REVIEW OF FOLIAGE PROTECTION SPRAY OPERATIONS AGAINST THE SPRUCE BUDWORM WITH *BACILLUS THURINGIENSIS KURSTAKII* FROM 1980 TO 1983 IN NOVA SCOTIA AND NEW BRUNSWICK, CANADA

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Spray operations against the spruce budworm have been conducted in New Brunswick in 1980, 1982 and 1983 and in Nova Scotia from 1980 to 1983. The results obtained in terms of foliage protection have been extremely variable. Attempts to pinpoint the causes for this variable result suggest that a number of factors are responsible. These are weather during and after spraying and sampling problems.

Introduction

The purpose of this paper is to review the usage of *Bacillus thuringiensis kurstakii* (B.t.k.) in foliage protection programs against the spruce budworm (*Choristoneura fumiferana* Clem.) in New Brunswick and Nova Scotia and attempt to pinpoint the resaons for the frequent failures in foliage protection. Operational foliage protection spray programs using commercial formulations of B.t.k. were conducted in Nova Scotia from 1980 to 1983, and in New Brunswick in 1980, 1982 and 1983. In Nova Scotia B.t.k. was the only material allowed for use against the spruce budworm on large tracts of forests while in New Brunswick both B.t.k. and chemical insecticides were used.In New Brunswick B.t.k. has been used only in the woodlot protection program (along with chemicals) in an attempt to provide protection to select select stands of fir and spruce.

There is a trend to increased use of B.t.k. throughout eastern Canada so it is important to try and understand why the results are so erratic. This type of performance plus the higher cost of spraying B.t.k.'s offset the environmental advantage of them, hence there is a reluctance to use more B.t.k.

Assessment Of Efficacy

In both Nova Scotia and New Brunswick efficacy in terms of foliage protection is estimated by comparing the level of defoliation in treated and unsprayed control plots with similar pre-spray spruce budworm population densities. Pre-treatment densities of larvae are determined for one 45cm. branch tip per sample tree. The branches are taken from the mid-crown area of the selected trees.

In Nova Scotia defoliation for each sample tree (fir or spruce) is assessed by classifying the level of defoliation on each of forty shoots per tree using the Fettes method(Dorais and Kettela, 1982). In New Brunswick defoliation on balsam fir (*Abies balsamea* Mill.) is estimated for the whole tree crown using methodology developed by Webb(1956). However for **spruce** (*Picea* sp.) defoliation is estimated as either nil, light, moderate or severe. In the case of the spruces it is the authors opinion that both methods used are inadequate in estimating defoliation on spruce, particularly the red/black hybrid complex.

Unsprayed control data are used to generate graphs showing the relationship between larval population density and resultant defoliation. These relationships need to be examained each year as the degree of defoliation **caused** by a given population of larvae varies from year to year on both species of trees (Fig. 1&2).

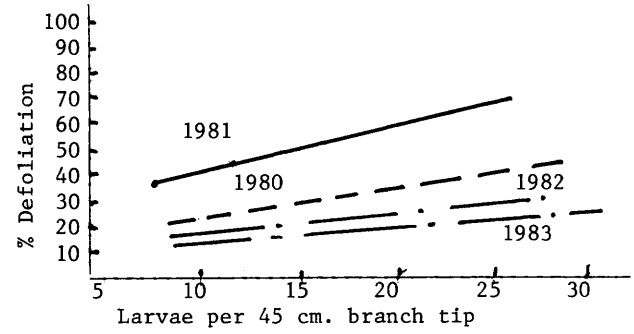

Figure 1. Defoliation as a function of early instar spruce budworm larvae per 45 cm. branch tip on red/black spruce in the Maritimes region of Canada.

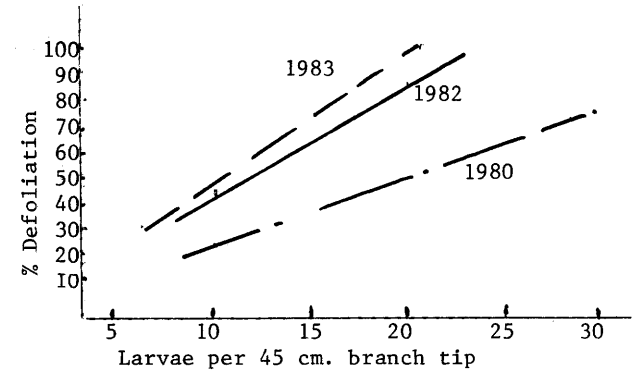

Figure 2. Defoliation as a function of early instar spruce budworm larvae per 45 cm branch tip on Balsam fir in the Maritimes region of Canada.

It is apparent from Figures 1. and 2. that fewer budworm larvae cause more defoliation on balsam fir than on spruce.

Foliage protection due to treatment can be estimated a number of ways; first as simply the difference between expected defoliation and observed defoliation, secondly by using Abbott's formula(Dorais and Kettela, 1982) which is

$$\frac{\text{expected defoliation - observed}}{\text{expected defoliation}} \times 100\%$$

and thirdly as the difference between observed defoliation and 100%. This last method estimates total foliage retention **which though** very important to the tree is a poor measure of efficacy. Essentially it is possible to generate three estimates of foliage protection from the same set of data. This is an important consideration when arbitrary values for good foliage protection are established such as those in New Brunswick and Nova Scotia.

Two important factors that influence efficacy are the stages of development of larvae and shoots at the time of spray application.At this point in time there is some disagreement as to the appropriate timing for good foliage protection on fir and spruce. It is generally accepted that the shoots on balsam fir should be starting to flare when B.t.k. is applied. This more or less coincides at the peak of fourth instar development. In Nova Scotia , where considerable areas of red/ black spruce are sprayed,spraying is commenced when the buds of spruce have started to swell and the bud caps have fallen off. This more or less coincides with development of larvae between fifth and sixth instar. Delays in spraying caused by weather when this type of late timing is used can result in poor foliage protection. Apparently adequate foliage protection of spruce has been obtained at a considerably earlier timing of B.t.k. sprays. How this works is not understood.

Results Of B.t.k. Applications In New Brunswick

1980

In 1980 10 521 ha were treated with either Thuricide 16B or Novabac-3 at a dosage rate of 20 B.i.u's per ha in 11.5 l per ha.Three spray systems were used ; fixed wing aircraft with boom and nozzle spray equipment, fixed wing aircraft with Micronaire rotary atomizers and a rotary wing aircraft equipped with boom and nozzle spray equipment.

Of the 251 woodlots sprayed 148 were sampled to determine efficacy of spraying. Results of this investigation are detailed by Kettela and Steel (1984). Essentially , the results in terms of foliage protection were extremely variable. From 40 to 60% of the woodlots had a detectable level of foliage protection, depending on the region in New Brunswick. Analysis of the data showed no clear relationship between efficacy and timing aircraft type, spray system used or forest composition and condition. Interestingly red/black was apparently better protected than balsam fir. In light of experiences in 1983 with red/black spruce sampling the result noted in 1980 may be due simply to inadequate sampling of spruce. Further, the mediocre result may have been due to the dilution rate of B.t.k.

1982

In 1982 4 000 ha of forest were treated with B.t.k., 3 200 ha operationally with Dipel 88 and 800 ha in a test program with Novabac-3 and Bactospeine.

With respect to the Dipel 88 treatment one half of the area was treated at 20 b.i.u. per ha and the other half at 30 b.i.u. per ha. Sampling for efficacy was concentrated in that area treated at 30 b.i.u. per ha. The results (Table I) showed that although there was excellent larval mortality foliage protection was very poor.

Table I. Results of spraying Dipel 88 undiluted at a rate of 30 B.I.U per ha in New Brunswick,1982.

	Budworms/ 45 cm branch		Development Index		Defoliation %	
	larvae	pupae	shoots	larvae	Observ.	Expt.
Balsam Fir						
Treated	19	0.4	5.0	4.5	70	84
Control	20	2.6				
Red Spruce						
Treated	18	0.3	1.5	3.4	50	50
Control	16	0.5				
White Spruce						
Treated	17	0.9	5.0	3.8	75	75
Control	25	1.5				

Easy explanations for this result are not forthcoming. By all measures conditions for spray application were excellent,weather conditions were good, before, during and for days after the spray, and shoot and larval development were optimum.

1983

In 1983 some 10 117 ha of irregular shaped woodlots of from 25 to 500 ha were treated with Novabac-3 at a rate of 30 b.i.u./ha in 4.7 l/ha. The bulk of the area treated was located in the Fredericton area(central N.B.), with small areas located in southern NB by the Fundy Coast, and in northern NB south of Campbellton. Spraying was done with small agricultural type fixed wing

aircraft equipped with Micronaire AU 3000 rotary atomizers.

Spray efficacy was estimated from pre-spray larval counts on both balsam fir and spruce (usually red/black spruce), and post spray estimates of defoliation. Three blocks in northern N.B. were sampled for just post spray defoliation. Development of shoots and larvae were estimated from the appropriate graphs. A summary of the results is shown in Table II. Red/black spruce data is omitted because of its inconclusive nature.

Table II. Summary of spray results with B.t.k. (Novabac-3) on woodlots in New Brunswick in 1983.

Shoot Development Index	Pre-spray Larvae per 45 cm branch	Defoliation % observed	Defoliation % expected
3.1	2.2	80	10
3.1	4.7	80	30
3.1	4.9	30	35
3.1	5.2	80	40
3.1	12.3	60	72
3.4	7.5	10	60
3.4	8.1	100	61
3.4	9.8	20	65
3.4	13.6	100	78
3.9	3.8	60	20
3.9	5.7	60	45
3.9	7.7	60	60
3.9	20.4	10	90
4.0	11.5	30	67
4.4	11.1	50	66
	spray blocks in northern NB		
4.5	high	20	70+
4.5	high	10	70+
4.5	high	30	70+

Of the eighteen blocks sampled only 10 had a detectable level of foliage protection. There appears to be a weak relationship of better foliage protection with increasing shoot development. Examination of weather records showed that all the blocks sprayed in the Fredericton area were treated during a cold wet spell where there was rain most every day and mean daily temperatures of 16°C. It is suspected that this weather inhibited larvae from feeding and retarded shoot growth. Further, the irregular shape of the blocks made it difficult to spray the areas accurately. Similarly poor results were obtained on woodlots in the Fredericton area treated with the chemical fenitrothion. However, the three spray blocks in northern N.B. seem to have been adequately protected. Post spray weather for these blocks was generally warm with no rain for at least two weeks.

Results of B.t.k. Spraying in Nova Scotia

An experimental spray program to provide foliage protection to balsam fir and spruce was carried out in 1979. This program was apparently very successful and set the stage for operational usage of B.t.k. against the spruce budworm in Nova Scotia. Initially spray operations were concentrated on Cape Breton Island but were expanded to include red spruce forests in Cumberland and Colchester County in western Nova Scotia. From 1981 to 1983 spray operations were concentrated there. Although considerable data exist on spray effects on balsam fir, it is the spruce data that is particularly interesting. Details on area sprayed, costs and related items are presented in a report edited by J.R. Carrow (1983).

The spray format followed for the past three years has not varied, although a variety of B.t.k. formulations were used. Spray applications were started when red spruce buds started to swell and lose their bud caps. Larval development on average was between the fifth and sixth instar. Agcat spray aircraft with standard boom and nozzles were used. Swath width was a nominal 30 meters per aircraft and they flew in formations of two or three planes. The dosage used was 20 b.i.u./ha in 4.7 l/ha.

Of the spray blocks examined here, four were sprayed for the past two years, two for the past two years, and two for the first time in 1983. This provides an opportunity to examine protection applied consistently over time (Table III). Blocks were selected for protection based on tree condition, stand type and egg-mass infestation. Timing and weather are not overriding factors for all blocks were sprayed within guidelines established for the program.

It is evident from Table III that there was a large difference between observed defoliation and expected defoliation in 1981, indicating that the B.t.k. application provided a measurable level of foliage protection. However in 1982 and 1983 the difference between observed and expected defoliation was considerably less. This does not mean that there was a decrease in the effectiveness of the B.t.k. applications in 1982 and 1983. In fact, in view of the guidelines set down for adequate foliage protection, this is the case. Figure 2 shows clearly that less defoliation was caused by similar larval densities in both 1982 and 1983 than in 1981. Observed defoliation was generally low in all blocks in all years. This problem with spruce is a recurring thing and greatly affects the way data on spray efficacy are analyzed. Similar results were obtained on spruce in New Brunswick in 1983. This spruce sampling-interpretation problem must be acknowledged particularly when analyzing data from experimental spray trials. It would be very easy to draw the wrong conclusion on efficacy.

In general the efficacy of B.t.k. against the spruce budworm has been mixed with good results in 1981 but apparently poor results in both 1982 and 1983.

Table III. Results of spraying B.t.k. at 20 b.i.u per ha on selected red spruce stands in Cumberland and Colchester Counties in Nova Scotia from 1981 to 1983.

Location and Year	Pre-spray Larvae per 45 cm branch	Defoliation	
		Observed	Expected
Advocate			
1981	18	18	49
1982	37	28	41
1983	26	27	29
Shulie			
1981	19	16	52
1982	38	29	42
1983	14	24	16
Moose River			
1981	17	15	47
1982	14	8	18
1983	4	9	4
Economy			
1981	9	8	36
1982	10	5	11
1983	9	7	10
Welton Lake			
1982	33	30	39
1983	21	21	23
Eatonville			
1982	31	30	39
1983	6	7	7
Chicnecto			
1983	20	21	22
Sand River			
1983	33	14	37

Conclusions

Looking for the clues as to why B.t.k. at times gives poor results , or apparently poor results is a frustrating task. The reasons for failure can range from poor timing,to bad weather following application, block size and configuration, and an inability to separate cause and effect because there is no apparent difference between treated and non-treated stands of trees.

Certainly,in the New Brunswick experience in 1983 cold wet weather seemed to be the cause for the poor result in those blocks sprayed in central N.B. Delaying spraying to take advantage of forecasted good weather seems to be at best a very hazardous option. The longer you wait to apply B.t.k. consigns at least some of the foliage you want to protect to the budworm. This is particularly so when budworm larval populations are very high.

Sampling and data interpretation problems appear to be particularly acute with red/black spruce. Sampling systems currently being used are apparently not sensitive enough to at times clearly show the differences between treated and non-treated areas, This is true for areas treated with chemicals as well.

Studies that are to be reviewed elsewhere in this symposium point to deposit as a key factor in the performance of B.t.k. as well as the concentration of B.t.k. in each drop.Surely development of more stable formulations with stickers and more potent Bt. strains will remove some of the chance out of protection operations with B.t.

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