the presence of tall trees along narrow roads. The data collected suggest a correlation between a combination of road width and tree height with the percentage of spray deposited with a screening effect to result in a low deposit at ground level on narrow roads. Thus, with plots H,J,K, 42, 101 and 126 being sprayed under very good conditions, and plot K receiving two of the three sprays under good conditions, there is the possibility that, although the ground sample plates indicated a low deposit, there may have been a good deposit on the foliage in the upper crown.

3. Population Reduction

In Table V is given the percent population reduction and the percent defoliation on balsam fir and white spruce in the test plots. In the calculation of population reduction Abbott's formula (Abbott, 1925)) was used to correct for the normal population decline as measured in the untreated check plots. The data on percent defoliation show the percentage of foliage lost by budworm feeding activity; no correction factor was calculated and the normal defoliation in the untreated check plots is shown.

Table V

Population Reduction and Defoliation Rate in Orthene Treated Plots

Plot	Corrected % Population Reduction Bf	Corrected % Population Reduction Ws	% Defoliation Bf	% Defoliation Ws
A	71	0	8.2	43.8
B	0	0	26.6	55.9
D	100	55	7.3	16.7
E	87	70	28.4	32.8
F	85	41	25.9	62.4
G	100	75	2.7	4.1
H	0	0	32.8	58.9
J	89	0	31.2	65.5
K	69	0	28.1	48.6
42	-	27	-	-
126	-	30	-	-
101	-	0	-	-
Untreated	-	-	32.9	65.4

The application of a total of 0.63 kg/ha (9 oz AI/acre) at 9.35 and 4.67 l/ha (1.0 and 0.5 gpa) per treatment resulted in an indicated 100 percent population reduction on balsam fir and 55 and 75 percent reduction on white spruce (plots D and G). These plots had a deposit of 0.26 and 0.41 kg/ha (3.76 and 5.96 oz AI/acre) and >135.4 and >76.1 drops/cm^2. Plots J, E and F with population reductions of 89, 87 and 85 percent on balsam fir and 0, 70 and 41 percent on white spruce received deposits of 0.05, 0.21 and 0.23 kg/ha (0.68, 3.0 and 3.22 oz AI/acre) and drop deposits of >38.8, 52.8 and 42.5 drops/cm^2. Treatments at lower rates of insecticide and/or volumes of spray emitted gave less control on balsam fir and no control on white spruce. Plots 42 and 126 which received 0.63 kg/ha (9 oz AI/acre) in a single application of 4.67 and 9.35 l/ha (0.5 and 1.0 gpa) showed about 30 percent population reduction on white spruce; there were no balsam fir in these plots.

The graph in Figure 3 shows the correlation between number of drops/cm^2 deposited and the percentage mortality on balsam fir and white spruce. The data from Table V and Figure 3 show that using a 70 percent budworm mortality as a minimum acceptable level of spray efficacy, the most effective treatment on white spruce was the 4.5 percent Orthene spray with a deposit of more than 50 drops/cm^2. With the 2.25 percent spray solution more than 135 drops/cm^2 would be required and with the 9.0 percent spray the lower volume used did not give sufficient coverage. Again, on balsam fir the most effective treatment was with the 4.5 percent solution in which 40 drops/cm^2 gave approximately 85 percent mortality. The 9.0 percent solution gave approximately the same results.

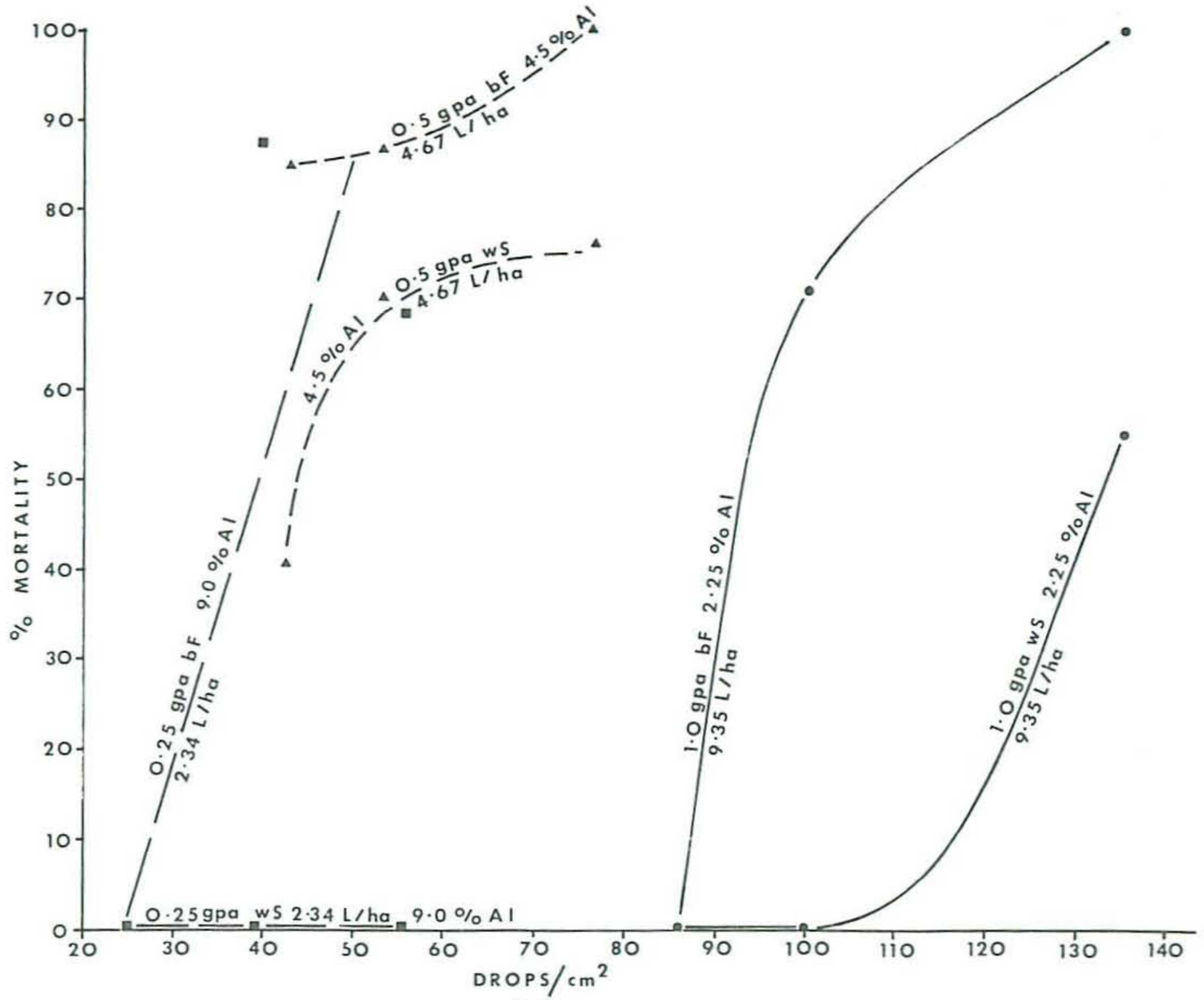

FIG. 3

CORRELATION OF DEPOSIT ON BALSAM FIR (bF) AND WHITE SPRUCE (wS) WITH BUDWORM MORTALITY

With the 2.25 percent solution 100 drops/cm^2 were required to give a minimum 70 percent mortality.

4. Defoliation

Determination of the extent of defoliation of untreated and treated balsam fir and white spruce was made after adult emergence. As with other data, plot averages were calculated based on grouped samples from each plot. Plots 42, 101 and 126 being white spruce plantations did not have any balsam fir for assessment. The results of the defoliation assessment are shown in the last column of Table V and in Figures 4 and 5 with data plotted as means and standard deviations. The best correlation exists between the deposit in terms of drops per square centimetre and the percentage defoliation. For each tree species there are two general relationships (1) that with the application at 9.35 l/ha (1 gpa), a 2.25% AI solution, and (2) that with the 2.34 and 4.67 l/ha (0.25 and 0.5 gpa) applications which were 4.50 and 9.0% AI solutions.

On balsam fir (Figure 4) it is seen that the 9.0 percent spray did not result in any effective reduction in defoliation compared with that in untreated areas. With the 4.5 percent solution the defoliation rate was reduced to about 20 percent with a deposit of more than 55 drops/cm^2. Application of the 2.25 percent solution of Orthene did not reduce the rate of defoliation below that of the untreated check until a deposit of more than 90 drops/cm^2 was achieved.

The same relationship held with white spruce (Figure 5). Application of a 9.0 percent solution to give more than 50 drops/cm^2 did not provide any foliage protection. Foliage protection was attained using a 4.5 percent solution to give a deposit of at least 50 drops/cm^2. With the 2.25 percent solution a deposit of more than 90 drops/cm^2 was necessary to provide foliage protection.

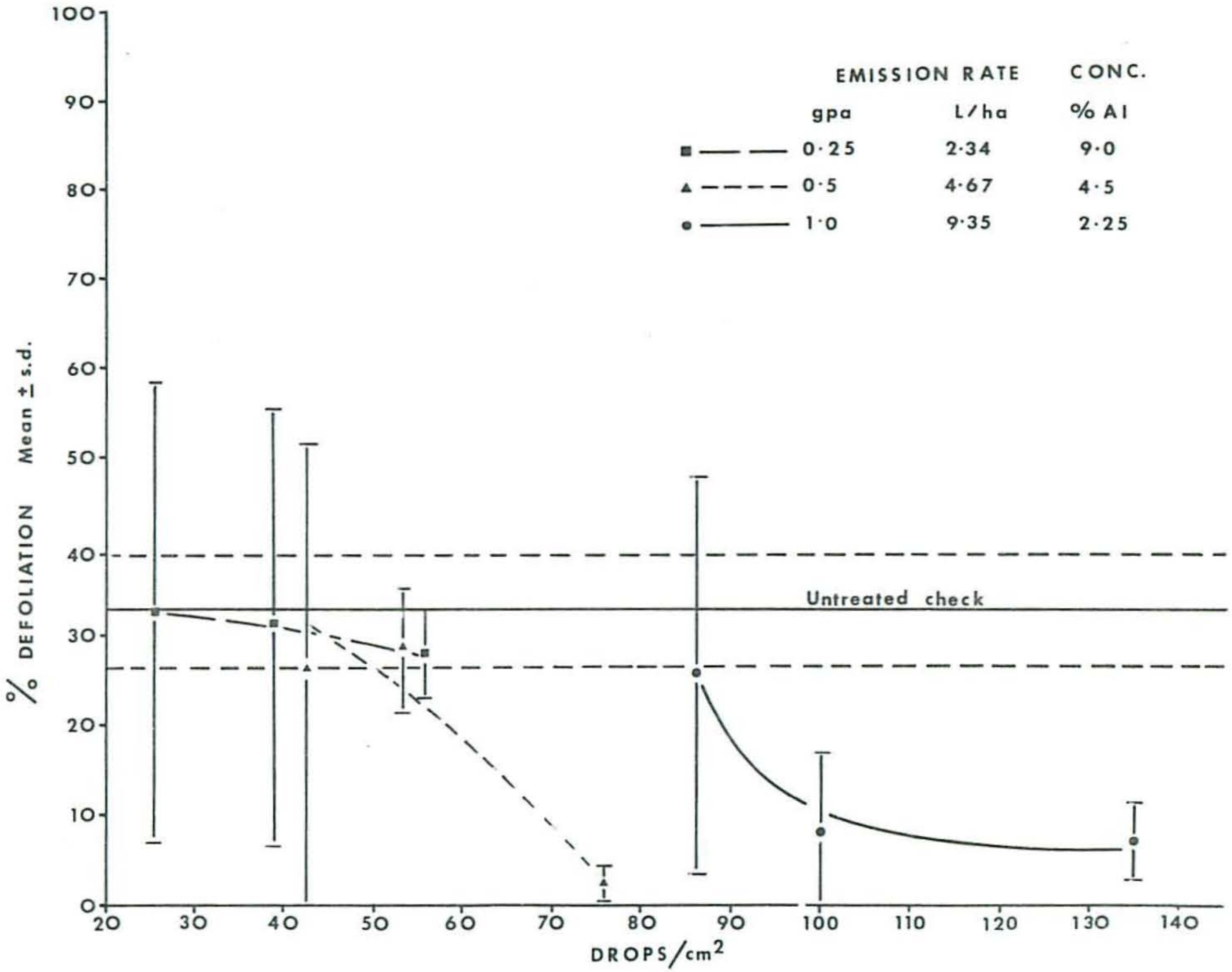

FIG. 4

CORRELATION OF DEPOSIT ON BALSAM FIR WITH PERCENT DEFOLIATION

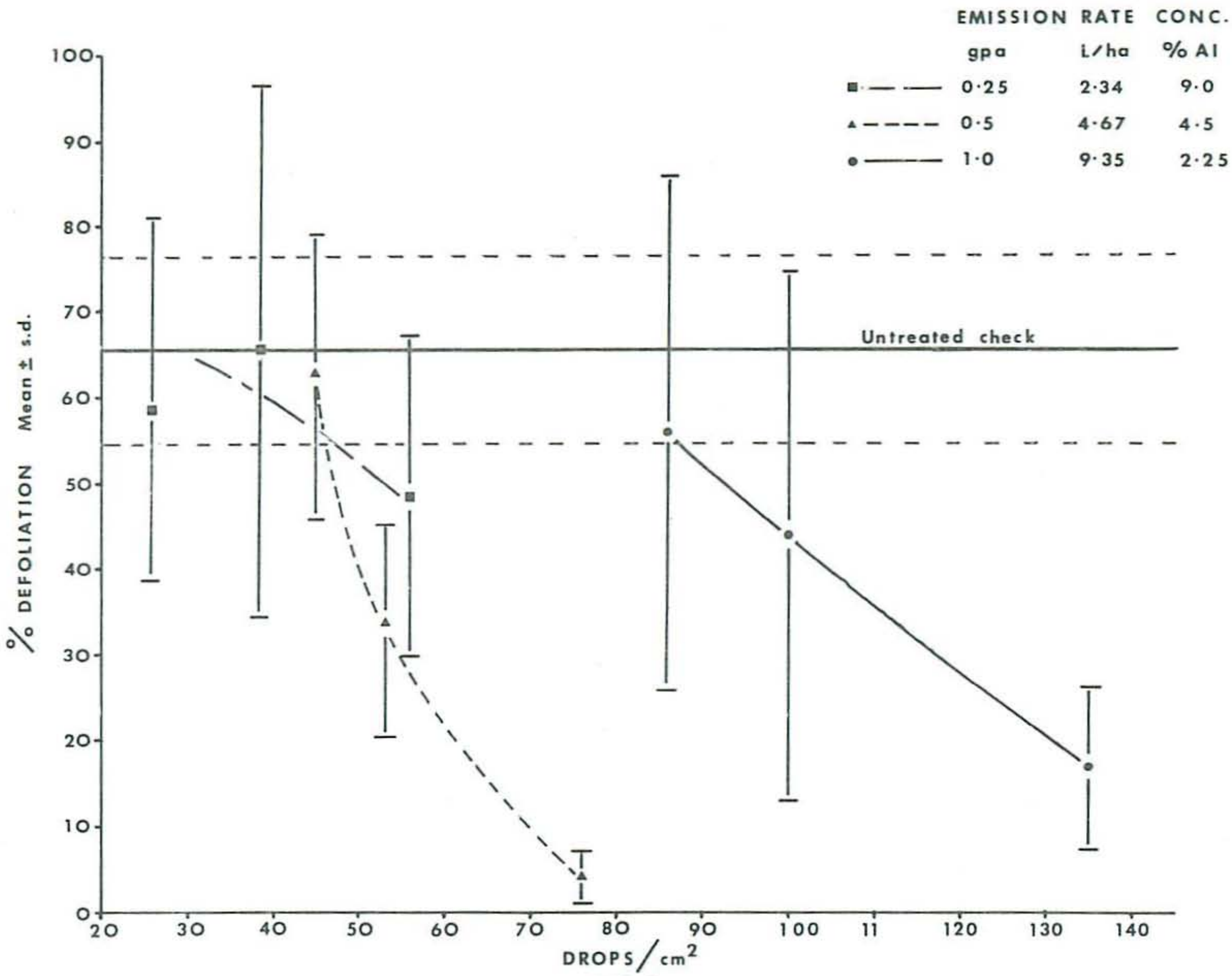

FIG. 5

CORRELATION OF DEPOSIT ON WHITE SPRUCE WITH PERCENT DEFOLIATION

CONCLUSIONS

1. Orthene® was shown to be an effective treatment against the spruce budworm larvae on balsam fir and white spruce in terms of population reduction and foliage protection.

2. Effective control of a budworm population on white spruce was achieved with a 4.5 percent solution of Orthene applied at 4.34 l/ha (0.5 gpa) giving a minimum deposit of 0.21 kg/ha (3.0 oz AI/acre) and 50 drops/cm^2.

3. Control of budworm on balsam fir was obtained with a single application of 4.5 percent solution of Orthene at 4.67 l/ha (0.5 gpa) or two applications of 9.0 percent solution at 2.34 l/ha (0.25 gpa) to give a deposit of at least 0.19 kg/ha (2.75 oz AI/acre) and 40 drops/cm^2.

4. Foliage protection on white spruce was achieved using a 4.5 percent Orthene solution at an emission rate of 4.34 l/ha (0.5 gpa), with a deposit of at least 0.26 kg/ha (3.76 oz AI/acre) and 50 drops/cm^2.

5. Foliage protection on balsam fir was achieved with a 4.5 percent Orthene solution applied at 4.34 l/ha (0.5 gpa) giving a deposit of at least 0.14 kg/ha (2.0 oz AI/acre) and a droplet density of more than 55 drops/cm^2.

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