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E.G. Kettela and Victor Steel

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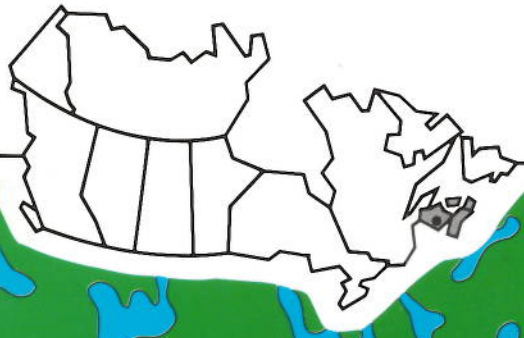
Maritimes Forest Research Centre



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RESULTS OF THE 1980 WOODLOT PROTECTION PROJECT WITH *BACILLUS THURINGIENSIS KURSTAKI* IN NEW BRUNSWICK

by

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Information Report M-X-150

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ABSTRACT

In 1980, Forest Protection Limited on behalf of the New Brunswick Department of Natural Resources obtained an easement of the 1-mile (1.6 km) setback, which had been established for conventional budworm spraying in 1977, for the application of Bacillus thuringiensis kurstaki (B.t.k.) to severely damaged private woodlots. Of approximately 400 requests received, it was possible in the limited time available to treat 251 woodlots, 148 of which were sampled for prespray population levels and postspray foliage preservation under the direction of the Maritimes Forest Research Centre. Thuricide 16B and Novabac-3 were applied at 20 BIU in 11.5 L formulation/ha by agricultural fixed-wing aircraft or helicopter. The results were generally poor to indifferent, ranging from 40 to 60% of woodlots showing detectable foliage protection. The report discusses some of the possible reasons for these results and the adequacy of assessment procedures.

RESUME

En 1980, on a proposé d'utiliser Bacillus thuringiensis kurstaki (B.t.k.) pour protéger, contre la tordeuse des bourgeons de l'épinette, des boisés privés de la zone périphérique de 1.6 km (1 mille) de toute habitation permanente. L'épandage aérien a été confié à Forest Protection Limited. Environ 400 demandes de traitement ont été reçues de propriétaires et leur bien-fondé évalué. Au total, 251 boisés ont été traités, et 148 ont fait l'objet d'une évaluation des effectifs larvaires et du degré de défoliation avant le traitement. La préparation de B.t.k. renfermait du Thuricide 16B et du Novabac 3 et elle a été appliquée à l'aide d'un avion d'épandage agricole et d'un hélicoptère à raison de 11,5 L/ha (20 x 10^9 UI/ha). Le résultat du traitement a été mesuré par comparaison de la défoliation réelle causée par un effectif donné dans les blocs traités avec celle de zones témoins. La proportion des boisés sensiblement protégés variait de 40 à 60% selon les régions de la province. Les résultats variables provenaient en partie des difficultés à évaluer le degré de défoliation et les effectifs quand ceux-ci étaient peu nombreux et de modes différents d'épandage. La grand variété de types de forêts, de conditions forestières et des effectifs de la tordeuse dans les boisés ont aussi contribué au succès inégal du traitement.

INTRODUCTION

By 1977 a set-back zone consisting of most forest lands within 1.6 km from year-round habitation, 3 km from water supplies, 4 to 8 km from blueberry fields, and all federally owned lands was established in areas designated to be sprayed for protection against the spruce budworm, Choristoneura fumiferana (Clem.). Insecticides were not to be applied aerially by Forest Protection Limited (FPL) for control of spruce budworm damage in these areas. This removed almost all privately owned woodlots from protection.

In response to pressure from private woodlot owners and their local and provincial associations, the New Brunswick Department of Natural Resources (NBDNR) with the consent of the New Brunswick Departments of Health and Environment agreed to resume a limited spray program for private woodlots within the set-back zones, in 1980. Assessment of this woodlot protection program was carried out by the Maritimes Forest Research Centre (MFRC) with professional and technical staff seconded to MFRC by FPL. The maximum size of the project was specified as 20 240 ha using Bacillus thuringiensis Berliner var. kurstaki.

METHODS

Selection of treatment areas

All privately owned woodlots were eligible to be included in the area designated for treatment. Responsibility was left with the owners to send requests for inclusion to NBDNR. All requests were identified by assessment number, located on 1:20,000 scale forest cover type maps and forwarded to Forest Protection Limited, where they were located on 1:20,000 scale aerial photographs. Approximate locations are shown in Fig. 1.

Suitability for treatment was assessed first by aerially surveying each lot and recording forest type, predominant budworm susceptible species, general tree vigor, and an estimate of the percentage of dead or moribund trees. A recommendation was made by the observer as to suitability for treatment based on the presence of susceptible species in a condition likely to benefit from protection.

Concurrently, NBDNR and FPL assessed conditions from aerial photographs. Finally, a ground survey of as many woodlots as possible was undertaken to determine budworm populations and to verify the woodlot condition.

The criteria for deletion of woodlots were

1) forested area consisting of less than 25% budworm susceptible species;

2) tree conditions indicating little possibility of benefits from protection;

3) forested area less than 20.2 ha;

4) budworm populations of less than 2/45-cm branch;

5) operationally impractical because of shape.

The decision to delete a woodlot was made by NBDNR in consultation with FPL and with technical advice from the Canadian Forestry Service (CFS). The number of woodlots, hectares treated, and the number sampled for budworm populations are presented by district in Table 1. Districts 1K and 1L have been combined as district 1, 3E, 3H, and 3I as district 3, and 5A and 5B as district 5, because of the small number of treated woodlots in each.

Application of B.t.k

The B.t.k. was formulated (a) 1 part Thuricide 16B, 1 part water and 1/600 parts Chevron Sticker, or (b) 1 part

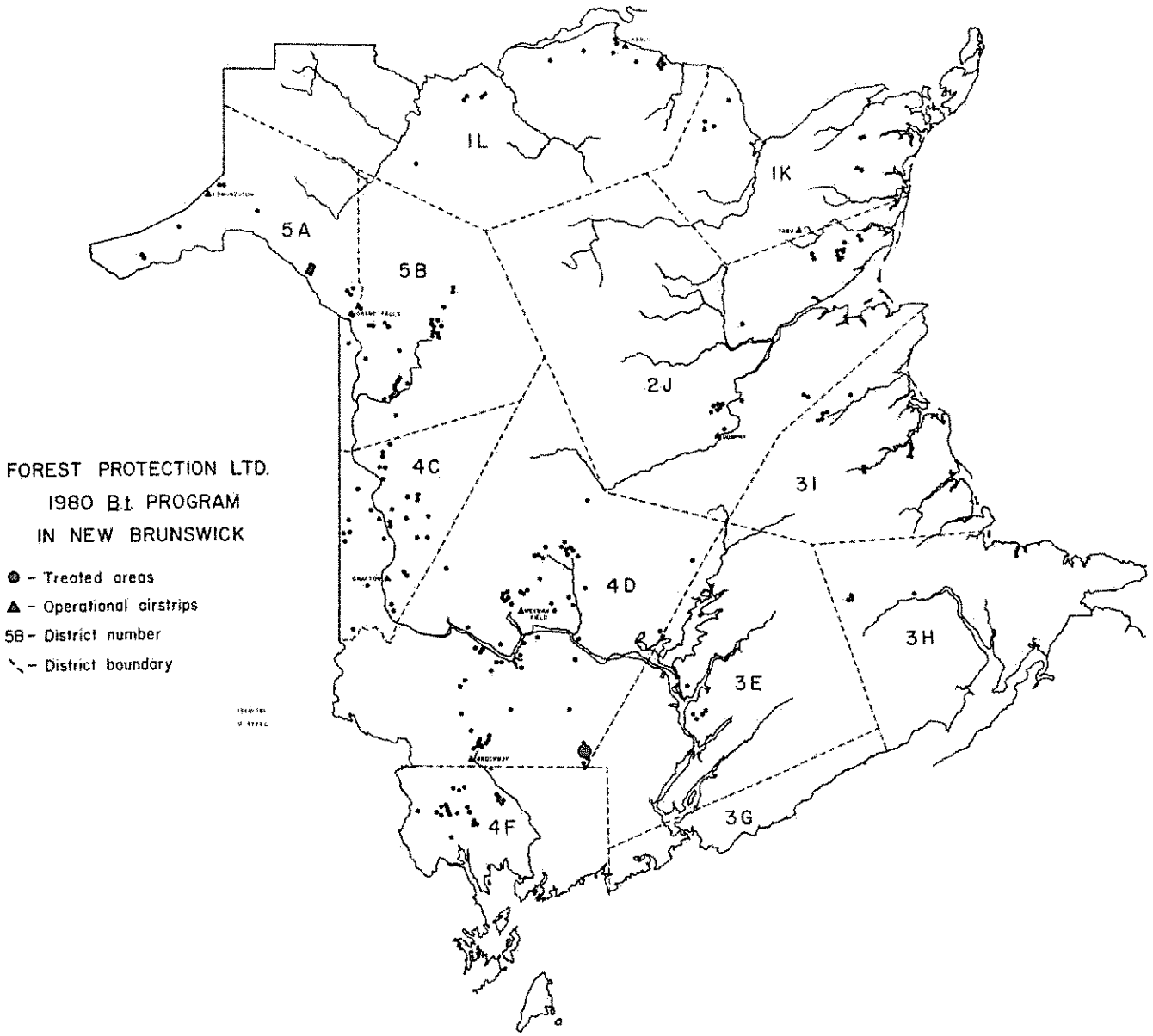


Fig. 1. Districts, location of treated woodlots and airstrips used for the B.t.k. program in New Brunswick

Table 1. Number of woodlots treated, hectares treated, and number sampled for budworm populations by district

	Number of woodlots		
District	Treated	Hectares treated	Sampled
1	26	1050	12
2J	24	1144	12
3	17	607	12
4C	31	1450	23
4D	79	3580	44
4F	26	1200	21
5	48	1500	24
Total	251	10 531	148

Novabec 3 (Cyanamid of Canada), 3 parts water and 1/1600 part Chevron Sticker. These formulations were applied at a nominal rate of 11.5 L/ha to give 20 BIU per hectare, by either fixed-wing agricultural aircraft (Piper Pawnee, Stearman, or Cessna AgTruck) or by helicopter (Bell Jet Ranger 206). It should be noted that there were insufficient woodlots treated with Novabac to provide an adequate basis for comparison of results.

The fixed-wing spray aircraft worked singly or in teams of two, guided by one or two pointer aircraft, Cessna 172s, in visual and radio contact with the spray team. The pointers navigated on the block by use of 1:20,000 scale aerial photographs with the woodlots marked on them. The helicopter worked alone and was used for woodlots located too far from airstrips to make use of the fixed-wing aircraft practical. The effective swath width of the fixed-wing aircraft was 30.5 m, and that of the helicopter was 20 m. The atomization system was boom and nozzle for all the fixed-wing aircraft except the Cessna AgTruck, which was equipped with four Micronair AU3000 rotary atomizers. The helicopter spray apparatus was a bucket equipped with a boom and nozzle system.

Biological Assessment

Depending on accessibility, from 1 to 10 plots per woodlot were sampled for larval populations before treatment. Some adjacent woodlots were combined for assessment purposes. Balsam fir (Abies balsamea (L.) Mill.), white spruce (Picea glauca (Moench) Voss), and red spruce (P. rubens Sarg.) were sampled, if present, and as many branches as required by the sequential sample method (Cameron 1963; Beanlands 1967) were selected.

Tables 2 and 3 illustrate the population density ranges used in the sequential method to classify the larval population as low, medium, or high for balsam fir/white spruce and red spruce, respectively.

After cessation of larval feeding, each woodlot that had been sampled prior to treatment was resampled for surviving budworm population and assessed for damage from budworm feeding. Defoliation estimates were made by three methods:

1. Individual shoot defoliation Two branches were selected from each of two trees of each species present at the plot locations. All current shoots on

Table 2. Example of tally sheet used when sampling by the sequential method for determining prespray larval populations on balsam fir and white spruce (Cameron 1963)

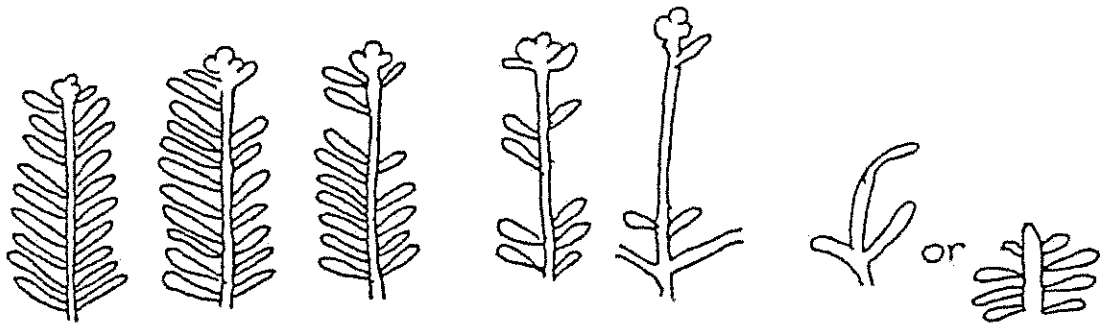
Location	Units* 1	2	3	4	5	6	7	8	9	10	Total no. budworm	Budworm/ 45-cm branch	Population category
Number													
Cumulative Number													
Number of Units	1	2	3	4	5	6	7	8	9	10			
If cumulative numbers equal or less than	–	–	2	9	16	24	32	39	46	54	Population category is low		
If cumulative numbers equal or greater than	28	36	43	50	58	65	73	80	88	95	Population category is high		

* One sample unit = one 45-cm branch tip.

Table 3. Example of tally sheet used when sampling by the sequential sample method for determining prespray larval populations on red spruce (Beanlands 1967)

Location	Units* 1	2	3	4	5	6	7	8	9	10	Total no. budworm	Budworm/ 45-cm branch	Population category
Number													
Cumulative number													
Number of Units	1	2	3	4	5	6	7	8	9	10			
If cumulative number equal or less than	–	–	3	7	11	16	20	25	29	33	Population category is low		
If cumulative number is between				23	27	32	36	40	45	49			
	–	–	–	30	43	56	69	83	96	109	Population category is medium		
If cumulative number equal or greater than	34	47	60	74	87	101	114	127	140	154	Population category is high		

*One sample unit = one 45-cm branch.



1 = no defoliation
2 = 1-25% needles removed
3 = 26-50% needles removed
4 = 51-75% needles removed
5 = 76-100% needles removed, shoot axil intact
6 = 100% needles removed, shoot axil destroyed

Fig. 2. Categories of defoliation used for estimating current defoliation by the individual shoot method.

each branch were classified and tallied into six categories of defoliation (Fig. 2).

2. Whole tree defoliation The defoliation of current shoots was estimated for each tree as a whole, sampled by the first method.

3. Transect A transect through the woodlot was followed, and at every 30.5-m interval an estimate of defoliation was made according to the whole tree method for each host species present.

Check areas were established in each assessment district and population counts and defoliation assessment were carried out at the same time as in the treated areas. Larval development was determined as close as possible to the spray date.

The aim of the project was control of budworm damage, thus defoliation is the most appropriate measure of success or failure. The defoliation estimates presented were determined by pooling the estimates made by the individual shoot, whole tree, and transect methods. The data were arranged into classes by district, host species, prespray budworm population, larval development at time of treatment, and aircraft and atomization system used.

A relationship between prespray budworm population and resulting current defoliation in the control areas was required. This was done for both fir and spruce by plotting the control data graphically and smoothing curves through the scatter of points. Figures 3 and 4 present the resulting relationship for balsam fir and spruce. For the purposes of this report 0-25% defoliation is considered light, 26-50% defoliation is moderate, and greater than 50% defoliation is severe. The relationship between prespray population and current defoliation for balsam fir was

Number of budworm per 45-cm branch	Defoliation %
0- 9	0-25
10-22	26-50
>22	>50

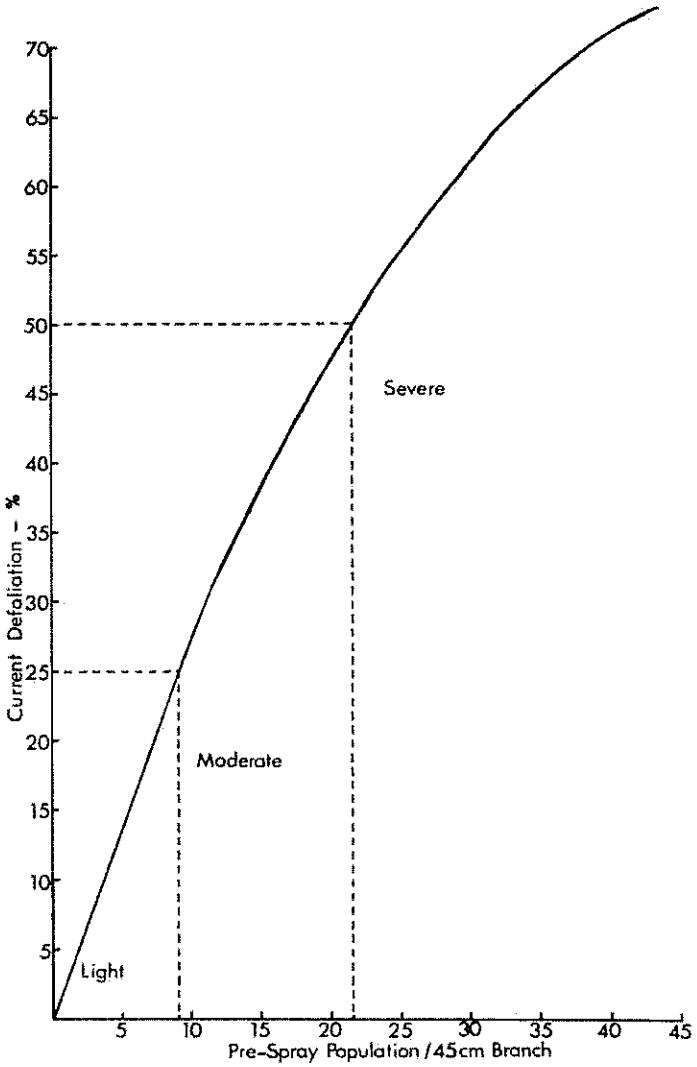


Fig. 3. Relationship between prespray budworm population and current defoliation for balsam fir control data.

The relationship for red and white spruce combined was

Number of budworm per 45-cm branch	Defoliation %
0-14	0-25
15-42	26-50
>42	>50

One point worth noting is that when similar populations of budworm occurred on both balsam fir and spruce, balsam fir suffered a higher degree of current defoliation.

The degree of success of the B.t.k. treatment in terms of foliage protection was determined by comparing the prespray population and resulting current defoliation on each sampled woodlot with the population/defoliation curves for fir and spruce generated from the control data. With equal-sized prespray populations on the treated woodlot and the control curve, the treatment was rated as

1) successful if the treatment defoliation was less than the control defoliation, and

2) unsuccessful if the treatment defoliation was equal to or greater than the control defoliation.

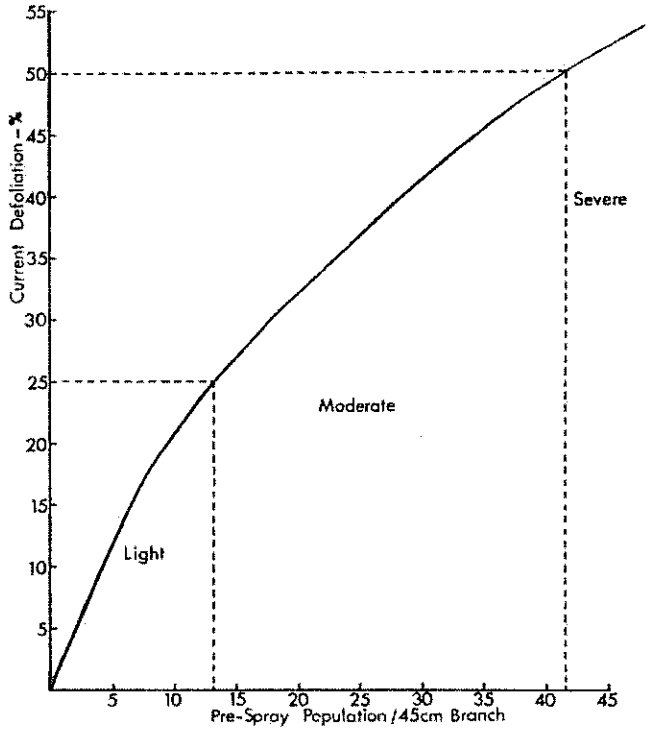


Fig. 4. Relationship between prespray budworm population and current defoliation for spruce control data.

RESULTS

Analysis by district and host

The success of the B.t.k. treatment as a percent of sampled woodlots that received adequate protection is shown in Table 4 for each district and host species. From this it becomes obvious that the proportion of treatment success varies widely between districts for all three host species. White spruce had the widest range of success, although with the exception of district 4C, the sample sizes were small, i.e., <10. Balsam fir and red spruce had similar ranges of success. Overall, spruce seemed to receive slightly higher foliage protection than balsam fir in districts 2J, 4D and 4F. The results presented in Table 4 raise two questions: Why was the success of treatment as variable as it was over all the districts? and Why did spruce seem to receive better foliage protection than balsam fir in some districts but not in others?

To examine the first question, the treatment data were stratified into population categories based on the three levels of defoliation - light, moderate, and severe. The effect of different prespray populations on the success of the treatment could then be observed. Tables 5 and 6 show treatment success and compare treatment defoliation with expected defoliation for balsam fir and spruce. The mean defoliation of balsam fir on treated blocks was greater than the expected defoliation in every district in the low population category. In the medium and high population categories, the treatment defoliation was less than the expected defoliation in almost all districts. This trend was also evident for red and white spruce. The success of treatment for both balsam fir and spruce was lowest in the low population category and increased quite dramatically in the medium and high categories. This showed that most of the variability in treatment success could be accounted for when the prespray population was in the low category. Table 7 shows the proportion of sampled woodlots in the low prespray population category, which suffered greater than 25% current defoliation in each district and indicates the degree of variation and its effect on the overall success of the program. Districts 1, 4D, and 5 had high proportions of low population/high defoliation woodlots containing balsam fir. These three districts were also those with the lowest overall treatment successes (Table 4). Similarly, districts 1 and 5 had very high proportions of woodlots containing spruce in the low population/high defoliation grouping. These were the two districts with the lowest treatment success (Table 4).

Table 4. Success of B.t.k. treatment in sampled woodlots by district and host species in percent

	Balsam fir		White spruce		Red spruce	
District	Woodlots sampled	% successful	Woodlots sampled	% successful	Woodlots sampled	% successful
1	10	20	9	33	3	0
2J	12	50	4	100	10	60
3	9	33	2	50	9	45
4C	22	77	21	100	8	62
4D	44	23	6	50	36	58
4F	21	43	7	43	11	55
5	23	17	3	0	16	6
Pooled mean		38		54		41

Table 5. Comparison of mean current defoliation on B.t.k. treated blocks with expected defoliation on controls for balsam fir

	Mean prespray budworm larvae density/45-cm branch tip								
	0 - 9%			9.1 - 22.0%			22%		
District	Treatment success	Treatment defoliation	Expected defoliation	Treatment success	Treatment defoliation	Expected defoliation	Treatment success	Treatment defoliation	Expected defoliation
1	13	26	12	---	---	---	---	---	---
2J	---	---	---	50	31	48	75	39	68
3	0	14	4	---	---	---	75	41	52
4C	---	---	---	33	44	42	88	32	69
4D	16	24	10	86	24	36	---	---	---
4F	10	16	10	80	21	35	100	22	61
5	8	38	11	29	46	36	---	---	---

Table 6. Comparison of mean current defoliation on B.t.k. treated blocks with expected defoliation on controls for red and white spruce

District		Mean prespray budworm larvae density/45-cm branch tip								
		0 - 14%			14.1 - 42%			42%		
		Treatment success	Treatment defoliation	Expected defoliation	Treatment success	Treatment defoliation	Expected defoliation	Treatment success	Treatment defoliation	Expected defoliation
1	rs	0	30	14	---	---	---	---	---	---
2J	rs	25	16	18	83	23	37	---	---	---
	ws	---	---	---	100	13	62	---	---	---
3	rs	33	12	9	67	18	34	---	---	---
4C	rs	33	18	18	67	24	42	---	---	---
	ws	---	---	---	---	---	---	100	32	72
4D	rs	52	13	17	83	19	34	---	---	---
	ws	---	---	---	---	---	---	---	---	---
4F	rs	50	12	15	---	---	---	---	---	---
	ws	20	22	16	---	---	---	---	---	---
5	rs	8	31	16	0	47	32	---	---	---

Table 7. Number and percent of sampled woodlots in the low population category with moderate to severe (>25%) defoliation resulting

	Balsam fir		Spruce	
	0 - 9 budworm/45-cm branch		0 - 14 budworm/45-cm branch	
District	No.	% with >25% defoliation	No.	% with >25% defoliation
1	8	50	8	88
2J	-	--	4	25
3	5	0	6	17
4C	-	--	5	20
4D	36	50	27	11
4F	12	17	15	20
5	15	87	15	87

There are several possible explanations for such high variability in success when the larval population was low. One explanation that cannot be dismissed is that it is a result of inaccurate sampling and unreliable defoliation estimates. This could also apply to the control data. Neither of these can be checked so this analysis must stand or fall on what is available. This leaves only those factors outside the control of the sampling crew. In low to medium population densities, assessing the level of infestation is more difficult and variable than when populations are high. Current defoliation resulting from these population levels is also more variable and difficult to predict and assess. Intertree variation is important because the sequential sample method does not require that the same trees be sampled at each visit by the sampling crew. The action of B.t. itself may contribute to variations in its success of protecting foliage. Because B.t. must be ingested by the larva to be effective, it follows that the larva must first find the contaminated foliage. At low population levels the larvae may be required to travel over more foliage than at high population levels to ingest a needle with B.t. on it. Also, there is a lower probability that the B.t. will fall on the tree near to where a budworm larva happens to be.

Analysis by Larval Development

Larval development at the time of treatment influences the efficacy of B.t.k. In another effort to explain variation in success of treatment, the data were stratified according to the development stage at treatment using a method for expressing the development stage of a population as a single percentage (Webb and McLeod 1957). This method entails weighting the proportion of larvae in each instar by the approximate cumulative time required to complete the successive stages and results in a single percentage indicating the proportion of the total development time from III instar to adult completed to that point. Use of this method, rather than showing proportions of the population in each instar, was felt to give a more concise indication of the development stage. The timing for application of B.t.k. depends on the larvae being exposed and feeding on the foliage of opening buds. This restricts the window for efficacy to III and IV instars after the larvae exit mined needles and shoots but before the worst defoliation is caused.

On examination of the percentage of woodlots experiencing successful protection, it is evident that there are no consistent differences between woodlots treated at different stages of development (Table 8). One exception is the success of treatment on spruce in district 1; the woodlots treated when <20% development was completed showed no protection effect. All remaining woodlots in the project were treated when development was >20% complete and overall, experienced similar proportions of successful treatment, although individual variation was high. Again, spruce seemed to experience slightly better protection than balsam fir.

The larval development stage at the time of treatment does not account for variations in success of treatment except to a small degree for spruce in district 1 where 11% of woodlots were treated when development was <20% complete and the treatment was unsuccessful.

Analysis by Application System

A comparison was made of the effectiveness of the three application systems used

1) fixed-wing (Pawnee, Stearman) with boom and nozzle atomization which treated 85% of sampled woodlots;

2) helicopter (Bell 206 Jet Ranger) with boom and nozzle atomization which treated 11% of sampled woodlots; and

Table 8. Percentage of woodlots treated and percentage success of treatment for each district and host species according to the proportion of the total development time from III instar to adult completed at the time of treatment (Webb and McLeod 1957). Less than 20% development indicates the presence of II instar larvae

		Proportion of total development time completed at treatment					
		Balsam fir			Spruce		
District	%	20–24	25–29	30–34	15–19	20–24	25–29
			- % -			- % -	
1	Treated	20	40	40	11		89
	Successful	100	0	0	0		38
2J	Treated	42		58		56	44
	Successful	20		72		40	100
3	Treated	40		60		50	50
	Successful	100		33		0	10
4C	Treated	100				100	
	Successful	77				100	
4D	Treated	95	5			100	
	Successful	21	50			66	
4F	Treated	100				100	
	Successful	43				55	
5	Treated	100				100	
	Successful	17				8	
Pooled	Treated	85	4	11	1	85	14
mean	Successful	38	17	43	0	62	62

3) fixed-wing (AgTruck) with Micronair AU3000 rotary atomization which treated 4% of sampled woodlots.

A summary of the treatment success for each application system is presented in Table 9. By district, there were no consistent differences between application systems. The pooled averages, however, indicate that on balsam fir the helicopter was the least effective while on spruce the fixed-wing boom and nozzle and helicopter had similar success, and fixed-wing Micronair had the lowest. The success of both the helicopter and the fixed-wing boom and nozzle systems was highly variable although the latter was consistently more effective over all districts. It was difficult to compare Micronair with the other systems because it was used to treat only a few of areas in district 5, where it was more successful than boom and nozzle.

Some of the variability of treatment success may be accounted for where more than one application system was used within a district. In district 3 when areas treated by helicopter were disregarded, the high success by fixed-wing boom and nozzle was evident. Although Table 9 does not clearly show whether any one system was more successful than the other two, it does point out that there was variable success with all systems and that possibly under different circumstances any one could be effective.

DISCUSSION

The data give some indication of the reasons for high variability in the results of the woodlot protection project. It should be emphasized at this point that the 1980 B.t.k. project was an operational project, and that the assessments were not designed to elucidate cause and effect.

The success of this project can be rated no more than poor to fair. Slightly less than 50% of all woodlots sampled received any indication of protection from budworm damage, with the rest receiving no perceptible protection. The data were variable, although this was expected since the program encompassed a wide range of forest types, initial budworm populations, and forest conditions. Among the probable reasons for the wide range in success were difficulty in sampling populations and assessing damage when budworm populations were low, and use of different application systems.

The method of assessing the success of protection was decided on after several other methods had been tried. Often an arbitrary level of defoliation is selected to determine when successful protection occurs. This way of expressing the results was deemed to be unacceptable since it in no way took into account different levels of infestation. Thus a relative measure of success was needed. After several attempts at using linear regression to illustrate a relationship between prespray population and defoliation it was found that a straight line could not express this relationship adequately. Intuitively, it was felt that the actual relationship was curvilinear increasing as the population increased and reaching a maximum at a population level where all current foliage would be destroyed. The curves presented in Figs. 3 and 4 for the control data were decided to be the best approximation for relating population and defoliation. This way of expressing success in terms of the control data was felt to be no more biased than any other. It depends on reasonably accurate counts of prespray populations, especially in low to medium populations. However, categorizing these levels accurately would mean a large increase in sampling effort.

No explanation for better protection on spruce than on fir was evident, but two points may be relevant. Both red and

Table 9. Success of B.t.k. treatment by application system for each district and for all districts combined

Application system	Treatment success by district (%)							
	1	2	3	4C	4D	4F	5	All
Fixed-wing Boom and Nozzle								
Fir	20	55	100	74	24	43	11	38
Spruce	8	77	80	88	56	50	0	54
Helicopter Boom and Nozzle								
Fir	---	---	0	100	14	---	---	24
Spruce	---	---	17	100	67	---	---	53
Fixed-wing Micronair								
Fir	---	---	---	---	---	---	40	40
Spruce	---	---	---	---	---	---	20	20

white spruce have more foliage area on a given length of branch than does balsam fir. Because of this extra foliage area, spruce may intercept more B.t.k. than fir, resulting in more being available to that population. Secondly, it is possible that in some areas conditions such as shoot growth and larval development were better for B.t.k. efficacy on spruce than on fir. This would be an excellent topic for further investigation.

It should be emphasized again that this project was operational and not research and thus specific data for comparing application systems, conditions at time of treatment, and effects of sampling methods were not collected since only an assessment of foliage protection was required. An attempt has been made here to explain the results of the project in very general terms. A more detailed explanation would require a highly controlled and monitored pilot project.

In view of the investment of dollars and manpower in this project and the basically unacceptable results obtained, it is recommended that before another operation of this type is launched, better operational usage patterns for B.t.k. should be established to yield a greater return in foliage protection for the investment.

ACKNOWLEDGMENTS

This report deals mainly with attempts to measure the efficacy of the woodlot protection project. Assessment design was provided by R. Lidstone; manpower and other resources were provided chiefly by Forest Protection Limited. F.E. Webb assisted in report presentation.

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APPENDIX 1

SUMMARY OF WOODLOTS SAMPLED IN EACH ASSESSMENT DISTRICT FOR THE 1980 B.t.k. PROJECT

1980 B.t. Project - Summary of Sampled Woodlots

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
District 1K													
1K-43-1	June 6	5.0	----	----	June 11 AM	Pawnee	Boom & Nozzle	0.0	----	0.0	43.0	33.0	21.3
1K-45	June 6	5.0	----	----	June 11 AM	Pawnee	Boom & Nozzle	0.0	----	0.0	43.0	33.0	21.3
1K-46	June 5	5.2	31.0	2.0	June 11 PM	Pawnee	Boom & Nozzle	0.0	----	0.0	19.4	12.0	23.6
District 1L													
1L-4	June 2	3.0	7.1	----	June 11 AM	Pawnee	Boom & Nozzle	0.8	1.8	----	27.3	50.3	----
1L-7	June 2	1.6	3.7	----	June 11 AM	Pawnee	Boom & Nozzle	4.2	2.0	----	19.0	35.0	----
1L-12	June 2	----	3.0	----	June 10 AM	Pawnee	Boom & Nozzle	0.5	0.2	----	8.3	13.0	----
1L-13	June 2	----	20.0	----	June 10 PM June 11 AM	Pawnee	Boom & Nozzle	1.0	0.5	----	32.5	22.0	20.0
1L-16	June 2	2.5	13.5	----	June 11 AM	Pawnee	Boom & Nozzle	0.1	0.5	----	18.0	36.0	----
1L-17	June 2	4.0	23.0	5.0	June 11 AM	Pawnee	Boom & Nozzle	0.2	----	0.0	27.7	66.0	36.0
1L-19	June 2	8.0	8.2	----	June 10 AM	Pawnee	Boom & Nozzle	0.1	1.0	----	12.3	38.0	----
1L-20-1	June 2	14.6	18.5	----	June 10 PM	Pawnee	Boom & Nozzle	0.5	1.5	----	49.3	26.0	17.0
1L-23	June 1	11.6	----	10.8	June 11 PM	Pawnee	Boom & Nozzle	0.5	----	0.0	22.5	54.0	30.0
District 2J													
2J-4-1	June 3	36.0	37.0	----	June 7 AM/PM	Pawnee	Boom & Nozzle	0.2	1.5	----	27.7	7.8	17.8
2J-4-2	June 4	20.3	----	20.5	June 8 PM	Pawnee	Boom & Nozzle	0.8	----	3.2	19.5	----	6.0
2J-4-3	June 3	30.8	40.0	29.0	June 8 AM/PM	Pawnee	Boom & Nozzle	3.7	0.8	0.8	31.6	15.3	12.5
2J-4-4	June 3	21.5	31.0	----	June 8 PM	Pawnee	Boom & Nozzle	0.9	0.2	----	16.9	5.0	10.0
2J-6-1,2	June 3	5.6	16.4	7.7	June 6 PM June 7 AM June 8 AM	Pawnee	Boom & Nozzle	1.5	0.8	3.0	35.9	24.1	12.1

1980 B.t. Project - Summary of Sampled Woodlots

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
District 2J													
2J-10-2	June 7	6.2	----	13.0	June 11 AM	Pawnee	Boom & Nozzle	6.0	----	4.0	61.3	20.0	26.2
2J-11	June 7	10.8	----	4.6	June 11 AM	Pawnee	Boom & Nozzle	0.2	----	0.2	29.0	----	13.0
2J-14	June 7	15.0	----	18.2	June 11 AM	Pawnee	Boom & Nozzle	10.0	----	6.5	61.3	20.0	26.2
2J-17	June 5	10.6	----	5.5	June 11 AM	Pawnee	Boom & Nozzle	1.0	----	1.0	35.0	3.0	13.4
2J-20	June 6	40.2	----	25.9	June 11 AM	Pawnee	Boom & Nozzle	1.3	----	0.7	25.0	10.0	14.8
2J-26-1	June 3	38.0	31.0	20.0	June 8 AM	AG Truck	Micronair	20.2	----	6.5	70.7	----	52.0
2J-26-2	June 3	12.5	35.0	37.0	June 8 AM	Pawnee	Boom & Nozzle	0.2	----	3.8	27.0	----	24.0
District 3													
3E-1	May 13	14.0	----	14.0	May 27 PM	Helicopter	Boom & Nozzle	0.2	----	0.5	47.7	50.0	26.3
3E-11	May 15	0.7	----	0.0	May 28 PM	Helicopter	Boom & Nozzle	0.2	----	0.0	9.0	3.0	22.5
3E-14-3	May 15	1.8	----	1.0	May 27 PM	Helicopter	Boom & Nozzle	0.0	----	0.0	20.0	----	3.0
3E-15	May 15	1.0	----	2.2	May 29 PM	Helicopter	Boom & Nozzle	0.0	----	0.0	11.7	----	10.7
3H-2-1,2,3	May 30	2.0	----	3.4	June 6 PM June 7 AM	Helicopter	Boom & Nozzle	0.6	0.3	0.6	4.0	10.2	5.7
3H-17	May 30	1.8	----	6.9	June 7 AM	Helicopter	Boom & Nozzle	0.8	----	0.6	23.3	----	20.6
3I-8-2	June 4	33.0	34.0	18.8	June 8 AM	Pawnee	Boom & Nozzle	0.5	----	1.2	62.5	53.0	9.0
3I-9-3	June 5	33.0	----	32.2	June 8 AM	Pawnee	Boom & Nozzle	1.0	----	0.9	35.5	----	19.8
3I-13-1,2	June 4	11.8	17.1	7.0	June 7 AM	Pawnee	Boom & Nozzle	2.8	----	4.6	18.0	61.0	7.0
District 4C													
4C-47-1	May 26	32.0	----	----	June 4 AM/PM	Pawnee	Boom & Nozzle	0.0	----	---	28.0	----	----
4C-47-2	May 26	29.8	51.0	81.0	June 4 PM	Pawnee	Boom & Nozzle	0.5	----	0.8	18.0	63.0	69.0
4C-48-1,2	May 30	19.0	48.5	----	June 3 PM	Helicopter	Boom & Nozzle	0.0	0.2	---	37.3	[illegible]	----

1980 B.t. Project - Summary of Sampled Woodlots

District 4C

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
4C-49-2	May 28	40.0	52.0	----	June 6 AM	Pawnee	Boom & Nozzle	0.1	0.2	---	17.7	17.7	----
4C-51	May 28	40.0	52.0	----	June 6 AM	Pawnee	Boom & Nozzle	0.1	0.2	---	17.7	17.7	----
4C-53-1	May 31	50.5	38.0	----	June 4 PM	Pawnee	Boom & Nozzle	0.0	0.0	---	11.8	12.3	----
4C-56-18	May 26	15.8	41.5	----	June 4 PM	Pawnee	Boom & Nozzle	0.1	0.2	---	56.0	29.8	----
4C-56-2	May 26	15.4	33.8	----	June 4 PM	Pawnee	Boom & Nozzle	0.2	0.8	---	37.5	23.8	----
4C-57-1	May 24	45.5	81.5	52.0	June 3 PM June 6 AM	Helicopter	Boom & Nozzle	0.0	0.1	---	69.0	42.7	----
4C-59	May 25	30.0	52.5	39.0	May 30 AM	Pawnee	Boom & Nozzle	0.4	0.8	---	18.6	46.4	34.0
4C-66-2	May 30	45.5	35.0	----	June 4 PM June 6 AM	Helicopter	Boom & Nozzle	0.0	0.0	---	50.4	42.4	----
4C-67	May 28	40.5	69.0	29.0	June 6 AM	Pawnee	Boom & Nozzle	0.0	0.0	---	16.5	16.0	3.0
4C-81	May 26	39.0	37.0	----	June 4 PM	Pawnee	Boom & Nozzle	0.0	0.2	---	33.5	40.0	----
4C-83	May 31	36.0	53.5	----	June 5 AM	Pawnee	Boom & Nozzle	0.0	0.5	---	67.0	65.5	----
4C-84-18	May 31	43.5	42.0	----	June 6 AM	Pawnee	Boom & Nozzle	0.2	0.0	---	32.8	10.3	----
4C-86	May 28	29.5	35.0	----	June 6 AM	Pawnee	Boom & Nozzle	5.0	2.0	---	26.3	19.7	----
4C-87	May 27	29.0	51.0	6.4	June 4 PM	Pawnee	Boom & Nozzle	0.2	1.2	---	16.3	20.7	18.0
4C-90	May 25	5.4	9.7	8.6	June 6 AM	Pawnee	Boom & Nozzle	0.0	0.0	0.0	12.0	7.0	7.3
4C-92	May 26	24.0	30.3	53.6	June 3 PM	Pawnee	Boom & Nozzle	0.5	0.4	0.0	11.0	36.3	16.0
4C-94	May 25	3.1	3.8	8.4	May 30 AM	Pawnee	Boom & Nozzle	0.0	0.1	---	15.5	6.8	30.0
4C-98-2	May 27	34.0	52.5	40.0	June 5 AM	Pawnee	Boom & Nozzle	0.0	0.8	---	69.0	38.3	30.0
4C-105-2	May 26	41.6	22.3	21.0	June 4 PM	Pawnee	Boom & Nozzle	0.0	0.0	0.0	48.0	40.0	39.0

1980 B.t. Project - Summary of Sampled Woodlots

District 4D

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
4D-1	May 17	1.4	----	----	May 29 PM	Pawnee Stearman	Boom & Nozzle	0.0	----	----	0.0	----	-----
4D-4-2	May 21	0.6	----	----	May 28 AM	Helicopter	Boom & Nozzle	0.5	----	0.2	18.2	----	19.5
4D-5-1	May 15	1.5	----	6.8	June 2 AM/PM	Helicopter	Boom & Nozzle	4.3	----	2.0	36.0	8.0	16.0
4D-7-1,2	May 20	3.7	----	22.5	May 28 PM	Pawnee	Boom & Nozzle	1.8	----	0.5	60.7	----	46.0
4D-9	May 16	23.0	----	23.0	May 31 AM	Pawnee	Boom & Nozzle	6.5	----	4.5	56.7	----	34.3
4D-10-2	May 20	3.7	----	22.5	May 28 PM	Pawnee	Boom & Nozzle	0.5	----	0.5	36.0	----	12.5
4D-11	May 16	7.0	1.0	----	May 31 AM	Pawnee	Boom & Nozzle	3.0	3.5	----	17.0	22.0	----
4D-12-1A	May 17	4.0	----	1.5	May 29 PM	Pawnee	Boom & Nozzle	1.0	----	0.0	5.1	----	4.1
4D-12-2	May 17	6.2	----	3.3	May 28 AM May 30 AM	Stearman	Boom & Nozzle	2.5	----	0.2	35.0	----	22.7
4D-12-4	May 16	2.2	----	3.4	May 27 PM May 28 AM	Stearman Pawnee	Boom & Nozzle	1.5	----	0.0	20.8	----	12.0
4D-12-8	May 16	0.5	----	1.0	May 30 AM	Pawnee	Boom & Nozzle	1.8	----	----	31.7	----	10.0
4D-12-12	May 16	5.0	----	12.5	May 30 AM June 3 PM	Stearman Pawnee	Boom & Nozzle	0.2	----	0.2	13.3	----	2.1
4D-12-17	May 20	0.4	----	6.7	June 2 PM	Stearman	Boom & Nozzle	3.5	----	4.5	54.3	----	20.3
4D-12-18	May 15	2.3	----	0.0	June 1 PM	Pawnee	Boom & Nozzle	1.8	0.8	0.0	53.7	----	30.0
4D-12-19	May 16	6.8	----	18.5	May 30 AM	Stearman	Boom & Nozzle	0.6	0.8	4.3	12.9	21.8	20.7
4D-12-20	May 15	2.7	----	3.7	May 31 AM June 2 AM	Helicopter	Boom & Nozzle	0.5	----	0.0	35.3	----	2.1
4D-15	May 17	0.5	----	0.4	May 29 AM	Stearman	Boom & Nozzle	0.4	----	0.4	36.0	----	32.0
4D-17-1	May 20	4.0	----	5.6	May 28 AM	Pawnee	Boom & Nozzle	2.3	----	2.3	53.0	----	8.0
4D-18-2	May 16	10.0	----	5.0	May 29 AM	Pawnee	Boom & Nozzle	4.0	----	2.0	29.3	-----	11.1

1980 B.t. Project - Summary of Sampled Woodlots

District 4D

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
4D-21-2	May 20	0.6	----	1.4	May 29 AM	Pawnee	Boom & Nozzle	1.8	----	0.6	20.0	----	10.8
4D-28	May 14	17.0	----	23.0	June 2 PM	Pawnee	Boom & Nozzle	4.6	----	5.0	13.3	----	20.0
4D-29-1	May 16	10.5	4.0	----	June 1 PM	Pawnee	Boom & Nozzle	1.1	----	----	18.7	23.3	----
4D-31	May 20	9.8	----	29.4	June 2 PM June 3 PM	Stearman Pawnee	Boom & Nozzle	0.9	----	4.9	18.0	----	19.8
4D-34	May 15	3.0	----	31.0	June 2 AM	Pawnee	Boom & Nozzle	5.8	----	0.0	31.7	----	2.4
4D-35	May 15	1.3	----	14.0	June 2 AM	Pawnee	Boom & Nozzle	7.5	----	0.0	46.4	----	2.4
4D-36	May 20	0.5	----	6.6	May 31 AM	Helicopter	Boom & Nozzle	6.8	----	----	27.0	----	9.0
4D-38	May 20	20.0	----	9.0	May 30 AM	Helicopter	Boom & Nozzle	0.5	----	3.0	26.7	----	12.0
4D-39	May 20	3.7	22.5	----	May 28 AM	Pawnee	Boom & Nozzle	1.3	0.8	----	7.7	6.1	----
4D-40-1	May 20	3.0	----	5.0	May 30 AM	Helicopter	Boom & Nozzle	1.2	----	0.6	20.0	----	17.0
4D-40-2	May 20	2.5	----	11.0	May 30 AM	Helicopter	Boom & Nozzle	4.3	----	1.5	35.0	----	13.0
4D-41-2	May 20	7.0	----	7.5	June 2 AM	Pawnee	Boom & Nozzle	1.8	----	0.3	23.0	----	33.3
4D-41-3	May 20	0.8	----	----	May 29 PM	Pawnee	Boom & Nozzle	3.8	----	0.3	26.3	----	14.7
4D-41-5	May 20	12.0	----	20.0	May 29 PM	Pawnee	Boom & Nozzle	5.4	----	0.3	41.4	----	11.2
4D-44-2	May 20	4.0	----	8.4	May 29 AM	Pawnee	Boom & Nozzle	2.3	----	0.8	40.3	----	9.3
4D-44-4	May 20	1.7	0.9	----	May 29 AM/PM	Pawnee	Boom & Nozzle	0.25	0.25	----	9.4	5.1	----
4D-46	May 16	0.8	----	7.4	May 30 AM	Pawnee Stearman	Boom & Nozzle	3.3	----	2.5	26.4	----	11.0
4D-68-12	May 21	4.5	----	13.7	June 2 AM/PM	Pawnee Stearman	Boom & Nozzle	3.9	----	1.4	19.7	----	19.0
4D-68-13	May 20	2.4	----	20.6	June 2 AM	Stearman	Boom & Nozzle	1.1	----	0.0	18.7	----	16.0
4D-68-17	May 21	6.7	----	17.2	June 2 PM	Stearman Pawnee	Boom & Nozzle	2.2	----	0.6	27.3	----	18.0
4D-68-18	May 21	1.9	----	17.8	June 2 AM/PM	Stearman Pawnee	Boom & Nozzle	2.9	----	1.4	15.5	----	17.0

1980 B.t. Project - Summary of Sampled Woodlots

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
District 4D													
4D-74	June 2	20.2	21.8	20.3	June 2 AM	Pawnee	Boom & Nozzle	2.2	2.5	2.5	19.3	20.3	15.1
4D-79	May 21	4.0	18.0	-----	June 2 AM	Pawnee	Boom & Nozzle	3.0	8.7	-----	18.0	13.0	----
4D-103	May 20	5.0	-----	6.0	June 2 AM	Pawnee	Boom & Nozzle	1.4	----	0.8	15.7	----	5.7
4D-106	May 21	2.0	----	6.6	June 3 PM	Pawnee	Boom & Nozzle	0.0	----	0.2	15.0	----	19.0
District 4F													
4F-12-25	May 23	2.6	-----	11.7	June 6 PM	Pawnee	Boom & Nozzle	0.0	----	1.0	8.0	8.0	12.3
4F-12-29	May 22	5.5	2.1	----	June 7 AM	Pawnee	Boom & Nozzle	0.0	0.0	0.0	5.0	23.3	----
4F-25-1	May 21	0.7	----	5.4	June 5 PM	Pawnee	Boom & Nozzle	0.0	----	0.0	12.0	----	16.0
4F-61-3	May 22	2.5	----	0.5	June 3 PM	Stearman	Boom & Nozzle	0.0	-----	0.5	9.0	----	12.3
4F-62-1	May 22	4.4	----	8.5	June 6 AM	Pawnee	Boom & Nozzle	0.0	----	1.0	83.5	----	33.0
4F-62-2	May 22	3.7	4.6	----	June 6 AM	Pawnee	Boom & Nozzle	2.0	3.0	----	22.5	----	----
4F-63-1	May 22	5.2	-----	11.4	June 6 AM/PM	Stearman Pawnee	Boom & Nozzle	0.0	-----	0.0	15.0	----	8.5
4F-63-2	May 23	10.6	----	3.2	June 6 AM	Stearman	Boom & Nozzle	4.5	----	3.8	12.0	----	4.5
4F-63-3	May 23	11.1	5.0	0.9	June 6 AM	Stearman	Boom & Nozzle	0.0	0.0	0.0	9.0	3.0	6.5
4F-63-4	May 22	2.6	----	5.5	June 6 AM/PM	Stearman Pawnee	Boom & Nozzle	----	----	----	12.8	----	5.0
4F-70	May 22	13.4	6.6	----	June 5/6 AM	Stearman Pawnee	Boom & Nozzle	0.5	0.0	-----	26.7	26.0	----
4F-71-1	May 22	3.7	7.1	-----	June 6 AM	Pawnee	Boom & Nozzle	2.0	4.5	----	39.0	22.0	----
4F-71-2	May 22	4.0	8.3	----	June 6 AM	Pawnee Stearman	Boom & Nozzle	0.0	0.0	----	24.5	36.0	-----
4F-72-1	May 28	29.0	31.3	----	June 6 AM	Pawnee Stearman	Boom & Nozzle	1.2	3.3	----	15.0	..0	----

1980 B.t. Project - Summary of Sampled Woodlots

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
District 4F													
4F-75	May 28	28.2	----	5.3	June 4 PM June 5 AM	Stearman Pawnee	Boom & Nozzle	2.3	----	1.0	24.8	----	20.3
4F-76	May 28	26.0	26.5	----	June 5 AM	Pawnee	Boom & Nozzle	0.0	0.0	----	11.5	13.0	----
4F-77	May 21	1.6	----	11.0	June 6 AM	Pawnee	Boom & Nozzle	2.2	----	2.0	7.7	----	6.3
4F-80	May 28	16.3	----	----	June 5 AM	Pawnee	Boom & Nozzle	1.0	----	----	17.5	----	6.3
4F-96	May 22	2.8	----	----	June 6 PM	Pawnee Stearman	Boom & Nozzle	1.0	----	----	8.0	----	----
4F-99	May 29	36.2	----	32.9	June 6 AM	Pawnee	Boom & Nozzle	1.0	----	2.0	34.7	----	13.5
4F-101	May 29	15.7	----	----	June 6 AM	Stearman	Boom & Nozzle	1.0	----	----	40.3	----	----
District 5													
5A-14-1	May 28	17.6	9.0	9.9	June 6 AM	AG Truck	Micronair	0.0	0.0	1.0	24.0	44.0	26.5
5A-17	May 27	22.3	----	14.3	June 6 AM	Pawnee	Boom & Nozzle	0.8	----	2.0	29.0	----	26.0
5A-21-1	May 27	7.2	10.5	6.2	June 6 AM	Pawnee	Boom & Nozzle	0.0	----	1.8	41.0	60.0	36.0
5A-21-2	May 27	11.2	11.8	5.6	June 6 AM	Pawnee	Boom & Nozzle	0.5	----	1.0	28.0	73.0	32.0
5A-32-5	May 26	----	----	5.0	June 5 AM	AG Truck	Micronair	0.0	----	0.2	----	----	33.0
5B-1	May 26	6.7	----	12.0	June 3 PM	Pawnee	Boom & Nozzle	1.3	----	3.0	49.5	----	42.5
5B-3-1,2	May 25	5.8	----	8.1	May 29 AM	Pawnee	Boom & Nozzle	2.0	----	2.8	36.5	----	37.0
5B-8	May 29	16.6	----	22.0	June 3 PM June 4 PM	Pawnee	Boom & Nozzle	1.7	----	2.0	63.5	----	45.5
5B-9	May 29	3.2	----	4.8	June 4 PM	Pawnee AG Truck	Boom & Nozzle Micronair	0.0	----	1.5	0.0	----	5.0
5B-11	May 29	20.2	----	15.0	June 3 PM June 4 PM	Pawnee	Boom & Nozzle	3.5	----	2.0	69.0	----	63.0
5B-12	May 29	10.4	----	12.0	June 4 PM	AG Truck	Micronair	3.0	----	4.8	58.5	----	46.0

1980 B.t. Project - Summary of Sampled Woodlots

District 5

Lot Number	Date Sampled	Pre-Spray Budworm Pop'n /45 cm. Branch			Date Sprayed	Aircraft Type	Spray System	Post-Spray Budworm Pop'n /45 cm. Branch			Current Defoliation - %		
		BF	WS	RS				BF	WS	RS	BF	WS	RS
5B-13-1	May 25	3.0	----	----	May 28 AM	Pawnee	Boom & Nozzle	2.0	----	----	38.0	----	----
5B-16	May 28	2.0	----	2.6	June 4 PM	Pawnee	Boom & Nozzle	1.0	----	1.3	19.5	----	18.0
5B-23	May 25	4.5	----	----	May 30 AM	Pawnee	Boom & Nozzle	1.5	----	----	45.0	----	----
5B-24-1	May 26	2.0	----	3.5	May 30 AM	Pawnee	Boom & Nozzle	1.0	----	1.0	53.0	----	28.5
5B-24-4	May 26	2.0	----	----	June 3 PM	Pawnee	Boom & Nozzle	2.3	----	----	50.0	----	----
5B-24-5	May 26	11.0	----	----	June 3 PM	Pawnee	Boom & Nozzle	0.0	----	----	43.0	----	----
5B-26	May 29	4.1	----	----	June 4 PM	Pawnee	Boom & Nozzle	5.0	----	----	33.5	----	----
5B-30	May 25	3.1	----	----	May 27 PM	Pawnee	Boom & Nozzle	2.6	----	----	58.5	----	----
5B-35-1	May 25	3.6	----	1.0	May 27 PM May 28 AM	Pawnee	Boom & Nozzle	1.0	----	1.0	39.5	----	32.5
5B-35-2	May 25	11.3	----	----	May 28 AM	Pawnee	Boom & Nozzle	----	----	----	34.0	----	----
5B-36-2	May 26	1.3	----	----	June 5 AM	AG Truck	Micronair	0.0	----	----	31.5	----	----
5B-37-1	May 26	3.2	----	10.4	June 4 PM	Pawnee	Boom & Nozzle	4.3	----	6.3	43.0	----	33.0
5B-37-2	May 26	4.3	----	28.0	June 4 PM	Pawnee	Boom & Nozzle	3.3	----	7.0	50.5	----	54.0