

THE EFFICACY OF AERIALY APPLIED MATACIL® TO CONTROL SPRUCE BUDWORM

*CHORISTONEURA FUMIFERANA* (CLEM.) IN BATHURST, NEW BRUNSWICK

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Cette publication est aussi disponible en français sous le titre *Efficacité de la pulvérisation aérienne de Natarol® pour contrôler la teneuse des bourgeons de l'épinette* (*Choristoneura pinifera* (Olem.) à Sault Ste. Marie, au Nouveau-Brunswick.

#### ABSTRACT

Two Matacil® (Aminocarb) formulations were applied aerially, by a Cessna® 188B Ag-truck aircraft, as double applications. They were sprayed at 70 g A.I. in 1.5L total mix/ha to control spruce budworm, *Choristoneura fumiferana* (Clem.). Matacil 180F flowable insecticide was applied in both water and insecticide diluent ID585 while Matacil 1.8D oil soluble concentrate (OSC) was sprayed in ID585 and Sunspray® 6N oil. Atlox® 3409F, which was used as an emulsifier in the aqueous Matacil mixes, was also applied as a treatment at 0.04L in 1.5L total aqueous mix/ha to investigate its insecticidal activity.

Spray deposit recorded on ground level sample units showed that aqueous 180F deposited more sparsely ( $<2.0$  drops/cm<sup>2</sup> and 0.07 L/ha) than either of the oil sprays. Volume Median Diameters (VMD) and Number Median Diameters (NMD) from both aqueous and oil mixes were  $<100$   $\mu$ m. Less than 0.35 drops/cm<sup>2</sup> and  $<0.003$  L/ha of the Atlox sprays were recovered at ground level. Eighty-nine to ninety-four percent larval mortality were recorded in the aqueous Matacil 180F blocks and 72-83% in the areas sprayed with 180F in ID585. Defoliations in those treatment areas were 13.3-14.5 and 12.9-13.5% respectively. Larval reductions of 88% and 91% were recorded in the blocks treated with Matacil 1.8D in ID585 and Sunspray 6N respectively. The former experienced 8.7-19.9% defoliation and the latter 26%. There was 1.0% larval reduction and 56% defoliation in the Atlox treated block.

Matacil 180F sprayed in water or ID585 was as efficacious in controlling spruce budworm, as Matacil OSC applied in ID585 or Sunspray 6N; and Atlox 3409F was not toxic to spruce budworm.

#### RÉSUMÉ

Deux préparations de Matacil (aminocarbe) ont été pulvérisées du haut des airs par Cessna 188B Ag-truck, en double application à raison de 70 g d'ingrédient actif dans 1,5 L par hectare, contre la tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana* [Clem.]). Le Matacil fluide 180F a été utilisé en mélange dans l'eau et du diluant 585 (D585) tandis que le concentré oléosoluble Matacil 1.8D l'a été dans du D585 et de l'huile Sunspray 6N. L'émulsifiant Atlox 3409F des mélanges aqueux de Matacil, a également été pulvérisé à raison de 0,04 L dans un mélange aqueux de 1,5 L par hectare en vue d'en étudier l'action insecticide.

Les dépôts observés au sol ont montré que le Matacil 180F en préparation aqueuse s'est dispersé plus ( $<2,0$  gouttes/cm<sup>2</sup> et 0,07 L/ha) que les pulvérisations huileuses. Le diamètre moyen en volume et le diamètre moyen en nombre des mélanges aqueux et huileux étaient inférieurs à 100  $\mu$ m. Moins de 0,35 goutte/cm<sup>2</sup> et 0,003 L/ha des pulvérisations d'Atlox a été retrouvé au sol. On a enregistré des taux de mortalité de 89 à 94% chez les larves des blocs traités au Matacil 180F aqueux, et de 72 à 83% chez celles des blocs traités au Matacil 180F + D585. Les taux de défoliation dans les zones traitées étaient de 13,3 à 14,5% et de 12,9 à 13,5% respectivement. On a enregistré plus de 88% de réduction de larves dans les blocs traités au Matacil 1.8D + D585 et plus de 91%, dans les blocs traités au Matacil 1.8D + Sunspray 6N. Dans le premier cas, la défoliation était de 8,7 à 19,9% et dans le second, de 26%. Dans le bloc traité à l'Atlox, la diminution des larves était de 1% et la défoliation de 56%.

Le Matacil 180F pulvérisé dans l'eau ou le D585 a agi aussi efficacement contre la tordeuse que le concentré oléosoluble plus D585 ou Sunspray 6N; l'Atlox 3409F n'était pas toxique pour la tordeuse.



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# TABLE OF CONTENTS

	Page
ABSTRACT . . . . .	(i)
RÉSUMÉ . . . . .	(i)
ACKNOWLEDGMENTS . . . . .	(ii)
LIST OF TABLES . . . . .	(iii)
LIST OF FIGURES . . . . .	(v)
INTRODUCTION . . . . .	1
MATERIALS AND METHODS . . . . .	1
<i>Site, Experimental Design and Block Establishment</i> . . . . .	1
<i>Pesticide Formulations and Tank Mixes</i> . . . . .	5
<i>Aircraft Parameters</i> . . . . .	6
<i>Meteorological Monitoring</i> . . . . .	6
<i>Communication</i> . . . . .	9
<i>Spray Application</i> . . . . .	9
<i>Spray Assessment</i> . . . . .	9
Assessment on Artificial Media . . . . .	9
Assessment of Foliage and Insects . . . . .	10
Analysis of Foliage and Insects . . . . .	11
<i>Biological Assessment</i> . . . . .	11
Larval Sampling . . . . .	11
Assessing Population Reduction . . . . .	11
Arthropod Knockdown . . . . .	12
Assessing Defoliation . . . . .	12
RESULTS AND DISCUSSION . . . . .	12
<i>Chemical Spray</i> . . . . .	12
Mixing . . . . .	12
Spray Deposit . . . . .	12
Residue on Foliage & Insects . . . . .	15
<i>Biological</i> . . . . .	15
<i>Percent Population Mortality</i> . . . . .	26
<i>Arthropod Knockdown</i> . . . . .	26
<i>Defoliation</i> . . . . .	28
<i>Spray Deposit-Spruce Budworm Relationships</i> . . . . .	28
CONCLUSIONS . . . . .	29
REFERENCES . . . . .	33

# LIST OF TABLES

TABLE		Page
I	Experimental site characteristics (Bathurst, N.B. 1981) . . .	5
II	Summary of spray formulations (Bathurst, N.B. 1981) . . . . .	6
IIIa	A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981) . . . . .	7
IIIb	A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981) . . . . .	8
IV	Bud development prior to the first spray. Bathurst, N.B. 1981	9
V	Spruce budworm population (larval instar expressed as a percent) sampled prior to the 1 <sup>st</sup> and 2 <sup>nd</sup> sprays (Bathurst, N.B. 1981) . . . . .	10
VI	Summarized Matacil and Atlox ground level deposits (Bathurst, N.B. 1981) . . . . .	16
VII	Aminocarb residue on foliage, Bathurst, N.B. 1981 . . . . .	17
VIII	Larval spruce budworm population density on balsam fir <i>A. Balsamea</i> (Bathurst, N.B. 1981) . . . . .	18
IX	Larval spruce budworm population density on white spruce <i>P. glauca</i> (Bathurst, N.B. 1981) . . . . .	19
X	Larval spruce budworm population density on red spruce <i>P. rubens</i> (Bathurst, N.B. 1981) . . . . .	20
XI	Larval spruce budworm density on combined species <i>A. balsamea</i> , <i>P. glauca</i> , and <i>P. rubens</i> (Bathurst, N.B. 1981) . . . . .	21
XII	Larval spruce budworm population reduction and host tree defoliation on balsam fir <i>A. balsamea</i> (Bathurst, N.B. 1981) .	22
XIII	Larval spruce budworm population reduction and host tree defoliation on white spruce <i>P. glauca</i> (Bathurst, N.B. 1981) . . . . .	23

# LIST OF TABLES (concl'd)

TABLE		Page
XIV	Larval spruce budworm population reduction and host tree defoliation on red spruce <i>P. rubens</i> (Bathurst, N.B. 1981) . .	24
XV	Larval spruce budworm population reduction and host tree defoliation on combined species <i>A. balsamea</i> , <i>P. glauca</i> , and <i>P. rubens</i> (Bathurst, N.B. 1981) . . . . .	25
XVI	Spiders knocked down on three Matacil blocks (Bathurst, N.B. 1981) . . . . .	29
XVII	Droplet density and spruce budworm mortality on balsam fir <i>A. balsamea</i> (Bathurst, N.B. 1981) . . . . .	30
XVIII	Droplet density and spruce budworm mortality on white spruce <i>P. glauca</i> (Bathurst, N.B. 1981) . . . . .	31
XIX	Droplet density and spruce budworm mortality on red spruce <i>P. rubens</i> (Bathurst, N.B. 1981) . . . . .	32



# LIST OF FIGURES

FIGURE		Page
1	The Aminocarb experimental research site near Bathurst, N.B. showing (1) to (9) the spray blocks and (c) the unsprayed check area (1981) . . . . .	2
2	Design of experimental block showing location of sample lines, marker balloons, hypothetical sample tree position and preferred wind direction . . . . .	3
3	Distribution of sample trees in spray blocks . . . . .	4
4	Diagram of the drop tray to collect dislodged spruce budworm . . . . .	13
5	Defoliation assessment method showing damage classes, class limits (as percent defoliation) and class means (in brackets). Modification of Fettes' Method (1950) . . .	14
6	Number of dead (A) and live (B) spruce budworm collected prior to and after Matacil sprays . . . . .	27



## INTRODUCTION

Matacil® [Aminocarb; 4-(Dimethylamino)-3 methylphenol methyl-carbamate]<sup>1</sup> has been used experimentally and operationally in forests in Canada and the United States since 1967. This insecticide was first used in forests as an emulsifiable concentrate (EC) (Randall 1967), and later as an oil soluble concentrate (OSC) with a phenolic emulsifier incorporated into the formulation. This latter formulation was credited with repeated successes in controlling larval populations of the eastern spruce budworm *Choristoneura fumiferana* (Clem.)<sup>2</sup>, especially in eastern Canada. In 1978 concern was voiced about the aquatic toxicity of nonylphenol, the primary solvent cum emulsifier in the OSC formulation. This concern stimulated research into more acceptable formulations of Matacil.

In 1980 a new "flowable" or suspension concentrate (SC) formulation, Matacil 18CF, was tested in the laboratory at the Forest Pest Management Institute (FPMI). This showed toxicity to budworm which was similar to the old formulations. (Pers. Comm. P.C. Nigam, B.V. Helson).

This research was conducted to determine (1) if the flowable Matacil sprayed aerially in both water and oil was as efficacious as the old nonylphenol OSC formulation sprayed in oil, and (2) if and by how much does Atlox 340F®<sup>3</sup>, an exogenous emulsifier in the aqueous tank-formulations of the flowable, contribute to the insecticide's toxicity to budworm.

<sup>1</sup>Supplied by Chemagro Ltd. Mississauga, Ont., Canada.

<sup>2</sup>Lepidoptera: Tortricidae.

<sup>3</sup>Supplied by Atlas Chemicals Industries, Brantford, Ont.

## MATERIALS AND METHODS

### Site, Experimental Design and Block Establishment

The trials were conducted in Gloucester County, approximately 25 km southwest of the city of Bathurst, New Brunswick, Canada. The experimental area was bounded by 65°30'W, 66°30'W longitude and 47°15'N, 47°35'N latitude (Fig. 1). The treatment blocks, measuring 0.5 x 1.0 km (50 ha), were situated in comparatively flat, mature forests comprised of various combinations of balsam fir, *Abies balsamea* (L.) Mill., spruce *Picea* spp. and hardwoods. Each block was aligned in relation to a road and the boundaries were defined with balloons as illustrated in Figure 2. Two transects were cleared across each block. These lines were divided into 33 equal segments and 25-30 sample trees were selected within easy reach of the line (Fig. 3). The sample trees were marked with a fluorescent orange cloth cross-punched into the tree cambium. Trees, particularly those which neighbored the sample trees, were judiciously removed to create discrete canopy openings and ground clearings approximately 7-8 m in diameter. The openings facilitated relatively unrestricted movement of spray droplets in the vicinity of the sample tree, thus improving droplet deposition onto the tree itself as well as at the forest floor level.

An area which was not surveyed in the regular rectangular configuration was established as an untreated check block and was left undisturbed so that the larval population dynamics of *C. fumiferana*, affected by factors other than insecticidal treatments, could be measured and recorded.

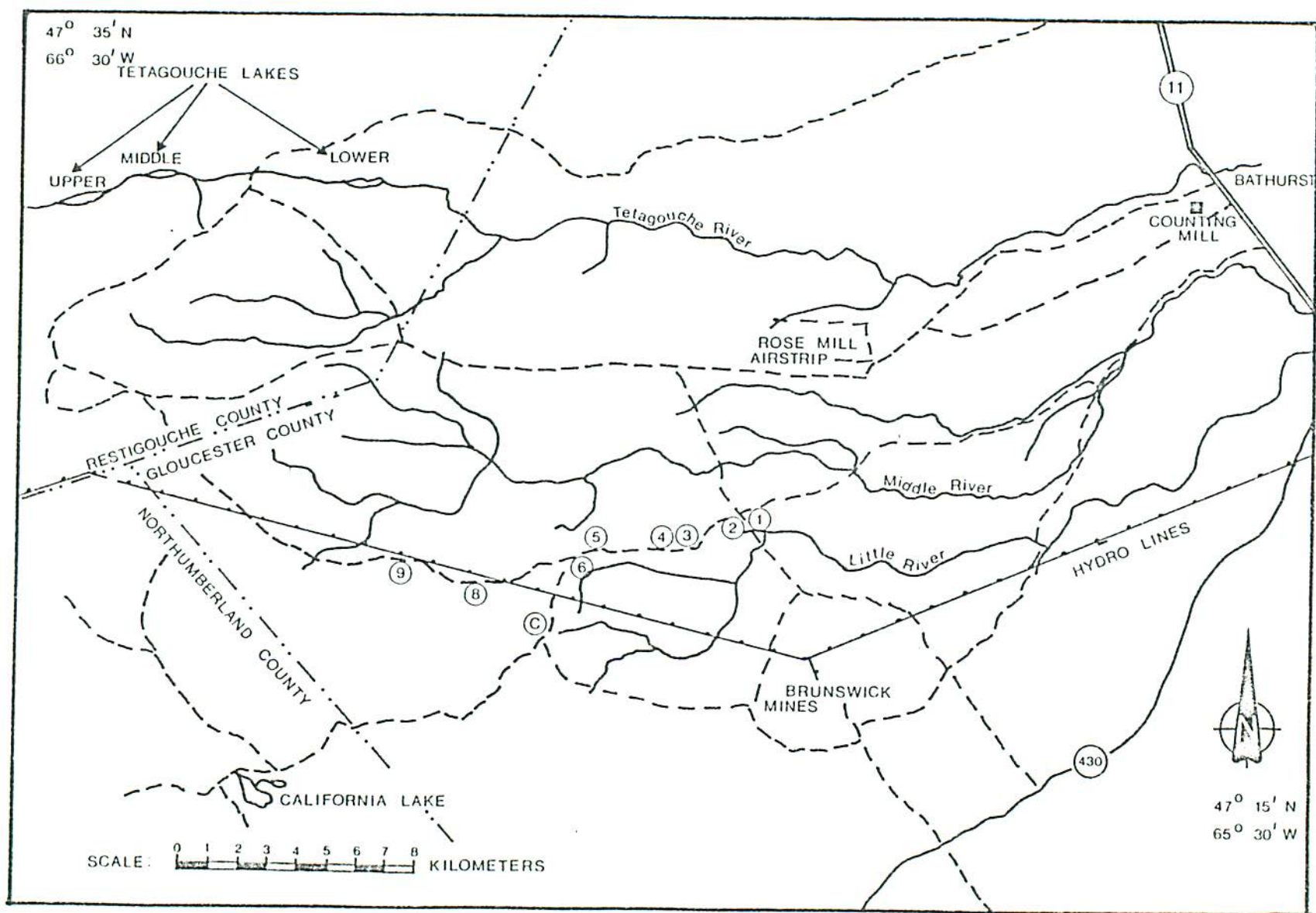


Fig. 1. The aminocarb experimental research site near Bathurst, N.B. showing ( 1-9 ) the spray blocks and C , the unsprayed check area. (1981)



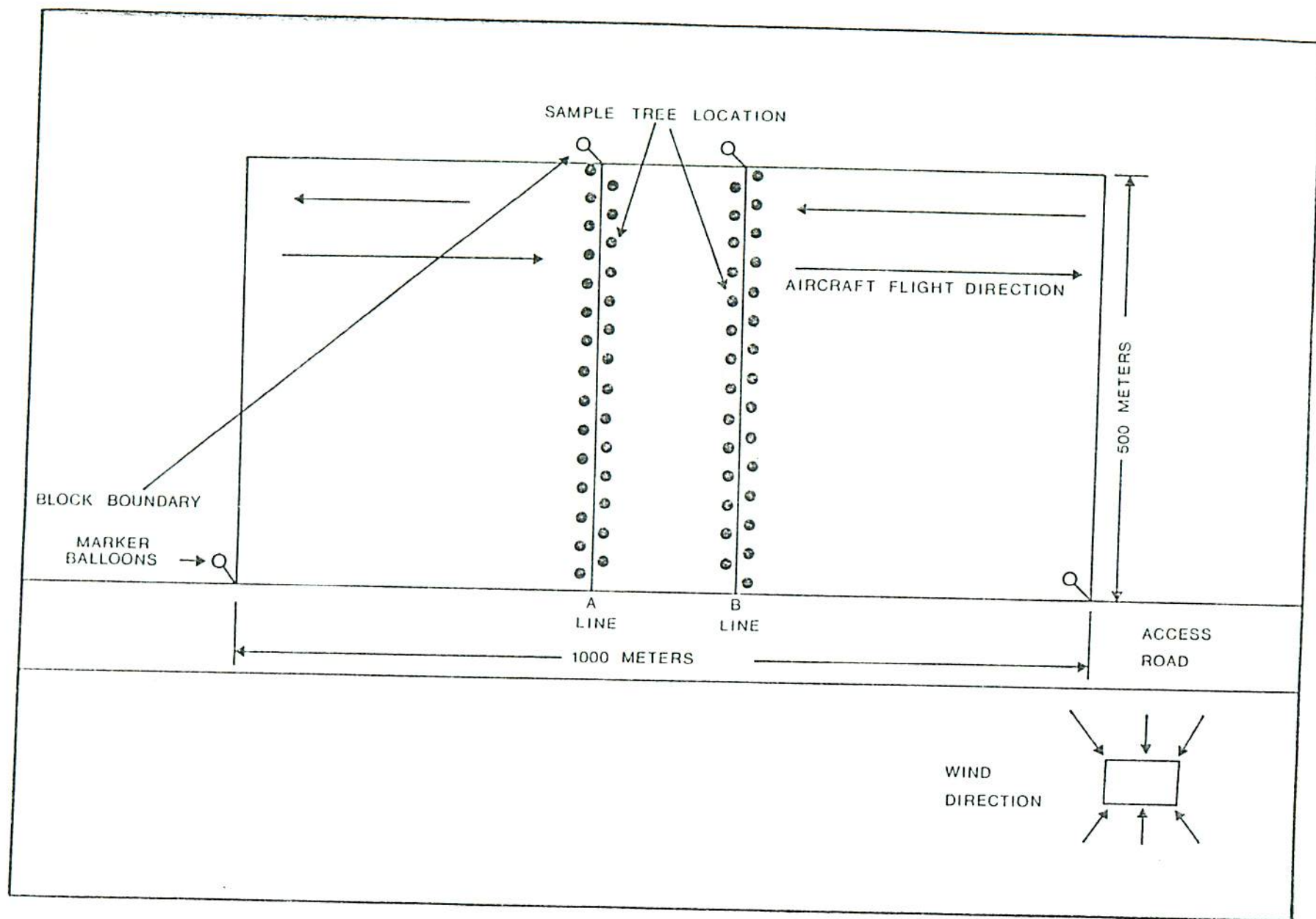


Fig. 2. Design of experimental block, showing location of sample lines, marker balloons, hypothetical sample tree position and preferred wind direction.

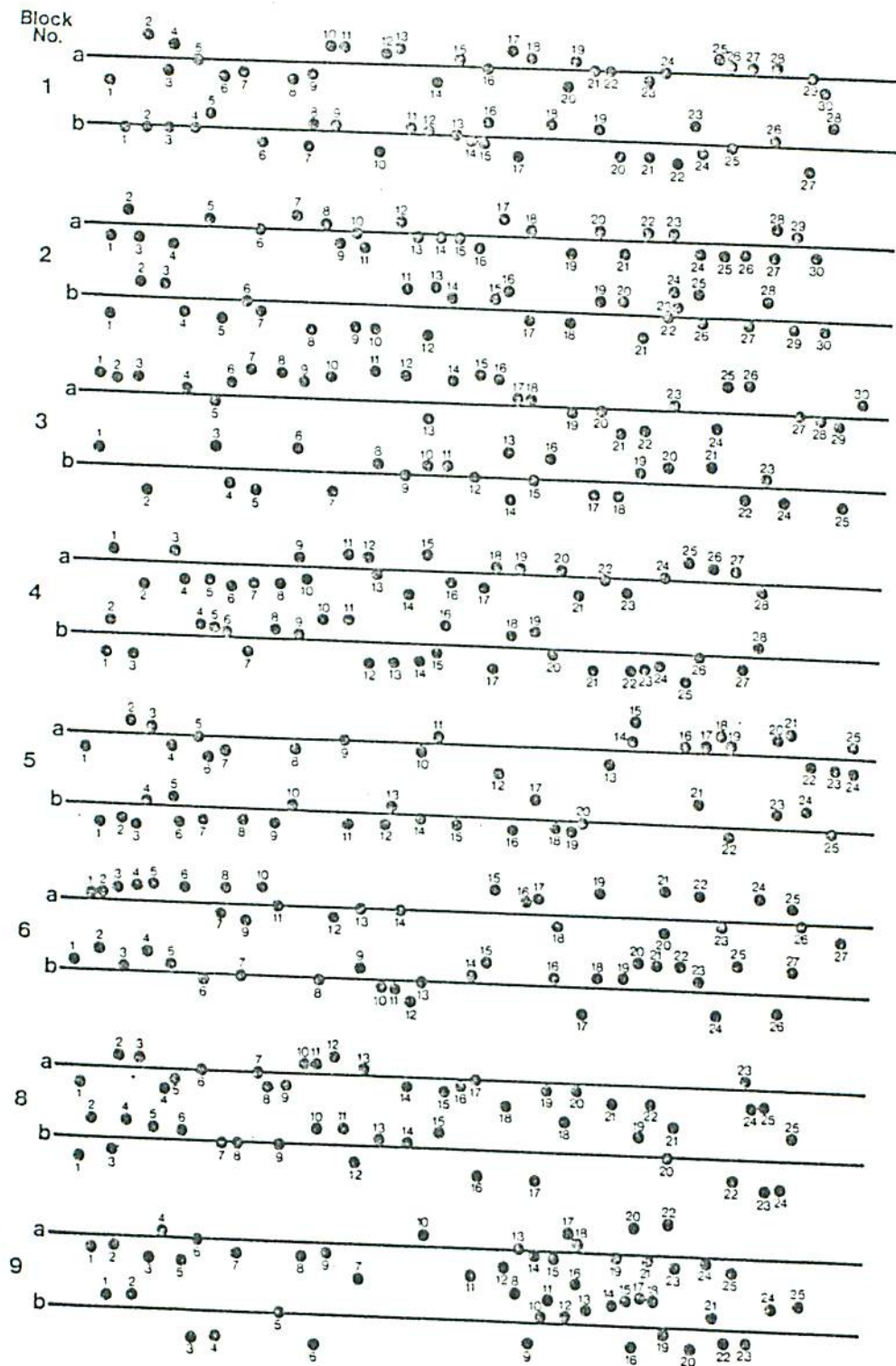


Fig. 3. Distribution of sample trees in spray blocks.



Forest stand characteristics of the blocks are presented in Table I.

#### Pesticide Formulations and Tank Mixes

Two different formulations of Matacil and one of Atlox 3409F were applied as treatments.

Matacil® 180F, flowable insecticide consists of very fine Aminocarb Technical particles suspended with special additives in an oil and contains 180 g (AI) litre<sup>-1</sup>. Matacil® 1.8D is an oil soluble concentrate (OSC), which contains 1.8 lbs AI U.S. gallon<sup>-1</sup> and nonylphenol as a primary solvent. These metric and imperial AIs are equivalent.

Table I. Experimental site characteristics (Bathurst, N.B. 1981)

Block	Treatment*	Species Composition		Transect	Number of Trees per Transect			Sample Tree Characteristics			
		Conifer %	Hardwood %		Balsam fir	White spruce	Red spruce	Tree Height		Diameter at 1.3 Metres	
								m X̄ ± S.D.	cm X̄ ± S.D.		
1	180F + H <sub>2</sub> O + Atlox	70	30	A	23	5	2	15.20	1.82	25.90	5.86
				B	20	0	8	14.36	2.84	24.68	5.05
2	180F + H <sub>2</sub> O + Atlox	85	15	A	28	0	2	13.39	1.80	22.97	4.53
				B	29	0	1	13.69	2.06	23.93	4.66
3	180F + ID585	50	50	A	16	14	0	15.03	2.12	26.06	6.66
				B	23	0	2	13.28	2.63	21.33	5.52
4	180F + ID585	65	35	A	16	5	7	14.46	2.13	26.54	6.18
				B	18	7	3	13.82	1.16	23.60	3.56
5	1.8D + GN	60	40	A	16	4	5	13.17	1.39	21.62	5.71
				B	17	8	0	13.16	1.64	21.72	6.27
6	1.8D + GN	80	20	A	21	1	5	13.73	2.23	22.07	4.72
				B	19	2	6	13.21	2.56	21.66	4.44
8	1.8D + ID585	50	50	A	17	5	3	13.83	1.74	22.67	5.08
				B	17	5	3	13.52	1.12	22.89	6.18
9	Atlox + H <sub>2</sub> O	50	50	A	15	4	6	13.22	1.88	24.59	6.70
				B	15	6	4	13.89	1.58	23.36	6.35
Check	Untreated	90	10	-	30	15	15	13.06	1.60	22.27	3.71

\*Matacil for blocks 1 to 8.

Atlox 3409F is a polyoxylene derivative and is used widely as an emulsifying agent in paints throughout North America.

Matacil 180F was mixed for application both in water and in insecticide diluent (I.D.) 585 in proportions as listed in Table II. Atlox was added as an emulsifier only to the aqueous solutions. Because Matacil tends to be unstable in highly alkaline media, care was taken to ensure that the solvent's pH was between 6.5-7.0. Matacil

Table II. Summary of spray formulations (Bathurst, N.B. 1981)

Block No.s	Insecticide Formulation		Volume	
			L/ha	%
1 & 2	Matacil 180F Atlox 3409F Water Rhodamine B Red Dye	*		
		a	0.389	25.9
		b	0.020	1.3
		c	1.083	72.3
3 & 4	Matacil 180F Shell ID585 Automate B Red Dye	d	0.008	0.5
		b	0.389	25.9
		a	1.081	72.1
		c	0.030	2.0
5 & 6	Matacil 180F Sunspray 6N Automate B Red Dye	b	0.389	25.9
		a	1.081	72.1
		c	0.030	2.0
8	Matacil 1.8D Shell ID585 Automate B Red Dye	b	0.389	25.9
		a	1.081	72.1
		c	0.030	2.0
9	Atlox 3409F Water Rhodamine B Red Dye	a	0.044	2.9
		b	1.448	96.6
		c	0.008	0.5

\*Ingredients mixed in alphabetical order.

1.8D was mixed in Sunspray® 6-N oil<sup>4</sup> and in I.D. 585 while Atlox as a treatment was mixed in water alone.

These mixes were dyed; the oil solutions with Automate® "B" red dye<sup>5</sup> and the aqueous ones with Rhodamine® "B" red dye<sup>6</sup> in order to facilitate spray deposit assessment.

In the insecticidal sprays all Matacil treatments were applied at 70.0 g (AI)/ha and Atlox at 0.04 L/ha. Application volumes for all treatments were 1.5 L/ha. A summary of these tank mix data is shown in Table II.

#### Aircraft Parameters

The treatments were applied by a Cessna 188 Ag-truck fitted with four AU 3000 Micro-nair atomizers.<sup>7</sup> The rate of flow was controlled to emit a total of 23.5 L/min and a calculated swath width of approximately 60 meters. The aircraft flew at 160 km/hr and about 15-17 m above the tree canopy. Airport facilities were provided at South Tetagouche (Fig. 1), which is approximately 6 minutes ferrying time from the experimental site. The flight lines of the aircraft during spray were generally perpendicular to the prevailing wind (Fig. 2). Data relevant to the aircraft are presented in Tables IIIa and IIIb.

#### Meteorological Monitoring

Weather is a very influential variable in determining the effectiveness of a compound in the field. Because the researcher has no direct control over these elements, weather conditions during the trials were monitored and the data used to determine suitable spray conditions and in explaining aspects of the results.

<sup>4</sup>Supplied by Sunoco Inc., Toronto.

<sup>5</sup>Supplied by Morton William Chemical Ajax, Ontario.

<sup>6</sup>Supplied by C.I.L. Willowdale, Ont.

<sup>7</sup>Supplied by Micronair (Aerial Ltd., Sandown, Isle of Wight, England).



Table IIIa. A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981)

	Block 1 and 2		Block 3 and 4		Block 5 and 6							
	1st applic.	2nd applic.	1st applic.	2nd applic.	1st applic.	2nd applic.						
Date	12-06-81	18-06-81	12-06-81	18-06-81	13-06-81	18-06-81						
Time (hrs)	1940	0620	2100	0715	2010	2015						
Insecticide	Matacil 180F		Matacil 180F		Matacil 1.8 OSC							
Active ingredient												
(g/ha)	70		70		70							
Solvent	H <sub>2</sub> O		*Shell I.D. 585 oil		Sunspray 6N oil							
Block size (ha)	50		50		50							
Aircraft												
Type	Cessna 188 Ag Truck		Cessna 188 Ag Truck		Cessna 188 Ag Truck							
Speed km/h	160		160		160							
Applic. height (m)	29-31	27	24	27-30	27-30	27-30						
Applic. equipment	(4) Micronair AU 3000		(4) Micronair AU 3000		(4) Micronair Au 3000							
Emission rate												
(L/min)	23.5		23.5		23.5							
Applic. rate												
(L/ha)	1.5		1.5		1.5							
Blade angle	25°		25°		25°							
Blade rpm	Maximum		Maximum		Maximum							
	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Weather												
Temp. °C (mean)	13.00	10.25	13.00	10.75	10.00	13.75	10.00	13.75	16.50	22.25	17.25	20.75
RH % (mean)	80	100	83	96	96	73	96	73	73	58	69	56
Wind speed												
( $\bar{X}$ km/h)	0.5	1.0	0.5	2.0	0.5	5.0	0.5	5.0	0.5	1.5	0.5	1.0
Wind direction	E	W	E	SW-W	E	W	E	W	SE-SW	W	SE-S	W
Stability**	↓	↓	↓	↓	←→	↓	←→	↓	↓	↓	↓	↓
Cloud cover	1/10	0/10	1/10	1/10	0/10	0/10	0/10	1/10	0/10	0/10	0/10	0/10

\*I.D.--Insecticide diluent.

\*\*I--Inversion.

†--Lapse.

←→--Neutral (isothermic).

Table IIIb. A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981)

	Block 8		Block 9	
	1st applic.	2nd applic.	1st applic.	2nd applic.
Date	16-06-81	19-06-81	15-06-81	19-06-81
Time (hrs)	0600	0715	2020	0600
Insecticide	Matacil 1.8 OSC		Atlox 3409F	
Volume Active				
Ingredient (g/ha)	70			
Solvent	Shell I.D. 585*		H <sub>2</sub> O	
Plot size (ha)	50		50	
Aircraft				
Type	Cessna 188 Ag-Truck		Cessna 188 Ag-Truck	
Speed (Km/h)	160		160	
Applic. height (m)	27	24-27	27-30	24
Applic. equipment	(4) Micronair AU 3000		(4) Micronair AU 3000	
Emission rate				
(L/min.)	23.5-24.2	23.5	23.5	23.5
Applic. rate				
(L/ha)	1.5		1.5	
Blade angle	25°		25°	
Blade rpm	Maximum		Maximum	
Weather				
Temp. °C (mean)	10.0	18.0	12.5	13.75
RH% (mean)	80	87	77	85
Wind speed				
( $\bar{X}$ Km/h)	0.50	1.0	0.50	< 0.5
Wind direction	S-SW	W-NW	SE-S	SW
Stability*	↑	↓	↑	↓
Cloud cover	10/10	0/10	10/10	0/10

\*I.D.--Insecticide diluent.

\*\* ↓ --Inversion.

↑ --lapse.

↔ --Neutral (isothermic).

The meteorological data were collected by an assembly of nonrecording instruments. A Heathkit weather computer model I.D. 4001 was the central instrument displaying digital readouts, which were manually recorded at 5-minute intervals. An anemometer/vane

to measure wind velocity and direction was attached to the top of a 12.8 m mast, and temperature probes were fitted at the 12.6 m and 2.0 m levels to determine the atmospheric stability. Wet and dry bulb temperature readings, from which relative humidities



were calculated were obtained from a motor psychrometer. These instruments and equipment were fitted onto a vehicle, and maneuvered to locations nearest the test block where meteorological conditions could be considered representative of those in the block. Weather conditions were monitored from 1.5 h prior to each spray until 1 h after. Tables IIIa and IIIb summarize the data obtained from the weather monitoring.

#### Communication

A radio network was established and contact was maintained between the airport and the base station, and the aircraft and mobile ground stations in the experimental blocks. Red colored helium filled balloons acted as the ground markers to define the block boundaries for the pilot (Fig. 2).

#### Spray Application

There is an intimate synchrony between the phenological development of the host tree and the development of budworm (Blais 1957). Each host species develops at a different rate and so do the budworm on it. Feeding responses and mobility of budworm and eventually accessibility with insecticides are related to the phenological development of buds, thus the timing of the initial sprays is critical if the most effective response is to be achieved.

The timing of the first spray during this study was based on a quantitative assessment of the bud development of the major tree species within 4 blocks. On the first application date (81-06-12) the buds on white spruce, *Picea glauca* (Moench) Voss, and balsam fir were fully flared and shoot growth from pooled samples measured  $\bar{X} = 2.8$  cm ( $n = 379$ ) and  $\bar{X} = 2.2$  cm ( $n = 382$ ) respectively. The second spray was applied (Table III) primarily to replenish the aminocarb of the first, which after approximately 3-4 days began to dissipate. Table IV shows the shoot development in the 4

individual blocks; approximately 90% of the buds on red spruce were still tightly closed. Larval development at that time is shown in Table V.

Table IV. Bud development prior to the first spray. Bathurst, N.B. 1981

Treatment block	Tree Species*	Mean Shoot Length ± S.D. (cm)
1	Sw	2.70 ± 0.75
	Bf	1.66 ± 0.40
2	Sw	3.60 ± 1.30
	Sr	0.76 ± 0.25
	Bf	2.30 ± 0.57
3	Sw	2.60 ± 0.77
	Sr	0.63 ± 0.19
	Bf	1.70 ± 0.35
4	Sw	2.46 ± 0.84
	Sr	0.94 ± 1.25
	Bf	3.00 ± 0.80

\*Sw: White spruce; Sr: red spruce; Bf: balsam fir.

#### Spray Assessment

##### Assessment on Artificial Media.

To assess the spray efficiency of the various formulations and tank mixes a sampling unit comprised of a Kromekote® card (10 x 10 cm) and two glass slides (5.0 x 7.5 cm), as described by Randall (1980), was placed in the clearing adjacent to each sample tree. These units were placed approximately 30 min before the spray and retrieved approximately 50 min after its completion. The cards and slides were stored in dry, dark conditions prior to evaluation. The cards were sent to the

Table V. Spruce budworm populations (larval instar expressed as a percent) sampled prior to the 1<sup>st</sup> and 2<sup>nd</sup> sprays.  
(Bathurst, N.B. 1981)

Block	Sampling Date	Instar						
		2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	Pre-pupa	Pupa
Bk 1	June 12	2.3	30.6	36.7	23.5	6.9	0.0	0.0
	June 18	0.0	14.8	30.1	17.5	36.6	0.7	0.2
Bk 2	June 12	8.5	35.5	33.6	15.6	6.7	0.0	0.0
	June 18	0.8	20.5	31.4	19.2	28.1	0.0	0.0
Bk 3	June 12	7.5	30.7	28.1	14.4	19.4	0.0	0.0
	June 18	0.0	16.1	20.8	19.4	41.4	0.7	1.5
Bk 4	June 12	1.9	22.3	25.2	23.7	26.5	0.4	0.0
	June 18	0.0	11.5	17.3	26.5	42.8	0.8	1.0
Bk 5	June 13	4.7	32.5	33.6	13.7	15.6	0.0	0.0
	June 18	0.0	5.3	26.6	29.9	38.2	0.0	0.0
Bk 6	June 13	3.1	29.7	34.5	18.2	14.5	0.0	0.0
	June 18	0.0	10.2	24.9	34.4	30.5	0.0	0.0
Bk 8	June 16	1.1	16.4	24.9	21.2	36.4	0.0	0.0
	June 19	0.0	4.0	18.1	23.0	54.5	0.1	0.3
Bk 9	June 16	0.5	9.2	22.2	23.4	44.7	0.0	0.0
	June 19	0.0	2.2	12.6	22.0	62.4	0.3	0.5

National Aeronautical Establishment, Ottawa, Canada where they were analyzed by a Flying Spot Scanner (Drummond 1980) and the droplet density and other characteristics of the spray spectra were determined.

In the laboratory at FPMI each glass slide was washed with an appropriate solvent; i.e., Toluene with the oil mixes and absolute alcohol with the aqueous ones. Colorimetric analysis of the dye content was performed using a Bausch and Lomb spectronic 100 Spectrophotometer.

Thus a quantitative (number of drops and volume of insecticide) as well as a qualitative (types of drops) assessment of the spray recovered at ground level were obtained.

#### Assessment of Foliage and Insects.

Host tree foliage and insects were investigated for residual aminocarb, which also gave a quantitative assessment of the spray which was deposited in the budworm's



feeding habitat. After the sampling units were retrieved from the blocks sprayed with the two Matacil formulations, in three different carriers, foliage was taken randomly from the midcrown of 10 trees in each treatment. Approximately 20 g of new growth was snipped with scissors and, without being handled, allowed to fall into amber colored bottles. The bottles were wrapped in aluminum foil and placed in a Thermos® picnic cooler half filled with ice. Approximately 10 g of budworm were removed from sample branches with #0 camel hair brushes and placed into identical bottles. The bottles were wrapped in aluminum foil and stored as described above. These foliage and insect samples were dispatched to New Brunswick Research and Productivity Council (RPC), Fredericton where they were analyzed.

#### Analysis of Foliage and Insects.

Analysis was carried out at RPC following the procedure of K.M.S. Sundaram *et al.* (1976) except that no derivitization of the Aminocarb was undertaken. Aminocarb was analyzed on a Hewlett-Packard Model 5830A gas chromatograph fitted with a flame-ionization detector. The column used was a glass 2 m x 2 mm 3% SE 30 on Gas Chrom Q (800/100 mesh). Recoveries from foliage extracts fortified with Matacil at levels of 5.0, 2.5, 1.0, 0.25 and 0.125 µg/g levels averaged 100%. The minimum level of detection was 0.2 µg/g for a 10-g sample (P.J. Silk *et al.* pers. comm.).

#### Biological Assessment

##### Larval Sampling.

Samples consisting of two 46-cm branches, one each from the upper and midcrown areas, were taken from each sample tree. The branches were cut with pole pruners with attached baskets and lowered to the forest floor. Each branch was placed in a large (16.0-kg capacity) paper bag and stapled shut to prevent larval escape. The samples

were taken to a counting mill at the field laboratory in Bathurst. The number of viable buds was counted and the living spruce budworm larvae were removed by beating the flushed shoot as described by Martineau and Benoit (1973) or by dissecting the buds which were still closed. In the prespray counts the needles were also closely examined under 100W lamps to account for early instars which might have still been in mines.

#### Assessing Population Reduction.

Assessing the levels of spruce budworm population decline assists in determining the effects of the treatments. The populations in the blocks were assessed at each sampling date by calculating the number of larvae per bud and the number per 46-cm branch for each sample tree. These two methods were used primarily to determine which might be more suitable for future research use. The percent population reductions recorded in the treatment blocks were corrected for natural mortality using Abbott's formula (Abbott 1925):

$$100 (C-T)/C = \% \text{ corrected control}$$

where C = % living in the untreated block

T = % living in the treated block

During this study, as often happens in large-scale forest trials, unfavorable weather and logistical support prevented the simultaneous or synchronous sampling of treated and untreated blocks. Uniformity of experimental conditions is a presumed and accepted prerequisite when applying the correction formula, so it was necessary to accurately determine the larval densities in both the treated and untreated blocks on any particular sampling date. This was accomplished by using the seasonal population data and generating best-fit exponential decay curves for each block. From these curves it was then possible to extract population densities and compute C and T on given dates.



#### Arthropod Knockdown.

Trays, built as shown in Figure 4, were placed on the forest floor just on the drip circle of 10 trees in blocks #2, #4, #6 and the untreated check. The sheer acted like a net and immobilized the larvae and other small arthropods. Trays were placed prior to the sprays and monitored after them to investigate if the 'flowable' exhibited unusual knockdown of arthropods.

#### Assessing Defoliation.

After the budworm had pupated and the moths emerged two branch samples were taken from each sample tree as described above. These branches were evaluated, to determine to what extent defoliation had occurred, using Kettela's method (E. Kettela, pers. comm. 1981) which involved a component of Fettes' (1950) method. The shoots from the 46-cm branch were removed and pooled. From this pool, 100 shoots were assessed randomly. In cases where there were <100 shoots on a branch the entire pool was used. The damage on each shoot was assessed according to Fettes (1950). Six damage classes (Fig. 5) were used instead of 12 as recommended by Fettes (1950), as the authors agreed with Kettela (Pers. Comm.) that 12 classes introduced much more subjectivity than 6.

### RESULTS AND DISCUSSION

#### Chemical Spray

##### Mixing.

The Matacil flowable formulation mixed with both IDS85 and water without any problem. The workers experienced no unusual discomfort at the mixing site.

##### Spray Deposit.

As a carrier of insecticides in Canada, water has the advantages of being easily

available and inexpensive, but has the disadvantage of having a high propensity to evaporate in conditions of low relative humidity. This significantly affects the deposition of droplets. Droplet density and size spectra are important factors which influence the efficacy of aerially applied pesticides by determining adequate or inadequate coverage of the target.

In this study the droplet spectra and volume deposits resulting from both applications, measured on Kromekote cards at ground level, are shown in Table VI. These might be conservative assessments as the Flying Spot Scanner's analytical method could not detect droplet stains <30  $\mu$ m in diameter. The Matacil 180F aqueous mixes (Blocks 1 and 2) deposited <2.0 drops/cm<sup>2</sup> consistently for both applications whereas the oil mixes of both the Matacil flowable and 1.8D showed significantly ( $P = 0.05$ ) different mean droplet densities between the first and second applications. Aquecus 340F deposited <0.5 drops/cm<sup>2</sup> for both applications which represents the least deposit of all the treatments.

Deposits expressed as droplet density or as volume (L/ha) recovered, (as eluted from glass slides) are usually heterogeneous. The results from these trials show there was a significant difference in droplet density between the block transects for the first application only in blocks 6, 8 and 9. For the second application, significant differences between transects were observed in blocks 5 and 8. Differences in eluted volumes were recorded for the first application in blocks 3 and 8 and for the second application, in block 8 only. Some of these differences might have been due to the tank formulation but a forest is a very dynamic system and many other variables might also be responsible for them. Inter block differences are noted in Table VI.

Droplet size is usually expressed as volume median diameter (VMD), the droplet diameter



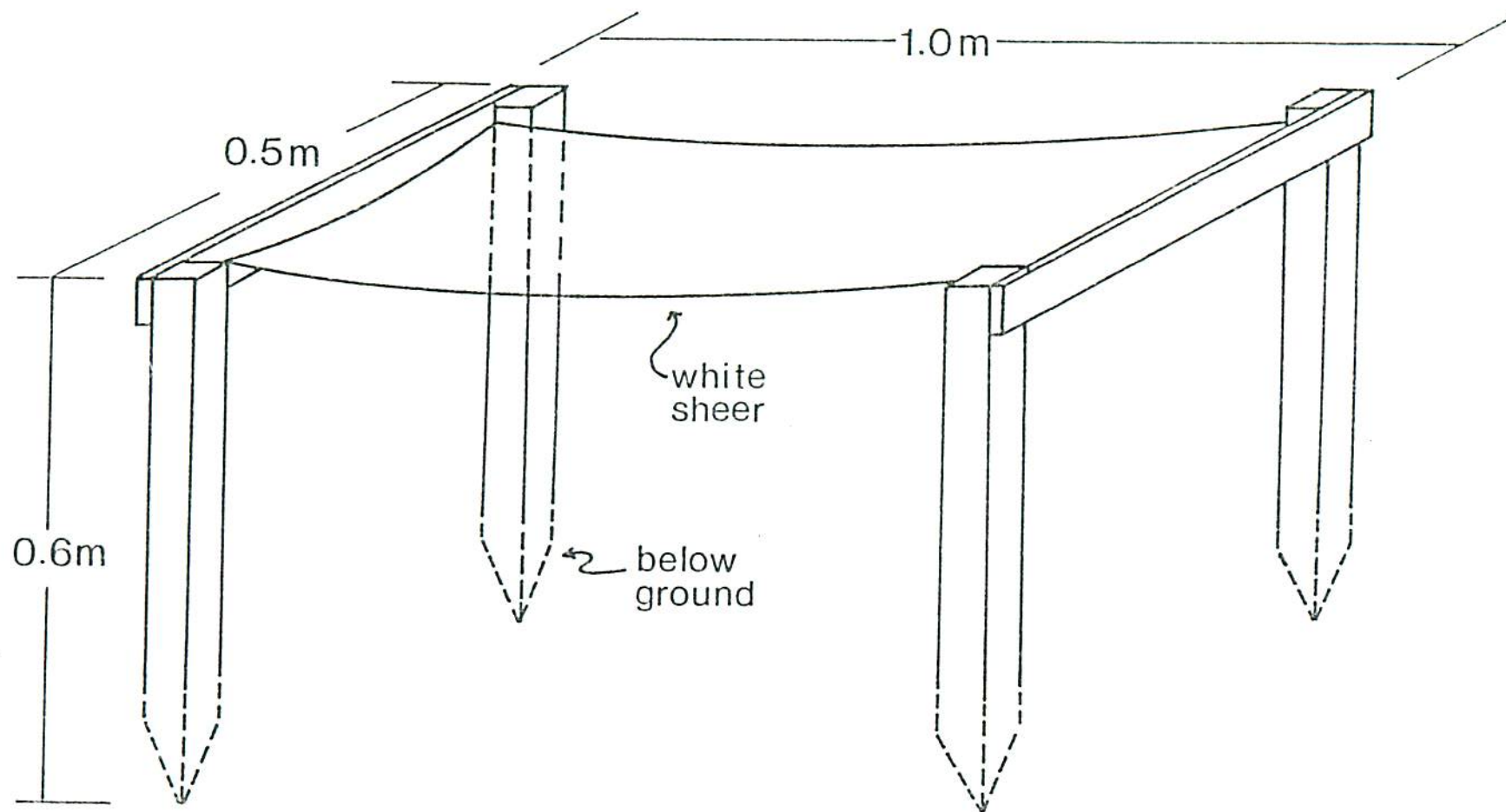


Fig. 4. Diagram of the drop tray to collect dislodged spruce budworm.






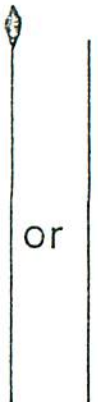
DEFOLIATION CLASS					
1	2	3	4	5	6
					
0 (0)	1 - 25 (12)	26 - 50 (37)	51 - 75 (62)	76 - 99 (87)	100 (100)

Fig. 5. Defoliation assessment method showing damage classes, class limits (as percent defoliation,) and class mean (in brackets.)  
-Modification of Fettes' Method (1950)

that divides the spray volume into two equal parts, i.e., 50% of the volume in droplets <VMD and 50% above it. A desirable insecticidal VMD for defoliating forest insects is considered generally to be <100  $\mu\text{m}$  (Himel & Moore 1967; Barry et al. 1977; Joyce & Spillman 1978). All the treatments of the first application produced VMDs in the 60-80  $\mu\text{m}$  range. In the second application, while VMDs for the Matacil 18CF in ID585 treatments remained in this range, those for 18CF in water increased to approximately 100  $\mu\text{m}$ . Matacil 1.8D in 6N oil produced a dense profile, consequently the Flying Spot Scanner had difficulty in analyzing what it considered "good droplets" on the cards. Thus no definitive size measurements of the droplets from these treatments were available. It was evident that the RH recorded at the times of the sprays (Tables IIIa and IIIb) influenced the evaporation and consequently the VMD, especially of the aqueous Matacil treatments (Table VI). Where the RH changed considerably the droplets of aqueous mixes responded accordingly; oil, however, did not appear to respond as sensitively even to significant changes in RH. The Atlox spray did not appear to react to small RH changes.

Although evaporation of aqueous droplets seems to be a liability, it might feasibly be manipulated to provide a desirable VMD. It is possible that by knowing or being able to predict the degree of evaporation which will occur it will be feasible to create the initial droplet size at the correct altitude which will ultimately deposit with optimum diameters.

#### Residue on Foliage & Insects.

The Aminocarb residues recovered from foliage in 4 treatment blocks are shown in Table VII. These values were calculated from deposits which ranged from nondetectable to 3.6  $\mu\text{g/g}$  foliage. Only balsam fir foliage had recoverable levels of deposit from both oil and aqueous treatments of Matacil. None of the samples of budworm,

comprising mainly dead and moribund larvae removed from sprayed foliage, had detectable levels of Matacil. This might possibly be because the AI which affected or killed larvae, irregardless of its mode of entry, was on a  $\mu\text{g/g}$  basis below detectable levels or the insects metabolized the AI (no tests were conducted for derivatives).

#### Biological

The effectiveness of insecticides sprayed against spruce budworm is usually assessed primarily by the postspray responses of the insect. These responses are normally measured by the degree of population decline and/or the extent of host tree defoliation. In these trials assessments were based on the insect responses on the three host species individually and as a combined unit. The phenological development of the three species differed substantially in the research area. Balsam fir and white spruce developed similarly and ~10 days earlier at the onset than red spruce. Since larval development is closely synchronized with host tree development (Blais 1957), the timing of pesticide applications tends to affect budworm populations differently in a multispecies complex than in a forest with a single species as its major component.

During this study the first spray applications coincided with substantial shoot development of the two major host species, balsam fir and white spruce (Table IV) and of the budworm larvae (Table V), thus potentially making the larvae more vulnerable to the spray deposit.

Spruce budworm densities influenced by the insecticide treatments are summarized in Tables VIII-XI. Tables XII and XV show how these influences are reflected when measured by percent mortality. Responses on balsam fir, white and red spruce are recorded in Tables VIII and XII, IX and XIII, and X and XIV respectively, while those based on the combined species are shown in Tables XI and



Table VI. Summarized Matacil and Atlox ground level deposits (Bathurst, N.B. 1981)

Block No.	Treatment	$\bar{Q}$	$\bar{Q}$ 1 <sup>st</sup> Appl.				2 <sup>nd</sup> Appl.				
		Drops/cm <sup>2</sup> $\bar{X} \pm \text{S.D.}$	Volumes L/ha $\bar{X} \pm \text{S.D.}$	NMD ( $\mu\text{m}$ )	VMD ( $\mu\text{m}$ )	D <sup>max</sup> ( $\mu\text{m}$ )	Drops/cm <sup>2</sup> $\bar{X} \pm \text{S.D.}$	Volumes L/ha $\bar{X} \pm \text{S.D.}$	NMD ( $\mu\text{m}$ )	VMD ( $\mu\text{m}$ )	D <sup>max</sup> ( $\mu\text{m}$ )
1	180F + water	1.76 $\pm$ 1.97 <sup>a</sup>	0.016 $\pm$ 0.020 <sup>a</sup>	50.4	61.1	142.2	1.20 $\pm$ 0.86 <sup>a</sup>	0.059 $\pm$ 0.043 <sup>a</sup>	95.1	99.2	168.9
2	180F + water	1.73 $\pm$ 1.93 <sup>a</sup>	0.017 $\pm$ 0.023 <sup>a</sup>	51.9	62.7	125.9	1.22 $\pm$ 1.34 <sup>a</sup>	0.062 $\pm$ 0.082 <sup>a</sup>	97.0	100.1	163.6
3	180F + ID585	5.20 $\pm$ 4.20 <sup>b</sup>	0.085 $\pm$ 0.112 <sup>b</sup>	58.9	78.6	141.6	0.88 $\pm$ 0.77 <sup>b</sup>	0.017 $\pm$ 0.014 <sup>b</sup>	66.6	77.6	122.1
4	180F + ID585	5.41 $\pm$ 5.47 <sup>b</sup>	0.075 $\pm$ 0.082 <sup>b</sup>	56.6	70.1	147.2	1.05 $\pm$ 1.03 <sup>b</sup>	0.017 $\pm$ 0.016 <sup>b</sup>	62.5	72.1	112.7
5	1.8D + 6N	3.81 $\pm$ 3.44 <sup>b</sup>	*	*	*	*	5.24 $\pm$ 5.00 <sup>c</sup>	*	*	*	*
6	1.8D + 6N	6.56 $\pm$ 5.85 <sup>c</sup>	*	*	*	*	11.11 $\pm$ 6.64 <sup>d</sup>	*	*	*	*
8	1.8D + ID585	4.61 $\pm$ 3.83 <sup>b</sup>	0.062 $\pm$ 0.056 <sup>b</sup>	57.9	70.9	146.5	0.77 $\pm$ 0.59 <sup>b</sup>	0.011 $\pm$ 0.008 <sup>c</sup>	61.8	67.4	155.8
9	Atlox 3402F + water	0.32 $\pm$ 0.27 <sup>d</sup>	0.002 $\pm$ 0.003 <sup>c</sup>	41.3	56.1	155.6	0.23 $\pm$ 0.15 <sup>e</sup>	0.002 $\pm$ 0.001 <sup>d</sup>	46.9	53.7	108.6

\*Incomplete analysis by flying spot scanner.

a-eFor each column only: means followed by unlike letters are significantly different at P = 0.05.



Table VII. Aminocarb residue on foliage, Bathurst, N.B. 1981

Block	Treatment	Host spp.	Date Sprayed	Date sampled	Aminocarb Deposit ( $\mu\text{g/g}$ ) $\bar{x} \pm \text{S.D.}$
1	Matacil 180F + water	Sw	12-06-81	12-06-81	N/D*
		Sr	12-06-81	12-06-81	$0.20 \pm 0.17$
		Bf	12-06-81	12-06-81	$1.38 \pm 1.62$
3	Matacil 180 + ID585	Sw	12-06-81	12-06-81	$0.30 \pm 0.22$
		Sr	12-06-81	12-06-81	$1.60 \pm 0.00$
		Bf	12-06-81	12-06-81	$0.94 \pm 1.28$
6	Matacil 1.8D + 6N oil	Sw	13-06-81	14-06-81	N/D
		Sr	13-06-81	14-06-81	$0.38 \pm 0.35$
		Bf	13-06-81	14-06-81	$0.68 \pm 0.59$
8	Matacil 1.8D + ID585	Sw	16-06-81	16-06-81	N/D*
		Sr	16-06-81	16-06-81	N/D*
		Bf	16-06-81	16-06-81	$0.20 \pm 0.12$
Check	Not sprayed	Sw	not sprayed	01-06-81	N/D*
		Bf	not sprayed	01-01-81	N/D*

\* nondetectable levels.

Sw White spruce.

Sr Red spruce.

Bf Balsam fir.

XV. The prespray budworm populations in the blocks assessed both on the per branch and the per bud (shoot) bases were moderate with white spruce having the highest larval density and red spruce the lowest. The populations on balsam fir were fairly representative of the combined species. The initial populations were lowest generally in blocks 3 and 4 and highest in the untreated check area.

Larval densities for combined species recorded 10-12 days after the 2nd spray application averaged  $<1.0$  insect/branch except in blocks 4 and 9 and the untreated check, and  $<4/100$  shoots in all blocks except 8, 9 and the check. These had residual larval densities exceeding 27 larvae/100 shoots (Table XI).

It became apparent when the tree species were assessed individually (Tables VIII-X) that low residual populations (per branch and per shoot) were left on balsam fir, except in block 9 and the check plot. Higher numbers of larvae appeared to survive on white spruce but this might have been due to the considerably higher prespray numbers found on this species. In a mixed coniferous stand red spruce characteristically seem to have much lower budworm populations. The data for the prespray populations in this study seem to support this (Table X); despite these low initial populations, the post spray residual densities on this species were still unacceptably high. It is likely that the sprays, though optimally timed for the other two host species, were

Table VIII. Larval spruce budworm population density on Balsam fir, *A. balsamea* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	Population Reduction								
				Prespray	1 <sup>st</sup> count	*	2 <sup>nd</sup> count	**	3 <sup>rd</sup> count	**	4 <sup>th</sup> count	**
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	86	21.2 <sup>+</sup> 0.221 <sup>++</sup>	8.3 0.093	2	1.4 0.023	2	1.0 0.022	6	0.5 0.009	10
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	114	14.1 0.133	6.7 0.083	2	1.3 0.021	2	1.1 0.018	6	0.6 0.011	10
3	Matacil 180F + ID585	12-06-81 18-06-81	78	8.5 0.084	4.7 0.059	3	0.8 0.011	2	0.8 0.015	7	0.4 0.007	11
4	Matacil 180F + ID585	12-06-81 18-06-81	68	11.5 0.095	5.3 0.046	3	1.2 0.014	3	1.2 0.017	7	1.2 0.025	11
5	Matacil 1.8D OSC + Sunspray 6N	13-06-81 18-06-81	66	9.0 0.077	3.9 0.043	5	1.0 0.015	4	0.4 0.004	8	0.3 0.006	12
6	Matacil 1.8D OSC + Sunspray 6N	13-06-81 18-06-81	80	21.1 0.192	10.3 0.115	4	0.7 0.007	4	0.2 0.002	8	0.2 0.004	12
8	Matacil 1.8D OSC + ID585	16-06-81 19-06-81	68	16.8 0.185	9.6 0.115	2	2.5 0.032	4	1.3 0.028	8	0.3 0.007	12
9	Atlox 3409F + H <sub>2</sub> O	15-06-81 19-06-81	60	19.5 0.173	17.4 0.193	3	20.2 0.255	4	12.7 0.285	8	10.9 0.357	12
Check	Untreated	N/A	60	26.8 0.232	18.0 0.258		24.3 0.510		16.0 0.446		13.7 0.817	

Matacil treatments at 70 g AI/ha.

<sup>+</sup> upper values denote insects per branch.

<sup>++</sup> lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.



Table IX. Larval spruce budworm population density on White spruce *P. glauca* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	Population Reduction								
				Pre-spray	1st count	*	2nd count	**	3rd count	**	4th count	**
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	10	54.5+	22.3		4.3		3.4		1.1	
		18-06-81		0.394++	0.170	2	0.050	2	0.055	6	0.016	10
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	0	-	-		-		-		-	
		18-06-81		-	-		-		-		-	
3	Matacil 180F + ID585	12-06-81	28	25.4	13.7		3.8		2.5		2.4	
		18-06-81		0.195	0.178	3	0.062	2	0.072	7	0.122	11
4	Matacil 180F + ID585	12-06-81	24	25.1	21.9		8.9		7.5		2.6	
		18-06-81		0.195	0.217	3	0.338	3	0.515	7	0.051	11
5	Matacil 1.8D OSC + Sunspray 6N	13-06-81	24	27.1	9.2		1.8		1.4		1.4	
		18-06-81		0.221	0.096	5	0.057	4	0.023	8	0.016	12
6	Matacil 1.8D OSC + Sunspray 6N	13-06-81	6	46.0	13.0		1.8		0.7		0.2	
		18-06-81		0.198	0.092	4	0.042	4	0.006	8	0.005	12
8	Matacil 1.8D OSC + ID585	16-06-81	20	53.9	22.5		8.9		4.4		2.5	
		19-06-81		0.432	0.213	2	0.105	4	0.544	8	1.305	12
9	Atlox 3409F + H <sub>2</sub> O	15-06-81	20	36.2	29.0		19.7		10.5		7.6	
		19-06-81		0.339	0.454	3	1.332	4	2.510	8	0.286	12
Check	Untreated	N/A	30	66.3	23.5		16.7		7.6		4.2	
				0.365	0.297		2.307		1.502		0.132	
Matacil treatments at 70 = ALA												

Matacil treatments at 70 g AI/ha.

+ upper values denote insects per branch.

++ lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.



Table X. Larval spruce budworm population density on Red spruce *P. rubens* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	Population Density								
				Pre-spray	1st count	*	2nd count	**	3rd count	**	4th count	**
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	20	7.9+ 0.082++	4.4 0.040	2	2.3 0.028	2	2.0 0.022	6	1.5 0.015	10
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	6	1.5 0.028	1.8 0.014	2	1.2 0.015	2	1.7 0.021	6	0.8 0.007	10
3	Matacil 180F + ID585	12-06-81 18-06-81	4	7.8 0.047	0.2 0.006	3	0.2 0.005	2	0.8 0.016	7	0.2 0.003	11
4	Matacil 180F + ID585	12-06-81 18-06-81	20	5.4 0.042	3.2 0.028	3	2.4 0.025	3	0.9 0.011	7	1.6 0.013	11
5	Matacil 1.00 OSC + Sunspray 6N	13-06-81 18-06-81	10	3.0 0.032	1.0 0.009	5	0.1 0.002	4	0.3 0.002	8	0.2 0.003	12
6	Matacil 1.00 OSC + Sunspray 6N	13-06-81 18-06-81	22	3.6 0.022	3.2 0.014	4	2.5 0.014	4	1.5 0.016	8	0.6 0.006	12
8	Matacil 1.00 OSC + ID585	16-06-81 19-06-81	12	8.0 0.053	6.2 0.062	2	5.0 0.051	4	2.2 0.036	8	1.6 0.032	12
9	Atlox 3409F + H <sub>2</sub> O	15-06-81 19-06-81	20	9.2 0.061	7.8 0.066	3	13.1 0.153	4	8.4 0.097	8	7.9 0.101	12
Check	Untreated	N/A	30	9.2 0.082	14.9 0.126		15.3 0.151		12.3 0.172		11.0 0.156	

Matacil treatments at 70 g AI/ha.

+ upper values denote insects per branch.

++ lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.

Table XI. Larval spruce budworm population density on combined species *A. balsamea*, *P. glauca* and *P. rubens* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	Population Density								
				Prespray	1 <sup>st</sup> count	*	2 <sup>nd</sup> count	**	3 <sup>rd</sup> count	**	4 <sup>th</sup> count	**
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	116	21.8 <sup>+</sup> 0.221 <sup>++</sup>	8.8 0.093	2	1.8 0.023	2	1.4 0.022	6	0.7 0.010	10
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	120	13.5 0.128	6.5 0.079	2	1.3 0.021	2	1.2 0.018	6	0.6 0.011	10
3	Matacil 180F + ID585	12-06-81 18-06-81	110	12.8 0.111	6.8 0.088	3	1.6 0.024	2	1.2 0.029	7	0.9 0.036	11
4	Matacil 180F + ID585	12-06-81 18-06-81	112	13.3 0.107	8.5 0.080	3	3.1 0.085	3	2.5 0.122	7	1.6 0.028	11
5	Matacil 1.80 OSC + Sunspray 6N	13-06-81 08-06-81	100	12.7 0.107	4.9 0.052	5	1.1 0.024	4	0.6 0.008	8	0.6 0.008	12
6	Matacil 1.80 OSC + Sunspray 6N	13-06-81 18-06-81	108	19.0 0.158	9.0 0.095	4	1.1 0.013	4	0.5 0.005	8	0.3 0.005	12
8	Matacil 1.80 OSC + ID585	16-06-81 19-06-81	100	23.2 0.219	11.8 0.129	2	4.1 0.049	4	2.0 0.132	8	0.9 0.270	12
9	Atlox 3409F + H <sub>2</sub> O	15-06-81 19-06-81	100	20.8 0.184	17.8 0.220	3	18.7 0.450	4	11.4 0.693	8	9.7 0.292	12
Check	Untreated	N/A	120	32.3 0.228	18.6 0.235		20.2 0.870		13.0 0.642		10.6 0.480	

Matacil treatments at 70 g AI/ha.

+ upper values denote insects per branch.

++ lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.

Table XII. Larval spruce budworm population reduction and host tree defoliation on Balsam fir *A. balsamea* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	% Population Reduction (corrected)								% Defoliation
				1st count	*	2nd count	**	3rd count	**	4th count	**	
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	86	57.7 <sup>+</sup>		91.7		93.4		96.4		10.4
		18-06-81		63.9	2	93.8	2	94.9	6	98.1	10	
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	114	34.3		85.1		86.1		91.5		13.9
		18-06-81		57.0	2	90.2	2	92.0	6	95.3	10	
3	Matacil 180F + ID585	12-06-81	78	20.3		84.6		82.6		90.2		10.4
		18-06-81		52.8	3	91.9	2	89.5	7	95.3	11	
4	Matacil 180F + ID585	12-06-81	68	35.0		83.0		82.0		79.0		9.5
		18-06-81		67.4	3	90.8	3	89.4	7	84.9	11	
5	Matacil 1.8D OSC + Sunspray 6N	13-06-81	66	36.1		81.8		92.0		93.3		6.1
		08-06-81		63.6	5	88.0	4	97.0	8	95.6	12	
6	Matacil 1.8D OSC + Sunspray 6N	13-06-81	80	32.2		94.8		98.3		98.9		23.2
		18-06-81		59.6	4	97.7	4	99.4	8	98.9	12	
8	Matacil 1.8D OSC + ID585	16-06-81	68	25.6		78.1		86.6		96.7		20.7
		19-06-81		56.3	2	88.9	4	91.0	8	97.8	12	
9	Atlox 3409F + H <sub>2</sub> O	15-06-81	60	0.0		0.0		0.0		0.0		62.3
		19-06-81		21.5	3	5.6	4	0.0	8	0.0	12	
Check	Untreated	N/A	60	N/A		N/A		N/A		N/A		75.5

Matacil treatments at 70 g AI/ha.

+ upper values denote insects per branch.

++ lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.



Table XIII. Larval spruce budworm population reduction and host tree defoliation on White spruce *P. glauca* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	% Population Reduction (corrected)								% Defoliation
				1 <sup>st</sup> count	*	2 <sup>nd</sup> count	**	3 <sup>rd</sup> count	**	4 <sup>th</sup> count	**	
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	10	42.4 <sup>+</sup> 46.3 <sup>++</sup>		79.3 79.3		75.4 74.4		87.8 86.4		30.9
					2		.2		6		10	
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81 18-06-81	- 0	- -		- -		- -		- -		-
3	Matacil 180F + ID585	12-06-81 18-06-81	28	0.0 0.0		37.7 0.0		37.5 0.0		17.2 0.0		24.4
					3		2		7		11	
4	Matacil 180F + ID585	12-06-81 18-06-81	24	0.0 0.0		0.0 0.0		0.0 0.0		16.1 0.0		31.0
					3		3		7		11	
5	Matacil 1.80 OSC + Sunspray 6N	13-06-81 18-06-81	24	0.0 0.0		70.0 36.7		67.4 15.8		54.8 0.0		17.3
					5		4		8		12	
6	Matacil 1.80 OSC + Sunspray 6N	13-06-81 18-06-81	6	23.5 0.0		83.8 67.7		91.3 90.0		96.7 92.3		27.8
					4		4		8		12	
8	Matacil 1.80 OSC + ID585	16-06-81 19-06-81	20	3.4 0.0		42.2 14.5		52.7 11.6		68.4 47.1		54.1
					2		4		8		12	
9	Atlox 3409F + H <sub>2</sub> O	15-06-81 19-06-81	20	0.0 0.0		0.0 0.0		0.0 0.0		0.0 0.0		73.4
					3		4		8		12	
Check	Untreated	N/A	30	N/A		N/A		N/A		N/A		76.3

Matacil treatments at 70 g AI/ha.

<sup>+</sup> upper values denote insects per branch.

<sup>++</sup> lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.

Table XIV. Larval spruce budworm population reduction and host tree defoliation on Red spruce *P. rubens* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	% Population Reduction (corrected)								% Defoliation
				1 <sup>st</sup> count	*	2 <sup>nd</sup> count	**	3 <sup>rd</sup> count	**	4 <sup>th</sup> count	**	
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	20	40.0		62.0		64.0		71.0		3.8
		18-06-81		43.1	2	63.0	2	68.8	6	66.7	10	
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	6	0.0		0.0		0.0		0.0		1.6
		18-06-81		0.0	2	0.0	2	0.0	6	0.0	10	
3	Matacil 180F + ID585	12-06-81	4	96.0		96.0		81.0		95.0		0.1
		18-06-81		96.9	3	96.4	2	79.2	7	85.7	11	
4	Matacil 180F + ID585	12-06-81	20	15.8		29.4		71.0		42.9		2.8
		18-06-81		20.0	3	0.0	3	72.7	7	47.4	11	
5	Matacil 1.80 OSC + Sunspray 6N	13-06-81	10	50.0		94.4		82.4		86.7		1.5
		18-06-81		50.0	5	94.4	4	75.0	8	85.7	12	
6	Matacil 1.80 OSC + Sunspray 6N	13-06-81	22	0.0		0.0		28.6		66.7		4.8
		18-06-81		0.0	4	0.0	4	8.3	8	70.0	12	
8	Matacil 1.80 OSC + ID585	16-06-81	12	0.0		7.4		52.2		63.6		9.2
		19-06-81		0.0	2	2.9	4	46.4	8	57.7	12	
9	Atlox 3409F + H <sub>2</sub> O	15-06-81	20	0.0		0.0		0.0		0.0		19.7
		19-06-81		0.0	3	0.0	4	0.0	8	0.0	12	
Check	Untreated	N/A	30	N/A		N/A		N/A		N/A		26.5

Matacil treatments at 70 g AI/ha.

\* upper values denote insects per branch.

\*\* lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.

Table XV. Larval spruce budworm population reduction and host tree defoliation on combined species *A. balsamea*, *P. glauca* and *P. rubens* (Bathurst, N.B. 1981)

Block	Spray Formulations	Spray Dates	No. of Samples	% Population Reduction (corrected)								% Defoliation
				1 <sup>st</sup> count	*	2 <sup>nd</sup> count	**	3 <sup>rd</sup> count	**	4 <sup>th</sup> count	**	
1	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	116	55.3 <sup>+</sup>		88.3		90.1		94.4		14.5
		18-06-81		50.3 <sup>++</sup>	2	82.0	2	79.6	6	88.4	10	
2	Matacil 180F + Atlox + H <sub>2</sub> O	12-06-81	120	30.9		83.1		82.4		89.8		13.3
		18-06-81		0.0	2	58.0	2	55.0	6	65.6	10	
3	Matacil 180F + ID585	12-06-81	110	20.9		78.1		80.6		83.3		13.5
		18-06-81		0.0	3	44.2	2	12.1	7	0.0	11	
4	Matacil 180F + ID585	12-06-81	112	1.1		59.2		62.1		72.4		12.9
		18-06-81		0.0	3	0.0	3	0.0	7	0.0	11	
5	Matacil 1.8D OSC + Sunspray 6N	13-06-81	100	38.8		84.3		90.2		88.9		8.7
		18-06-81		0.0	5	40.0	4	75.0	8	68.0	12	
6	Matacil 1.8D OSC + Sunspray 6N	13-06-81	108	29.1		89.8		94.7		96.4		19.9
		18-06-81		0.0	4	79.0	4	89.8	8	87.5	12	
8	Matacil 1.8D OSC + ID585	16-06-81	100	29.3		70.9		82.8		91.7		26.0
		19-06-81		0.0	2	48.4	4	0.0	8	0.0	12	
9	Atlox 3409F + H <sub>2</sub> O	15-06-81	100	0.0		0.0		0.0		1.0		56.0
		19-06-81		0.0	3	0.0	4	0.0	8	0.0	12	
Check	Untreated	N/A	120	19.8		0.0		27.4		32.5		63.5
				0.0		0.0		0.0		0.0		

Matacil treatments at 70 g AI/ha.

<sup>+</sup> upper values denote insects per branch.

<sup>++</sup> lower values denote insects per bud (shoot).

\* days after first spray sample taken.

\*\* days after second spray sample taken.



not as effective on red spruce because its phenological development was retarded and consequently its budworm population was not optimally accessible and susceptible to the sprays. Since red spruce was a minor component of all the sprayed areas (Table I) its late development might not have significantly influenced the spray's overall effects.

Aqueous Matacil 180F generally controlled spruce budworm as effectively as either the 180F in ID585 or the oil soluble concentrate in oil. The block sprayed with Atlox + water had residual larval densities not substantially different from the untreated check, thereby indicating that Atlox was not noticeably toxic to spruce budworm.

The two methods of population assessment did not appear to show any significant difference in trends. However, there were occasions where the insect to shoot ratio appeared to increase rather than decline (Table VIII). This was due to defoliation by the insects which reduced the number of viable shoots thus making the denominator in the 'insect:shoot' equation progressively smaller. This type of 'per shoot' assessment is in reality a combination of assessing, simultaneously, both the insect numbers and some of the tree defoliation. We have subsequently found that this anomaly can be avoided by adjusting the counting mill technique to include in the denominator all shoots on the branch and not only the viable ones. The variance observed in the number of shoots per branch should therefore be that found in heterogeneous forest systems and not induced by insect feeding which is independently measured as the degree of defoliation.

#### Percent Population Mortality

The percent insect mortality attributed to the treatments is considered as one of the most important and definitive expressions of the treatment's effectiveness. In this study all the treatments except Atlox + water gave very good percent larval mortality. Generally, the results showed no appreciable differences between the two assessment methods except on white spruce which reflected those anomalies in larval population densities discussed earlier. It was also observed that untreated populations in white spruce (Table IX) showed a high natural mortality which might have been due to the high numbers competing for limited food. Consequently, this resulted in the low corrected mortality figures shown for that species (Table XIII). Using percent larval mortality as an assessment criterion the results again indicate that Matacil flowable was as effective in reducing spruce budworm populations as the OSC. There was no observable toxicity to budworm which could be attributed to Atlox + water.

#### Arthropod Knockdown

The observations in this study were focused mainly on *C. fumiferana* and the results show that considerably more live than dead budworm were dislodged and that the bulk fell 2-3 days after the spray application (Fig. 6). Larval spruce budworm tend to react to unfamiliar stimuli by spinning out of their immediate habitat on silk-en threads which cascade in large quantities from the canopy like tinsel on a Christmas tree. This tinselling was evident in all the sprayed blocks. It was spectacular in blocks 1 and 2 (aqueous Matacil) one to

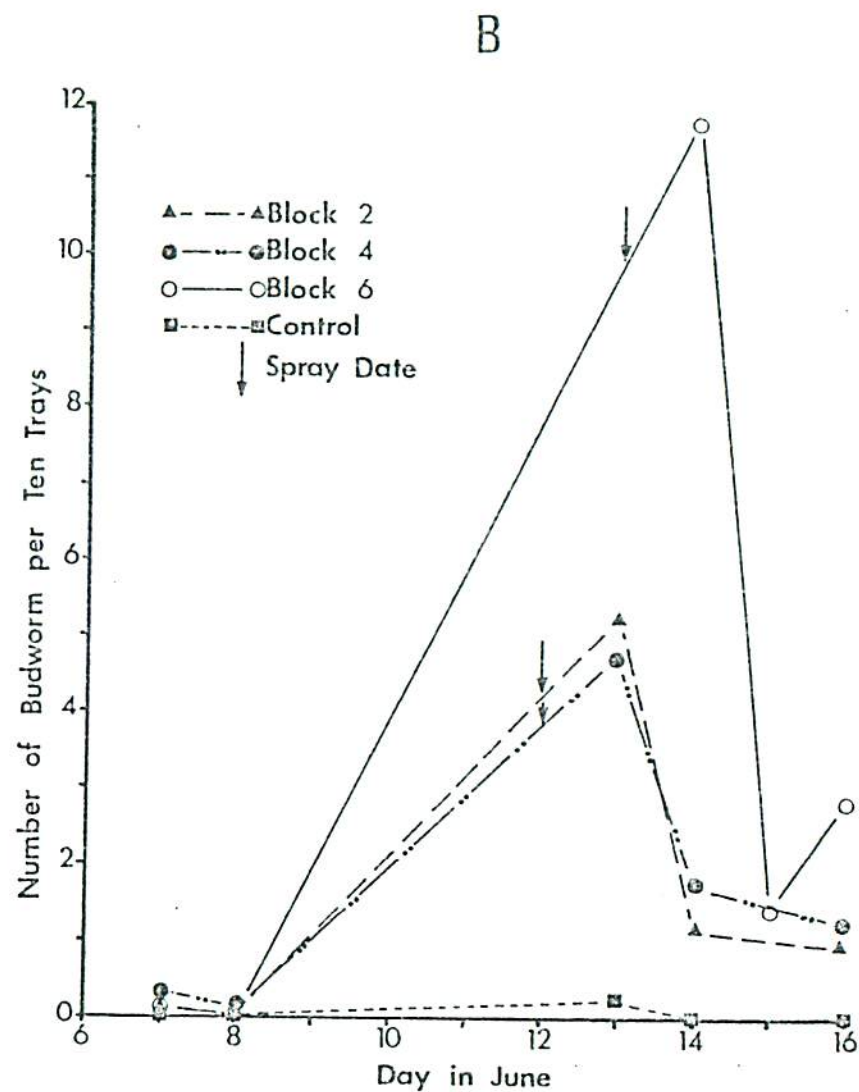
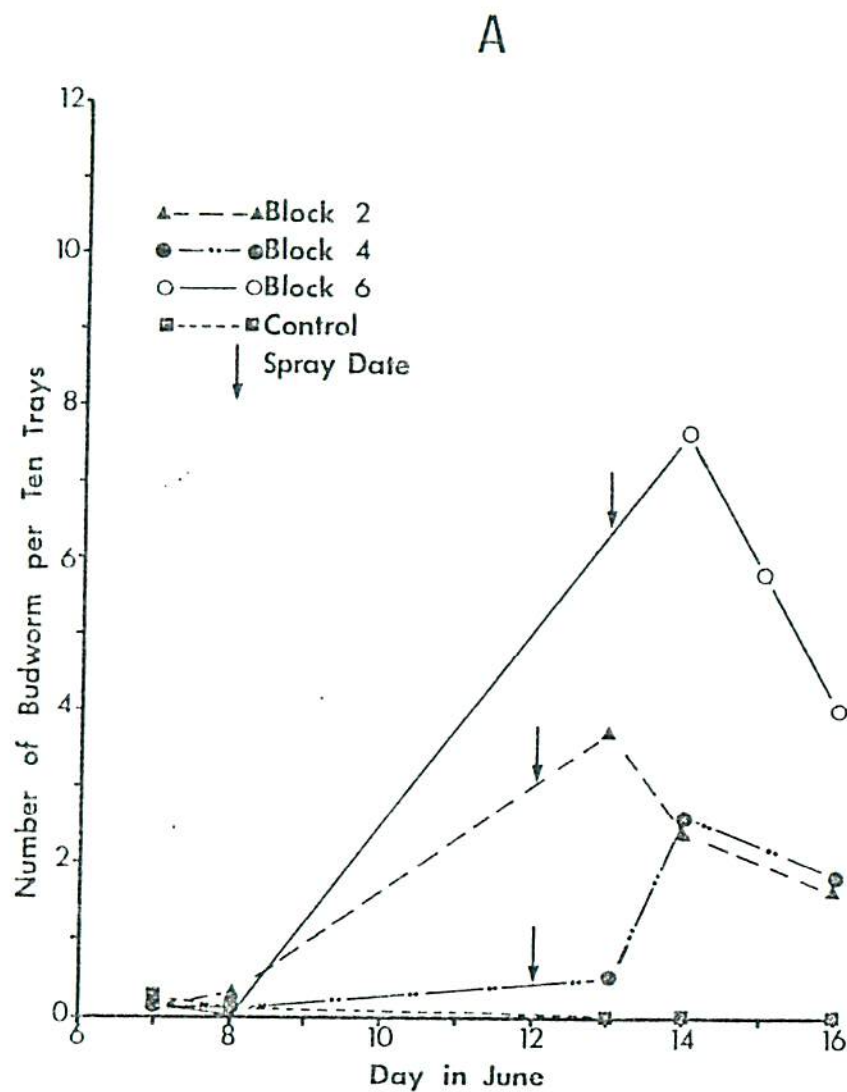


Fig. 6. Number of dead (A) and live (B) budworm collected prior to and after Matacil spray. Bathurst, N.B. 1981.



three days after the first spray application and barely observable in the block sprayed with Atlox + water. Matacil OSC + Sunspray 6N showed the greatest knockdown of larval budworm but the tinselling in the block was not unusually striking. These findings imply that substantial larval dislodgement could occur without its being manifested by tinselling and that stimuli other than regular droplets, possibly vapors or aerosols, might have caused the excessive larval irritability seen in the aqueous Matacil blocks. It was evident that, depending on the conformation of the host tree canopy, tinselling might result in intra-tree redistribution of budworm and not necessarily in ultimate dislodgement. However, unless the lower canopy is supportive, this redistribution might be just as catastrophic for larvae as dislodgement.

The Environmental Impact section of FPMI conducted a more thorough study of the impact of the treatments on terrestrial invertebrates and the report indicates that Coleoptera: Staphilinidae and Diptera were the only insects knocked down in sufficient numbers to merit any concern (R.L. Millikin --FPMI File Rept. No. 15). Even so, the techniques used during that study would suggest that the receptacles containing a formalin solution which were placed beneath the trees possibly did not just passively collect dislodged insects, but behaved as lures and also actively trapped some of them.

During our assessment of budworm knockdown it was observed that spiders appeared to be affected by Matacil. This is not unusual as some carbamates tend to display acaricidal characteristics. The results from our collection on drop trays show that Matacil was toxic to 8 genera of spiders (Table XVI), *Theridion montanum* Emerton was the species which appeared to be most affected. Whereas a high proportion of the dislodged larval insects were alive, all of the spiders were dead.

### Defoliation

The extent of host tree defoliation is a function of the feeding activity of insect pests. This activity is in turn influenced mainly by the size and health of the insect population, the tree vigor, and the weather. Insecticides are applied to affect the first two factors. The results (Tables XII to XIV) indicate that white spruce was most heavily defoliated and red spruce the least. However, these species also recorded the highest and lowest initial budworm populations respectively. The blocks sprayed with Matacil flowable in both water and ID585 suffered >15% defoliation except on white spruce. This is substantially better foliage protection than was received by blocks sprayed with the OSC, which experienced >5% defoliation except on balsam fir in block 5 and on red spruce. On a combined species basis, Matacil 180F was also as effective in protecting foliage from budworm defoliation as the other Matacil treatments (Table XV). All three species in the Atlox block were defoliated to a similar extent as in the untreated block (Table XV).

### Spray Deposit-Spruce Budworm Relationships

Aerially applied droplets in forests have seldom shown a consistent pattern of behavior. This is not surprising if one considers the extreme heterogeneity in natural forests and the diverse factors which can influence the sprays. The optimum and desirable droplet sizes to control various insects have been widely discussed (Himel and Moore 1967; Barry et al. 1977; Joyce and Spillman 1978) and there is agreement that it is also necessary to have good coverage in terms of droplet density. Even so, aerial spray deposits and insect mortality often will not give correlation when cards are used to collect droplets (Buffman et al. 1967). Although the average droplet densities recorded in this study were not high (Table VI), it was shown that budworm population reduction was generally related



Table XVI. Spiders knocked down on three Matacil blocks (Bathurst, N.B. 1981)

Block No. and Treatment	Species	Number of Spiders Dislodged	
		at Prespray	at Postspray
2 18CF + water + Atlox	<i>Clubiona</i> sp.	0	6
	<i>Dictyra phylax</i> G6risch & Ivie	0	1
	<i>Theridion montanum</i> Emerton	0	6
4 18CF + ID585	<i>Araneus</i> sp.	1	0
	<i>Ceraticelus fissiceps</i> (O.P.-Cambridge)	0	2
	<i>Clubiona</i> sp.	0	3
	<i>Grammonata angusta</i> Dondale	0	1
	<i>Metaphidippus</i> sp.	0	2
	<i>Theridion montanum</i>	0	2
9 1.8D + 6N	<i>Araneus</i> sp.	0	2
	<i>Clubiona</i> sp.	0	2
	<i>Grammonata angusta</i>	1	1
	<i>Metaphidippus</i> sp.	0	2
	<i>Philodromus cespitum</i> (Walckenaer)	0	1
	<i>Theridion montanum</i>	0	16
unsprayed check	<i>Theridion montanum</i>	1	0

to droplet density (Tables XVII to XIX). This relationship was more definitive in balsam fir than in the other host species, but this might be due to a statistically more acceptable number of samples in fir. We also found that the per shoot assessment of percent population reduction seemed to give inflated relationships, probably because of the denominator anomaly mentioned earlier. In all the treatments except aqueous Matacil on red spruce, 1 drop/cm<sup>2</sup> on Kromekote cards gave the least control and the classes 1-5, 5-10 drops/cm<sup>2</sup> the most consistently favourable results (Tables XVI to XIX).

#### CONCLUSIONS

Matacil 18CF was as effective in controlling *C. fumiferana* on *A. balsamea* and *Picea* spp. as the oil soluble concentrate

formulation. Both the flowable in ID585 and in water and the OSC in ID585 and Sunspray 6N effected ~90% corrected larval reduction, residual larval populations generally <1.0/46 cm branch tip, and very good foliage protection.

The 18CF mixed easily and presented no application problems. The deposition characteristics between that and the OSC were not substantially different.

The formulation showed no pronounced adverse effect on nontarget insect species; however a small number of spiders were collected on drop trays.

It was shown that aqueous tank formulations, once thought to be liabilities because of their propensity to evaporate and result in inadequate deposit, can be most efficacious, when applied with aircraft with delivery systems and under conditions which

Table XVII. Droplet density and spruce budworm mortality on Balsam fir *A. balsamea* (Bathurst, N.B. 1981)

Block No.	Treatment	Deposit Class. (Drops/cm <sup>2</sup> )	Number of samples	% Pop. reduction*	
				Per branch	Per bud
1	Matacil + Atlox + water	0-1	21	47	58
		1-5	17	66	73
		5-10	4	85	89
2	Matacil 180F + Atlox + water	0-1	25	16	66
		1-5	27	44	74
		5-10	3	61	87
		10-15	1	81	92
3	Matacil 180F + ID585	0-1	3	0	52
		1-5	17	0	58
		5-10	12	60	88
		10-15	4	85	92
		15-20	0	-	-
		20-25	1	18	76
4	Matacil 180F + ID585	0-1	6	0	54
		1-5	12	35	80
		5-10	6	76	91
		10-15	7	48	83
		15-20	3	79	92
8	Matacil OSC + ID585	0-1	2	0	46
		1-5	21	20	67
		5-10	6	52	85
		10-15	2	68	77
		15-20	2	4	63
9	Atlox 3409F + water	0-1	26	0	50
		1-5	1	0	49

Droplets from blocks 5 and 6 not included due to incomplete analysis by the spot scanner.  
\* Assessed 2 days after 1st application.

capitalize on the evaporative potential to produce optimum sized droplets at the target sites.

Assessments of larval budworm populations using per bud and per branch methods generally produced similar results.

The initial phenological development of red spruce *P. rubens* was much slower than that of either *P. glauca* or *A. balsamea*. Pesticide applications timed to the development of the latter two possibly were not as effective on the former. Thus the species composition of a forest should be of prime



Table XVIII. Droplet density and spruce budworm mortality on White spruce *P. glauca* (Bathurst, N.B. 1981)

Block No.	Treatment	Deposit Class. (Drops/cm <sup>2</sup> )	Number of samples	Pop. reduction*	
				Per branch	Per bud
1	Matacil 180F + Atlox + water	0-1	3	43	48
		1-5	2	58	72
2	Matacil 180F + Atlox + water	-	-	-	-
3	Matacil + ID585	0-1	3	0	0
		1-5	6	0	61
		5-10	5	26	76
4	Matacil ID585	0-1	3	0	39
		1-5	8	0	48
8	Matacil 1.8D + ID585	0-1	1	0	75
		1-5	5	27	60
		5-10	4	0	74
9	Atlox 3409F + water	0-1	10	0	10

Droplets from block 5 & 6 included due to incomplete analysis by the spot scanner.

\* Assessed 2 days after 1st application.

consideration in determining the timing of applications to control defoliators.

The response of *C. fumiferana* to Atlox 3409F sprayed as an independent treatment were similar to those seen in the unsprayed

check block. It is therefore apparent that whereas Atlox might improve the sprayability and consequently the efficacy of aqueous Matacil there is no evidence that it contributes insecticidally to the formulation.

Table XIX. Droplet density and spruce budworm mortality on Red spruce *P. rubens* (Bathurst, N.B. 1981)

Block No.	Treatment	Deposit Class. (Drops/cm <sup>2</sup> )	Number of samples	% Pop. reduction*	
				Per branch	Per bud
1	Matacil + Atlox + water	0-1	4	48	57
		1-5	5	33	55
		5-10	1	28	17
2	Matacil + Atlox + water	0-1	3	0	63
3	Matacil 180F + ID585	0-1	0	-	-
		1-5	0	-	-
		5-10	2	95	91
4	Matacil 180F + ID585	0-1	0	-	-
		1-5	4	0	32
		5-10	5	30	62
		10-15	0	-	-
		15-20	0	-	-
		20-25	1	0	0
8	Matacil 1.8D + ID585	0-1	0	-	-
		1-5	4	26	38
		5-10	2	0	0
9	Atlox 3409F + water	0-1	5	0	0
		1-5	1	0	0

Droplets from blocks 5 and 6 not included due to incomplete analysis by the spot scanner.

\* Assessed 2 days after 1st application.



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