THE PERSISTENCE OF NUCLEAR POLYHEDROSIS VIRUS AND ENTOMOPOXVIRUS IN POPULATIONS OF SPRUCE BUDWORM

by

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ABSTRACT

Population reduction due to virus carryover, the level of virus infection in the spruce budworm population and the degree of defoliation in treated and untreated areas, was studied in 4 plots which had been sprayed in 1971 with entomopoxvirus (contaminated with nuclear polyhedrosis virus and cytoplasmic polyhedrosis virus) and 2 plots sprayed in 1971 with nuclear polyhedrosis virus (contaminated with cytoplasmic polyhedrosis virus). Observations made in 1973, 1974 and 1975 are documented in this report.

The entomopoxvirus did not persist well and the nuclear polyhedrosis virus, which was originally a contaminant, was considerably more prevalent. The cytoplasmic polyhedrosis virus contaminant which originally gave high levels of infection in the plots sprayed with nuclear polyhedrosis virus declined but the nuclear polyhedrosis virus again persisted well. This virus had a considerable impact on the spruce budworm population over the 5 year period of this study, and although results were not dramatic, it probably exerted sufficient control of this insect to reduce defoliation and hereby prevent tree mortality.

Résumé

La diminution de population due aux effets des virus, le niveau d'infection chez la Tordeuse des bourgeons de l'Epinette et le degré de défoliation en des endroits traités et non traités dans 4 parcelles de terrain arrosées en 1971 avec le virus entomopox (auquel on avait ajouté un virus de la polyédrose nucléaire et un virus de la polyédrose cytoplasmique), ainsi que dans 2 parcelles, vaporisées en 1971 d'un virus de la polyédrose nucléaire (contaminé avec un virus de la polyédrose cytoplasmique), ont fait l'objet d'une étude. Les observations recueillies en 1973, 1974 et 1975 sont notées dans le présent rapport.

Le virus entomopox n'a pas bien persisté tandis que le virus de la polyédrose nucléaire, utilisé en premier lieu comme contaminant, s'est révélé beaucoup plus efficace. Le virus de la polyédrose cytoplasmique, contaminant qui provoquait initialement de hauts niveaux d'infection dans les parcelles arrosées avec le virus de la polyédrose nucléaire a démontré un fléchissement mais encore là, le virus de la polyédrose nucléaire a bien persisté. Ce virus a eu un effet considérable sur la population de la Tordeuse des bourgeons de l'Epinette au cours de cette étude échelonnée sur 5 ans et même si les résultats n'ont pas été spectaculaires, l'influence exercée sur la Tordeuse fut assez importante pour restreindre la défoliation et par le fait même, pour permettre aux arbres de survivre.

INTRODUCTION

In 1971, two viruses of the spruce budworm, Choristoneura fumiferana (Clem.), a nuclear polyhedrosis virus (NPV) and an entomopoxvirus (EPV) were compared in field tests near Pembroke, Ontario. Aqueous suspensions of the viruses were sprayed from a helicopter at a rate of 28 l/ha, the EPV being applied at 2.4 billion, 24 billion and 240 billion inclusion bodies per hectare and the NPV at 720 billion inclusion bodies per hectare. The applications were tested at two different times : at the peak of the second instar and at the peak of the fourth instar, making a total of 8 treated plots. The EPV plots were 2.5 ha and the NPV plots 3.3 ha (Howse et al., 1973).

The efficacy of the treatments was evaluated by population reduction studies, defoliation estimates and microscopic diagnosis of samples of insects to determine the level of virus infection in the population. After the application it was discovered that the EPV used was contaminated with NPV and cytoplasmic polyhedrosis virus (CPV) and the NPV sprayed was contaminated with CPV. Hence mixed virus infections resulted. The impact of the virus in the year of application and in the following year (1972) have been fully reported by Howse et al., (op. cit.). These studies were continued in 1973, 1974 and

1975 and this report contains information on the persistence of the virus and its impact over this time period.

Population reduction and defoliation estimates were made by GLFRC personnel and microscopic examination of insects to determine the levels of virus infection by IPRI staff.

MATERIALS AND METHODS

Experimental plots

The plots sprayed with EPV at Achray in Algonquin Park were designated A to F and the plots sprayed with NPV at Deluthier Rd. on Canadian Forces Base, Petawawa were designated G and H. Three check areas were established close to the Achray plots and designated Achray checks no. 1, 2 and 3; a further check area in Algonquin Park was located at Lone Creek, 6.5 km from the Achray plots. The plots at Deluthier Rd. were isolated white spruce plantations and check areas were located 3 to 4 km away on Petawawa Forest Experiment Station (Orange Road) and at Alice Station, 26 km south of Petawawa Forest Experiment Station. Information on the treated plots is summarized in Table 1.

Sampling for population reduction due to virus carryover

At Achray plots A, B, C and D and plots G and H at Deluthier Rd. were studied for the effects of virus carryover. Branch samples (46 cm) were taken at mid crown when larvae were mainly in the fourth instar and again when most of the larvae had pupated. Generally, twenty white spruce and 20 balsam fir samples were taken from each treatment plot and 10 samples of each species from each check area. The larvae were removed from the foliage by the "drum method" described by DeBoo

et al. (1973) and Martineau and Benoit (1973). The population reduction due to virus carryover was computed by Abbott's formula (Abbott, 1925).

Sampling for microscopic examination to establish levels of virus infection

Spruce budworm viruses which carryover from one year to the next are not detectable in insects until late in their development. It is thought that transmission of the viruses is by foliage contamination (Howse et al., 1973). Hence samples were collected when larvae were in the fifth and sixth instar and again when pupation had commenced.

At Achray plots A, B, C and D were sampled. In 1973, the Achray plots, Deluthier Rd. plots and 3 check areas were sampled twice and 10 random samples of white spruce 46 cm branch tips and 10 balsam fir 46 cm branch tips collected except at Deluthier Rd. where white spruce was the only species present. In 1974 the Achray plots and check areas were sampled once only and the Deluthier Rd. plots sampled twice. In 1975 the Achray plots were sampled twice and 20 random white spruce 46 cm branch tips and 20 balsam fir 46 cm branch tips collected. Two check areas close to the Achray plots were sampled twice and the Lone Creek check sampled once; here 10 random samples were collected from each species. Deluthier Rd. plots were sampled twice with 40 random samples of white spruce 46 cm branch tips on the first occasion and

20 samples on the second. Alice Station and Orange Rd. check areas were sampled twice and 10 branch tips collected each time.

Microscopic diagnosis

Methods used to determine virus and microsporidial infection in larvae and pupae are described by Howse et al. (1973).

Estimates of defoliation

The percent current defoliation was obtained by detailed examination and estimates of the degree of defoliation sustained by the 46 cm branch tips collected for the pupal sample from treated areas and check plots after spruce budworm had ceased feeding.

Table 1

Plots sprayed with EPV and NPV in 1971 to control spruce budworm

Plot	Locality	Tree species	Time application (instar)	Virus	Dosage PIB/ha x 10^9
A	Achray	bF & wS	IV	EPV	240
B	"	" "	IV	"	24
C	"	" "	II	"	240
D	"	" "	II	"	24
E	"	" "	II	"	2.4
F	"	" "	IV	"	2.4
G	Deluthier Rd.	wS	II	NPV	720
H		"	IV	"	720

RESULTS

Population reduction and defoliation estimates

In 1973 there was considerable mortality due to carryover of virus at both Achray and Deluthier Rd. as shown in Table 2. At Deluthier Rd. there was 82% population reduction on plot G and 68% on plot H. At Achray the population reduction was higher on white spruce than balsam fir with 83%, 59%, 60% and 47% on white spruce on plots A, B, C and D respectively as opposed to 15%, 0%, 3% and 50% on balsam fir. On all plots defoliation was less than the check areas on both white spruce and balsam fir (Table 2).

In 1974, the levels of population reduction due to virus carryover were lower than the 1973 levels with 56% on plot G and 62% on plot H. At Achray the population reduction had declined considerably from the previous year and no population reduction was recorded on balsam fir in any of the plots. On white spruce 48%, 34%, 5% and zero were calculated for plots A, B, C and D respectively. In spite of the lack of virus-associated mortality, current defoliation was lower on the treated areas than checks with the exception of the balsam fir in plot B (Table 3).

In 1975 the levels of population reduction due to virus carryover were similar to the 1974 results at Deluthier Rd. with 74% on plot G and 48% on plot H.

Table 2

Population reduction, pupal survival and current defoliation in two plots on Deluthier Road, PFES and four plots at Achray in 1973 following application of virus in 1971

Plot	Early sample larvae/46 cm branch tip		Surviving pupae/46 cm branch tip		% Population reduction due to NPV carryover		% Successful pupal emergence[a]		% Current Defoliation in 1973	
	bF	wS	bF	wS	bF	wS	bF	wS	bF	wS
Deluthier Road-G		42.0		.85		82		83		67
check		41.2		4.61		-		88		86
Deluthier Road-H		79.7		.95		68		93		76
check		66.4		2.45		-		82		95
Achray-A	18.2	71.0	2.88	1.25	15	83	77	86	70	59
check	22.0	79.4	4.10	8.30	-	-	79	92	95	76
Achray-B	14.0	62.5	3.30	.85	0	59	72	61	92	68
check	22.0	59.0	4.10	1.95	-	-	79	91	95	95
Achray-C	12.6	44.1	2.88	.68	3	60	78	100	67	74
check	14.0	51.0	3.30	1.95	-	-	72	91	92	95
Achray-D	19.5	58.9	2.05	1.02	50	47	74	91	73	79
check	22.5	59.0	4.72	1.95	-	-	77	91	84	95

a) % Successful pupal emergence = $\frac{\text{Emerged budworm}}{\text{Budworm alive on sample date}} \times 100$

Table 3

Population reduction (adjusted for natural mortality) pupal survival and current defoliation in two plots on Deluthier Road, PFES and four plots at Achray in 1974 following application of virus in 1971

Plot	Early sample larvae/46 cm branch tip		Surviving pupae/46 cm branch tip		% Population reduction due to NPV carryover		% Successful pupal emergence		% Current Defoliation in 1974	
	bF	wS	bF	wS	bF	wS	bF	wS	bF	wS
Deluthier Road-G		36.8		1.8		56		90		46
H		23.5		1.0		62		90		35
Check		39.5		4.4		-		86		63
Achray-A	13.5	48.0	6.0	3.5	0	48	64	88	41	46
B	12.2	41.3	5.4	3.9	0	34	76	87	59	38
Check	12.4	47.8	3.4	6.8	-	-	64	99	55	84
Achray-C	11.0	36.8	6.6	3.9	0	5	69	91	39	32
D	11.0	23.6	3.7	2.7	0	0	77	84	28	32
Check	12.4	39.5	3.4	4.4	-	-	64	86	55	63

Population reduction, pupal survival and current defoliation in two plots on Deluthier Road, PFES and five plots at Achray (including one check plot) in 1975 following application of virus sprayed 1971.

Plot	Early sample larvae/46 cm branch tip		Surviving pupae/46 cm branch tip		% Population reduction due to NPV carryover		% Successful pupal emergence[a]		% Current Defoliation in 1975	
	bF	wS	bF	wS	bF	wS	bF	wS	bF	wS
Deluthier Road-G		17.0		1.10		74		89		97
Check		18.7		4.70		-		100		90
Deluthier Road-H		25.5		1.33		48		95		91
Check		30.6		3.10		-		82		90
Achray-A	21.7	37.8	2.05	2.10	47	26	63	100	98	89
B	21.0	62.1	2.95	1.20	22	74	94	92	98	91
C	19.5	36.6	4.10	.60	0	78	94	100	95	96
D	14.1	39.6	3.30	.10	0	97	87	100	70	98
Check	20.1	38.8	3.60	2.90	-	-	86	100	99	90
Achray-Check 2	12.8	55.4	.60	.60	74	85	100	100	91	98
Check	20.1	38.8	3.60	2.90	-	-	86	100	99	90

a)% Successful pupal emergence = $\frac{\text{Emerged budworm}}{\text{Budworm alive on sample date}} \times 100$

At Achray on white spruce 26%, 74%, 78% and 97% population reductions were recorded on plots A, B, C and D respectively and 47% and 22% on balsam fir on plots A and B and none on C and D. Defoliation was very heavy on all plots and there was no difference between the areas sprayed in 1971 and the check areas (Table 4). Since virus was recorded from check area no. 2 (see following section) it was regarded as a treated area and data analyzed accordingly. It is probable that virus had spread from the sprayed area into this check. Assuming this to be so, 74% population reduction due to virus was estimated on balsam fir and 85% on white spruce (Table 4).

Each year the rate of successful pupal emergence on the treated and check areas was compared and is shown in Tables 2, 3 and 4. No consistent trend emerges from these results and it appears that NPV did not have an adverse effect on pupal survival.

Levels of virus infection

In 1973, at Achray very low levels of EPV were recorded with a maximum of 4.8% on white spruce in plot C. NPV was considerably more prevalent with maximum levels of 3.7% on balsam fir and 15.6% on white spruce on plot A, 3.7% on balsam fir and 2.2% on white spruce on plot B, 3.1% on balsam fir and 13.0% on white spruce on plot C

and 9.7% on balsam fir and 2.9% on white spruce on plot D. Levels of CPV were low with a maximum of 1.9% on balsam fir in plot A. No virus was recorded in check areas no. 1 and no. 2 (Table 5). Levels of microsporidia ranged from 0 to 15.4% with a mean of 4.6%. At Deluthier Rd. maximum levels of 16.7% NPV on plot G and 13.6% on plot H were recorded. In plot G, 4.9% CPV was recorded and none in plot H in spite of the high levels in 1972 (Howse et al., 1973). In the Orange Rd. check 7.3% CPV was recorded but no NPV. High levels of a fungus (Entomophthora sp.) were recorded in both plots and the check area which probably lowered the levels of virus infection, 30.6% was recorded in plot G, 15.4% in plot H and 26.1% in the Orange Rd. check. Levels of microsporidia ranged from 0 to 11.1% with a mean of 5.3% (Table 6).

In 1974, EPV levels were again low at Achray with a maximum of 2.0% on balsam fir on plot B. Levels of NPV had declined from 1973 with 2.5% and 1.0%, on balsam fir on plots A and B and none on plots C and D and 10.5%, 3.9%, and 1.9% on white spruce on plots A, B and C and none on plot D. On plot A, 1.3% CPV was recorded. In the Achray check areas no EPV or NPV were recorded and only 0.6% and 0.4% CPV on check area no. 1 and no. 2 on balsam fir. Levels of microsporidia had increased considerably since 1973 and ranged from 8.9% to 44.4%

with a mean of 22.7% (Table 7).

At Deluthier Rd. in 1974, NPV levels had declined from 1973 and maximum levels of 6.4% and 5.8% were recorded in plots G and H. Only 1.4% CPV was recorded from plot G and CPV was still found in the Orange Rd. check at 4.7%. Fungus was still prevalent in plot H with 21.2% recorded but only a trace, 1.2%, was found in plot G and none in the Orange Rd. check where 26% had been found in the previous year. Levels of microsporidia ranged from 0 to 30.2% with a mean of 19.7% (Table 8).

In 1975, at Achray some EPV was recorded with 0.8% on white spruce on plot A, 1.1% on white spruce on plot B, 0.7% on balsam fir and 6.3% on white spruce on plot C and none on plot D. Levels of NPV had increased considerably from 1974 with maximum of 16.7%, 5.3% and 2.4% on balsam fir on plots A, C and D with none on plot B and 11.1%, 7.3%, 15.6% and 4.8% on white spruce on plots A, B, C and D. Levels of 0.6% CPV on white spruce and 0.6% on balsam fir were recorded in plot B and 0.3% white spruce and 0.7% on balsam fir in plot C (Table 9). For the first time NPV was recorded in the Achray check areas with 1.9% on balsam fir in check no. 1 and 6.7% on balsam fir and 10.0% on white spruce in check area no. 2. No viruses were recorded in the Lone

Creek area (Table 10). Due to a declining insect population some of the samples were too small. The levels of microsporidia in the sprayed and check areas at Achray ranged from 11.1% to 41.7% with a mean of 25.2%.

At Deluthier Rd. in 1975, levels of NPV had increased since 1974 with 21.3% on plot G and 9.0% on plot H. No CPV was recorded in either plot. In the Alice Station and Orange Rd. check areas no NPV was found but, as in the past 3 years, CPV was found at the Orange Rd. check, this year at 3.7%. No fungus was found in 1975 in the plots or check areas. Levels of microsporidia in the treated and check areas ranged from 12.8% to 53.9% with a mean of 36.1% (Table 11).

Table 5

Incidence of viruses and microsporidia in 1973 in plots at Achray sprayed in 1971 with EPV (contaminated with NPV and CPV).

Plot	Sample date	Tree species	Number insects examined	Percent Virus Infection EPV	NPV	CPV	Percent microsp.
A	12 June 73	bF	152	0	2.6	0	5.3
	12 " "	wS	376	0.5	13.3	0.3	4.8
	18 " "	bF	54	0	3.7	1.9	1.9
	18 " "	wS	32	0	15.6	0	0
B	12 June "	bF	178	0	1.1	0	3.4
	12 " "	wS	317	0	2.2	0	5.7
	18 " "	bF	54	0	3.7	0	5.6
	18 " "	wS	63	0	1.6	0	4.8
C	13 " "	bF	193	2.1	3.1	0	4.2
	13 " "	wS	293	4.8	13.0	0	2.4
	19 " "	bF	114	0	0	0	1.8
	19 " "	wS	32	3.1	6.3	0	3.1
D	13 " "	bF	82	0	3.7	0	11.0
	13 " "	wS	171	0.6	2.9	0.6	7.6
	19 " "	bF	62	0	9.7		1.6
	19 " "	wS	39	2.6	0		15.4
Check No. 1	14 " "	bF	112	0	0	0	1.8
	14 " "	wS	146	0	0	0	1.4
	20 " "	bF	72	0	0	0	0.1
Check No. 2	13 " "	bF	110	0	0	0	10.0
	13 " "	wS	241	0	0	0	2.1
	19 " "	bF	72	0	0	0	9.7

Table 6

Incidence of viruses, microsporidia and fungi in 1973 in plots sprayed in 1971 with NPV (contaminated with CPV) at Deluthier Rd.

Plot	Sample date	Tree species	Number insects examined	Percent Virus Infection NPV	CPV	Percent other organisms Micro.	Fungus
G	4 June 73	wS	82	6.1	4.9	3.7	4.9
	21 " "	wS	144	16.7	0	3.5	30.6
H	4 " "	wS	135	7.4	0	11.1	0
	21 " "	wS	162	13.6	0	3.7	15.4
Orange Rd.	14 " "	wS	165	0	7.3	10.3	26.1
Check	20 " "	wS	33	0	0	0	0

Table 7

Incidence of viruses and microsporidia in 1974 in plots sprayed in 1971 with EPV (contaminated with NPV and CPV) at Achray.

Plot	Sample date	Tree species	Number insects examined	Percent Virus Infection EPV	NPV	CPV	Percent Micro sp.
A	19 June 74	bF	79	0	2.5	1.3	8.9
	19 " "	wS	153	0.7	10.5	0	12.4
B	19 " "	bF	100	2.0	1.0	0	11.0
	19 " "	wS	203	0	3.9	0	13.3
C	19 " "	bF	100	1.0	0	0	15.0
	19 " "	wS	208	1.9	1.9	0	15.4
D	19 " "	bF	27	0	0	0	44.4
	19 " "	wS	173	0	0	0	17.9
Achray Check No. 1	20 " "	bF	102	0	0	0	17.6
	20 " "	wS	161	0	0	0.6	18.6
Achray Check No. 2	19 " "	bF	91	0	0	0	19.8
	19 " "	wS	235	0	0	0.4	12.8

Table 8

Incidence of viruses and microsporidia in 1974 in plots sprayed in 1971 with NPV (contaminated with CPV) at Deluthier Road.

Plot	Sample date	Tree species	Number insects examined	Percent Virus Infection NPV	Percent Virus Infection CPV	Percent other Organisms Microsp.	Percent other Organisms Fungus
G	18 June 74	wS	141	6.4	1.4	19.9	0.7
	26 " "	wS	82	3.7	0	12.2	1.2
H	18 " "	wS	78	2.6	0	24.4	2.6
	26 " "	wS	52	5.8	0	0	21.2
Alice Station Check	18 " "	bF	76	0	0	7.9	0
	18 " "	wS	78	0	0	24.4	0
Orange Rd. Check	20 " "	wS	106	0	4.7	30.2	0

Table 9

Incidence of viruses and microsporidia in 1975 in plots sprayed in 1971 with EPV (contaminated with NPV and CPV) at Achray.

Plot	Sample date	Tree species	Number insects examined	Percent Virus Infection NPV	CPV	EPV	Percent Microsp.
A	11 June 75	bF	124	6.5			21.8
		wS	125	3.2		0.8	28.8
	24 " "	bF	24	16.7			25.0
		wS	27	11.1			14.8
B	11 June "	bF	172		0.6		32.6
		wS	178	3.4	0.6	1.1	38.2
	24 " "	bF	27				11.1
		wS	41	7.3			22.0
C	11 June "	bF	150	5.3	0.7	0.7	24.7
		wS	72	6.9	1.4		41.7
	24 " "	bF	51	3.9			17.7
		wS	32	15.6		6.3	18.8
D	11 June "	bF	178	1.1			28.1
		wS	97	3.1			23.7
	24 " "	bF	42	2.4			38.1
		wS	21	4.8			19.1

Table 10

Incidence of viruses and microsporidia in Achray check areas in 1975

Plot	Date of sample	Tree species	Number insects examined	Percent Virus Infection NPV	% Microsp.
1	11 June 75	bF	53	1.9	20.8
		wS	38		29.0
	24 June 75	bF	18		16.7
		wS	6		16.7
2	11 June 75	bF	70		24.3
		wS	65		24.6
	24 June 75	bF	15	6.7	20.0
		wS	10	10.0	40.0
Lone Creek	12 June 75	bF	12		33.3
		wS	17		23.5

Table 11

Incidence of viruses and microsporidia in 1975 in plots sprayed in 1971 with NPV (contaminated with CPV) at Deluthier Rd.

Plot	Date of sample	Tree species	Number insects examined	Percent Virus NPV	Percent Virus CPV	Percent Microsp.
G	12 June 75	wS	91	9.9		29.7
	25 " "	wS	94	21.3		12.8
H	12 " "	wS	136	7.4		39.0
	25 " "	wS	78	9.0		18.0
Alice Station Check	12 June 75	bF	45	0		37.8
		wS	47	0		44.7
	25 June 75	bF	25	0		40.0
		wS	13	0		53.9
Orange Rd. Check	12 June 75	wS	27	3.7		48.2
	25 " "	wS	19			36.8

DISCUSSION

At Achray EPV with NPV and CPV contaminants was sprayed in 1971 and in the 4 following years there were only low levels of the EPV and the NPV contaminant was considerably more prevalent. A histogram illustrating the level of EPV in plot C, where the virus was applied on second instar larvae, is shown in Fig. 1, and in spite of excellent initial infection on white spruce only low levels were recorded in the following 4 years. The level of NPV in the same plot is illustrated in a histogram in Fig. 2 and although the level was lower than the EPV in the year of application, it increased in the following two years, declined in 1974 but increased again in 1975. The application of EPV in 1971 on fourth instar larvae on plot A gave very poor initial infection and only traces of this virus were found in 1973, 1974 and 1975 as shown in the histogram in Fig. 4. EPV is slow to develop and, because of the late application larvae pupated before mortality occurred. However, in the same plot a low initial infection from NPV, which was a contaminant, increased in 1972 and has held a steady level until 1975 as shown in Fig. 4.

At Deluthier Rd. where NPV was applied with a CPV contaminant, the CPV caused considerable infection in the

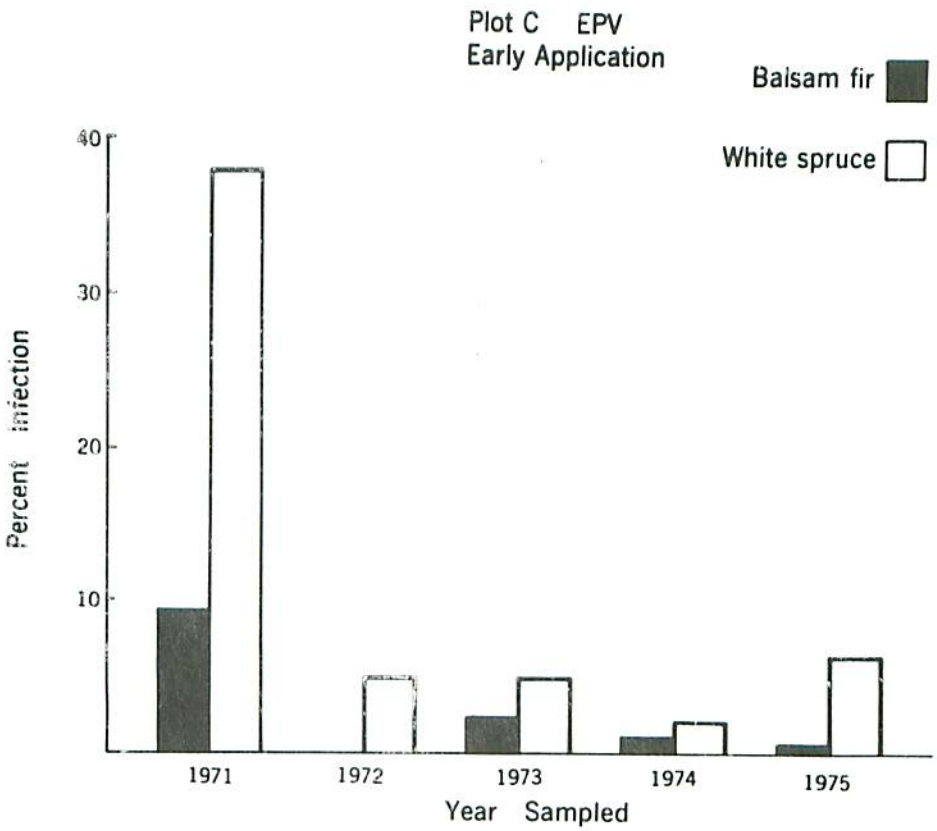

Fig. 1. Persistence of entomopoxvirus in plot C over a 5 year period. Plot was sprayed with 240 billion inclusion bodies/ha when larvae were mainly in the second instar in 1971 and nuclear polyhedrosis virus and cytoplasmic polyhedrosis viruses were present as contaminants of the suspension.

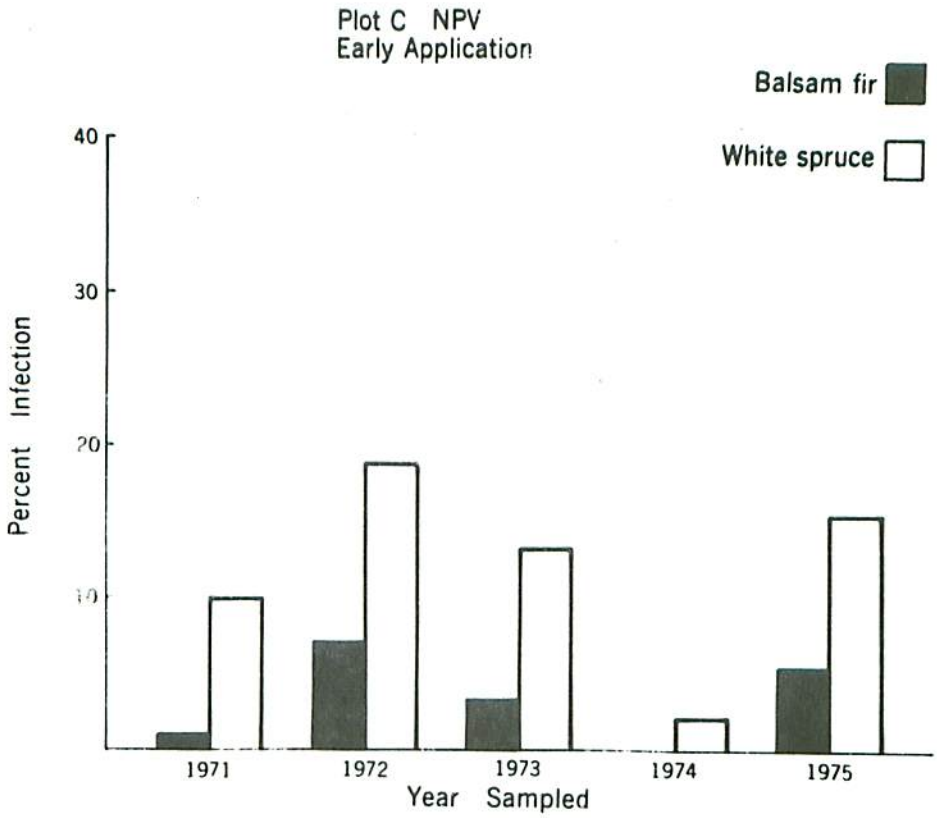

Fig. 2. Persistence of nuclear polyhedrosis virus in plot C over a 5 year period. This virus was present in the entomopoxvirus suspension sprayed in 1971.

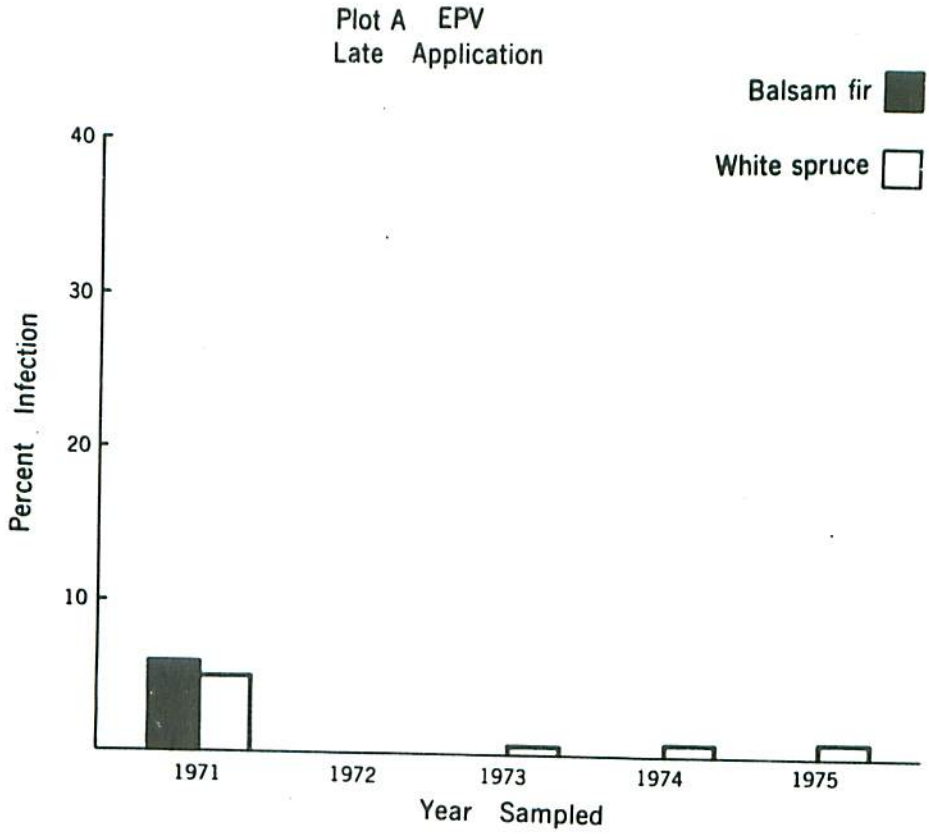

Fig. 3. Persistence of entomopoxvirus in plot A over a 5 year period. Plot was sprayed with 240 billion inclusion bodies/ha when larvae were mainly in the fourth instar in 1971 and nuclear polyhedrosis and cytoplasmic polyhedrosis viruses were present as contaminants of the suspension.

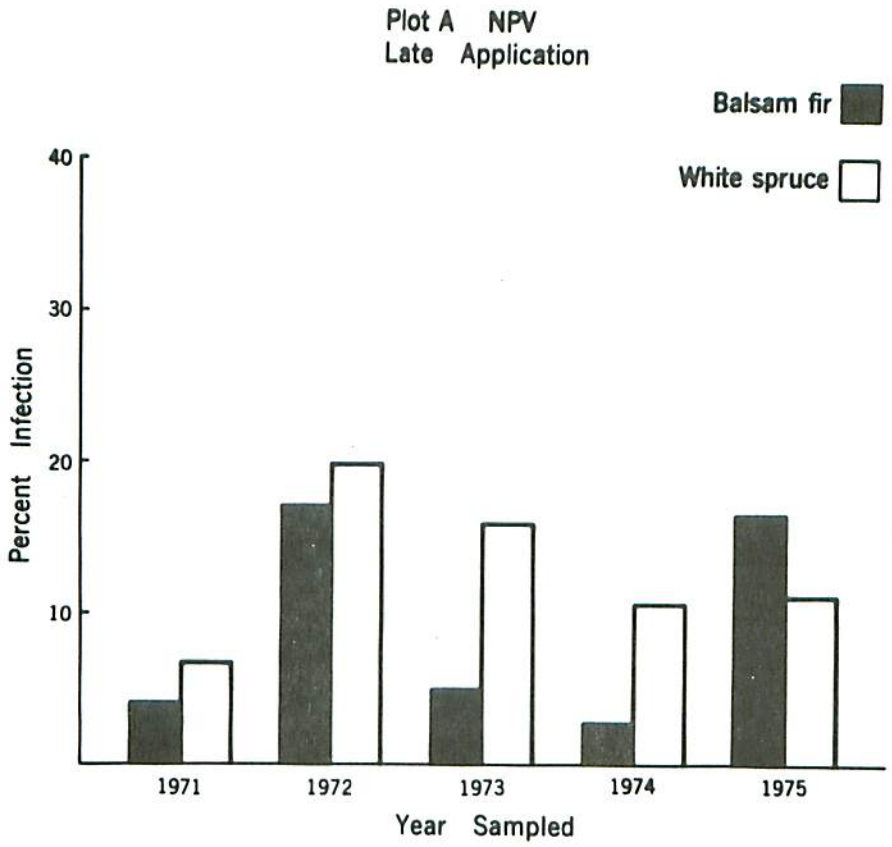

Fig. 4. Persistence of nuclear polyhedrosis virus in plot A over a 5 year period. This virus was present in the entomopoxvirus suspension sprayed in 1971.

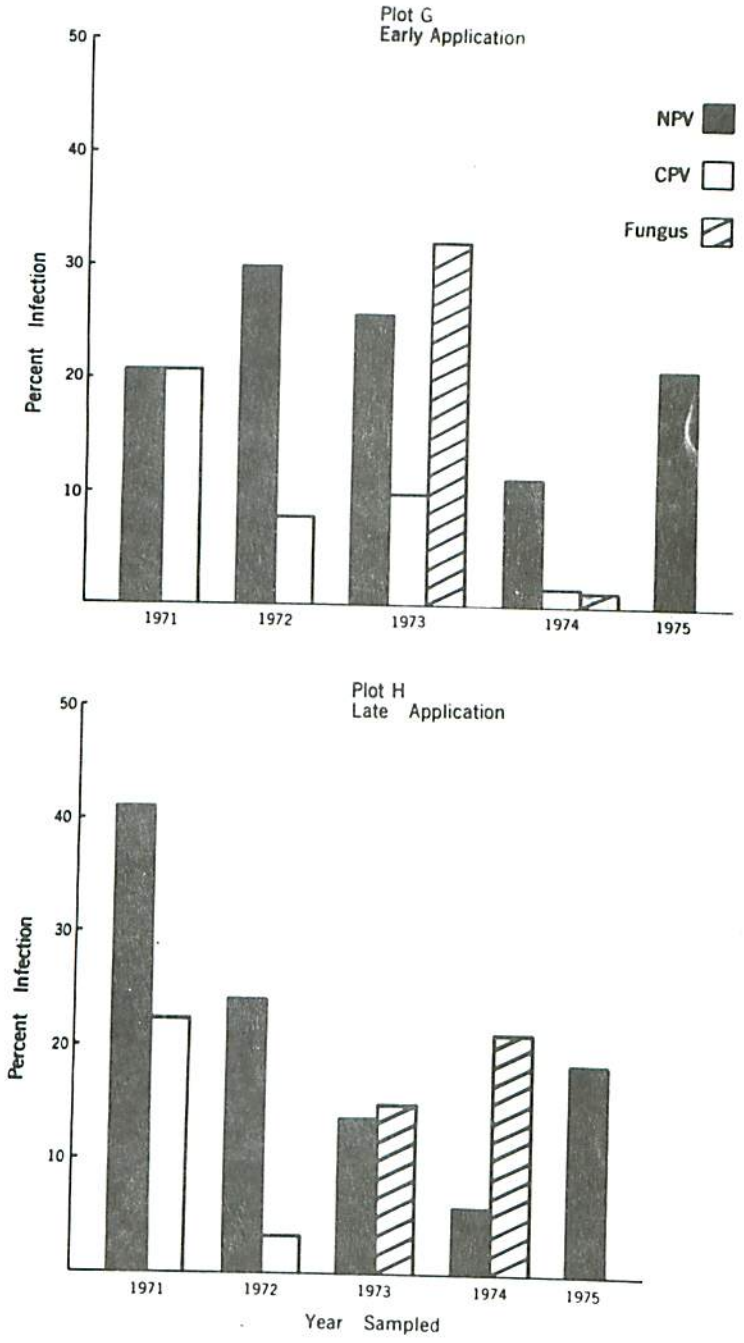

Fig. 5. Levels of nuclear and cytoplasmic polyhedrosis virus and a fungus in white spruce populations over a 5 year period following application of the nuclear polyhedrosis virus at a dosage of 720 polyhedra/ha. The cytoplasmic polyhedrosis virus was present as a contaminant. Plot G was sprayed when larvae were mainly second instar and plot H when they were mainly fourth.

year of application but declined thereafter. It disappeared in plot H in 1972 but persisted in plot G until 1974 disappearing in 1975. The levels of NPV, CPV and a fungus found in plots G and H are illustrated in Fig. 5 and it can be seen that the NPV has persisted well in these white spruce plantations.

It is hoped to determine the exact levels of the NPV contaminant in the EPV preparation and the CPV in the NPV preparation by electron microscopy. The results obtained on plots G and H are the best obtained in 5 seasons of field trials and it is possible that the CPV contaminant enhanced the establishment of the NPV in the spruce budworm population.

These population reduction studies have shown that the viruses have had an impact on the spruce budworm population for 5 consecutive years. Until 1975, defoliation of white spruce and balsam fir was, generally speaking, less in the virus carryover areas than in the checks. However, in 1975 there was little foliage protection in spite of substantial infection and larval mortality due to the carryover of NPV. Specific reasons for the lack of foliage protection in 1975 are not evident. High populations of spruce coneworm (Dioryctria reniculella (Grote)) were present in all study areas in 1975 but equally high numbers of this species were also recorded in

1974. The lack of foliage protection and the overall high levels of defoliation may somehow be related to the exceptional warm and sunny weather that occurred in May, particularly the latter part of May from the 17th to the 25th. This was the warmest May on record for this part of Ontario and budworm developed rapidly, in advance of foliage development. Consequently, it seems probable that most of the defoliation occurred before the virus had an impact on the budworm populations.

In 1975, NPV was found in the check areas at Achray for the first time and, although the sample was too small to be significant it is probable that the virus had spread from the treated areas. A similar phenomenon was noted on checks located close to treated areas on Manitoulin Island in 1975 (Cunningham et al., 1975). If this virus does indeed spread from the treated areas its usefulness as a biological control agent is greatly enhanced.

The levels of microsporidia were recorded for general interest when viruses were diagnosed microscopically and their increase year after year as the spruce budworm infestation ages is clearly shown. At Achray the level of microsporidia increased from 5.3% in 1973 to 22.7% in 1974 and 25.2% in 1975 and at Deluthier Rd. from 4.6% in 1972 to 19.1% in 1974 and 36.1% in 1975.

The data in this report clearly illustrates that NPV, once introduced into a spruce budworm population, persists from one year to the next and continues to have an impact. Although results are not dramatic, it probably gives sufficient control to reduce the population to a level where tree mortality is prevented and this effect may continue until other factors, such as weather, fungi, microsporidia and parasites, cause the final collapse of the infestation.

REFERENCES

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

Cunningham, J.C., W.J. Kaupp, J.R. McPhee, G.M. Howse and A.A. Harnden. 1975. Aerial application of nuclear polyhedrosis virus against spruce budworm on Manitoulin Island, Ontario in 1974 and a survey of the impact of the virus in 1975. Can. For. Serv. Sault Ste. Marie Inf. Rep. IP-X-8.

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

Howse, G.M., C.J. Sanders, A.A. Harnden, J.C. Cunningham, F.T. Bird and J.R. McPhee. 1973. Aerial application of viruses against spruce budworm, 1971. Part A: Impact in the year of application (1971). Part B: Impact in the year following application (1972). Can. For. Serv. Sault Ste. Marie Inf. Rep. O-X-189.

Martineau, R. and Paul Benoit. 1973. A sampling technique for estimating numerical trends in larval populations of insect defoliators on conifers. II. Modification and operational use of the technique

for extensive sampling of spruce budworm populations in Quebec. Phytoprotection 54, 23-31.