Operational and Experimental Use of Bacillus thuringiensis for Control of Western Spruce Budworm in Oregon and Washington, 1983 - 1987

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INTRODUCTION

Western spruce budworm (Choristoneura occidentalis Freeman) is native to the Douglas-fir, true fir and spruce forests of the Pacific Northwest. Periodically, outbreaks of this insect can occur in isolated or limited areas and last for only a few years; or they can encompass several million acres and last for up to 10 or more years. In the more severe outbreaks, repeated heavy defoliation can result in a reduction in tree growth, topkill, and some mortality, especially in the seedling and sapling size trees. Other resources that could be affected are seed and cone production, Christmas trees, visual quality, and wildlife habitat. The current outbreak was first detected in 1980 on 6,000 acres in Northeastern Oregon. It continued to expand in size and intensity until almost 6 million acres of defoliation were mapped in 1986. Defoliation was mapped on about 4.9 million acres in 1987.

During previous outbreaks, chemical insecticides such as DDT in the 1940's and 50's, and carbaryl in the 1970's, were used for direct suppression of western spruce budworm (Dolph, 1980). Although the biological insecticide, Bacillus thuringiensis (B.t.), has been available for several decades, it was not until the late 1970's to mid 1980's that B.t. formulations were developed to the point that they were cost competative with chemical insecticides, and would perform with some consistency in forest applications (Irland and Rumpf, 1987).

The current outbreak has provided the first opportunity to use B.t. formulations on an operational basis for control of western spruce budworm in the Pacific Northwest. Although various formulations of B.t. have been used both in field experiments and operationally during the last five years, there are still gaps in the technology.

The purpose of this paper is to summarize the field tests and operational uses of B.t. for western spruce budworm in the Pacific Northwest from 1983 to 1987. It will also discuss the trends in its use and application during this time.

SUMMARY AND RESULTS OF PROJECTS

1983

In 1983, over 524,000 acres in eastern Oregon were treated for control of western spruce budworm. These were primarily on the Umatilla and Malheur NF's and adjacent state and private lands. Most of the area was treated with the chemical insecticide, carbaryl; however, three separate units were set aside for an operational evaluation of carbaryl, mexacarbate, and B.t. The decision to use a B.t. formulation was based on several factors, which included the need for additional options for insecticide treatments, less environmental impacts from a biological insecticide, and the need to further evaluate the use of B.t.

The B.t. formulation for this project was Thuricide 32LV. It was diluted 1:1 with water and applied at a rate of 12 billion international units (BIU) in 96 oz. per acre. This rate represented a departure from the B.t. application rate of 8 BIU's in 1 gal. per acre, that was used in the West prior to 1983 (Stipe, et al., 1983; Ragenovich, 1983). Table 1 summarizes the results of the B.t. application on the 1983 project.

Table 1: Summary of B.t. Application on the Malheur NF, 1983.

Parameters	Treatment	
Formulation	Thuricide 32LV	Untreated Check
Application Rate (per acre)	diluted/12 BIU/96 oz.	
Acres Treated	12,472	
Application Equipment		
Aircraft	Hiller 12E	
Nozzles	Flat Fan	
Targeted Droplet Size (VMD)	180 microns	
Insect Development at Application	new buds unfurled larvae 50% 4th instar or later	
Efficacy		
avg. larvae/branch 1/ -early density	12.4	
avg. larvae/branch-prespray	10.8	13.1
(range)	(1.8-34.0)	(1.4-40.8)
avg. larvae/branch-postspray (14 day)	3.3	6.9
(range)	(0.5-9.0)	(0.6-21.9)
avg. larvae/branch-postspray (21 day)	2.1	4.9
(range)	(0.4-6.3)	(0.8-19.1)
percent defoliation class 2/	--	--
Spray Deposit Assessment (drops/cm2) 2/	--	--

1/ Branch is a 45 cm. branch tip

2/ Information not available

The targeted residual population objective for both the project and the operational evaluation was 1.5 larvae or less per branch. The three evaluation units for carbaryl, B.t., and mexacarbate, failed to meet the target objective. It was felt that weather factors and problems with inconsistant or poor applications were the primary reasons for the results, rather than the performance of the insecticides.

(Bridgwater, 1984; Bridgwater, personal communication; in-service letter 3440, 11/3/83).

1984

No operational projects were done in 1984. This decision was based on the 1984 Western Spruce Budworm Environmental Assessment. However, it was felt that futher evaluation of B.t. in forestry application should continue. A cooperative field test with Pacific Northwest Research Station was conducted to compare the efficacy of two commercial strains of B.t. at two dosage rates. In addition to efficacy, a bioassy of the length of activity of B.t. on the foliage, and the additional population reduction prior to adult emergence that could be attributed to B.t., were evaluated. The study was a randomized block design with four treatments and a check. It was replicated five times. The project was conducted in north central Oregon, on the Ochoco NF. The formulations used were Thuricide 32LV and San 415, a new strain of B.t. Both were applied at 8 and 12 BIU's diluted in water at 96 oz. per acre. Timing of the application was based on accumulated degree days, although the larvae were primarily in the 4th and 5th instars at the time of application.

The results of this study showed that there was no significant difference between the two strains of B.t. There was significantly better control with the 12 BIU per acre rates than with the 8 BIU per acre rates; and the 12 BIU rates reduced the average larval population to below the 1.5 larvae per branch target used in the 1983 project. Both B.t. strains maintained longer efficacy on the foliage than had previously been reported. Postspray larvae were reared and adult emergence was monitored. There was an addtional 30+ percent emergence reduction that could be attributed to B.t. in three of the four treatments (Table 2).

The results of this work indicated that B.t. was a viable alternative to chemical pesticides for the control of western spruce budworm.

(Beckwith, Steltzer, and Hostetler, 1984)

Table 2. Summary of the B.t. Field Test on the Ochoco NF, 1984.

Parameters	Treatment				
Formulation	Thuricide 32LV	Thuricide 32LV	SAN 415	SAN 415	Untreated
Application Rate (per acre)	8 BIU/96 oz.	12 BIU/96 oz.	8 BIU/96 oz.	12 BIU/96 oz.	Check
Acres Treated	205	227	163	210	
Application Equipment					
Aircraft	Hiller Soloy 12J3	Hiller Soloy 12J3	Hiller Soloy 12J3	Hiller Soloy 12J3	
Nozzles	Beecomist 360A	Beecomist 360A	Beecomist 360A	Beecomist 360A	
Targeted Droplet Size (VMD)	125 - 150 microns	125 - 150 microns	125 - 150 microns	125 - 150 microns	
Efficacy					
avg. larvae/branch 1/ - prespray					
DF	11.7 ± 2.4	19.0 ± 2.1	18.7 ± 1.7	16.5 ± 2.1	19.1 ± 2.5
GF	18.9 ± 5.2	22.4 ± 2.5	22.6 ± 3.4	18.9 ± 4.2	22.1 ± 5.5
	15.3 3.8	20.7 2.3	20.7 2.6	17.7 3.2	20.6 4.0
avg. larvae/branch - postpray (16 days)					
DF	2.3 ± 1.0	1.7 ± 0.6	3.1 ± 0.8	0.9 ± 0.3	3.9 ± 0.8
GF	1.3 ± 0.7	0.7 ± 0.2	2.7 ± 0.8	0.3 ± 0.1	3.3 ± 1.3
	1.8 .85	1.2 .4	2.9 .8	.6 .2	3.6 1.1
percent defoliation class	26 - 50%	26 - 50%	26 - 50%	26 - 50%	51 - 75%
Spray Deposit Assessment drops/cm2	14.1	20.8	9.0	17.3	

1/ Branch is a 45 cm. branch tip.

1985

In 1985, an operational evaluation using B.t. was conducted on the Malheur NF. While this project was an operational suppression project, it was determined that it would provide an opportunity to evaluate some alternative strategies for B.t. applications that had been tried on spruce budworm in the East. The two strategies of interest, were the use of fixed wing aircraft and the application of undiluted formulations. For the last several years in the Pacific Nothwest Region, all applications had been with helicopters. The advantages of an undiluted application are obvious - less mixing and handling problems and more production per load. Also, by 1985, it had become accepted that rotory atomizers provided a much better droplet pattern than the flat fan type nozzles.

Two undiluted and two diluted formulations of B.t. were applied at the rate of 12 BIU/acre on about 10,000 acres each. One of the diluted formulations was Thuricide 32LV, 12 BIU's diluted 1:1 with water and applied at 96 oz./acre. This was the formulation that had been used successfully in the 1984 field test, and was considered as the standard for the performance of the other formulations. The other formulations were Thuricide 48LV undiluted at 32 oz./acre, Dipel 8L undiluted and applied at 24 oz./acre, and Dipel 8L diluted 1:1 with water and applied at 48 oz./acre. This was the first time that an oil base B.t. formulation (Dipel 8L) was used. An additional smaller area of 480 acres was treated with a slightly diluted (10 parts B.t. product to 1 part water), higher potentcy formulation of 15 BIU's applied at 64 oz./acre. (Table 3).

The objective was to reduce the population to one or less larvae per 45 cm. branch. Neither undiluted formulation met this objective. Since the evaluation was not replicated, a comparison for significant differences is not appropriate. However, there appears to be a relationship between volume and efficacy; the higher the volume, the better the mortality. Another inference that could be drawn is that the aqueous formulations, both diluted and undiluted, performed better than the oil formulations. The exception was the higher potency material applied at 64 oz. per acre. This appeared to be a combination that balanced volume with maximum efficacy.

Problems with handling occured with the oil base material. It was found that diluted at 1:1, the water evaporated, and the material inverted at the nozzle. Some inversion also occured in the tanks on the helicopter, resulting in extra effort to keep equipment clean. On at least one occaision, cold weather resulted in a thickened product and problems in application with the fixed wing when applying the undiluted oil formulation of Dipel 8L.

Both undiluted formulations raised a number of questions regarding spray technology. The lower volumes require a much smaller droplet leaving the nozzle. Under western conditions, where extreme variations in aspect, slope and elevation cause unpredictable air current situations, it is possible that the smaller droplets would not reach the intended target area in a consistent manner.

Table 3. Summary of the operational evaluation using B.t. in the Malheur NF, 1985

Parameters	Treatment					
	Rail	Scotty	Burnt Cabin	Crooked-A	Crooked-B	
Formulation	Dipel 8L	Thuricide 48LV	Dipel 8L	Thuricide 32LV	Thuricide 32LV	Untreated
Application Rate (per acre)	undiluted/12 BIU; 24oz.	undiluted/12 BIU; 32oz.	diluted/12 BIU; 48oz.	diluted/12 BIU; 96oz.	diluted/15 BIU; 64oz.	Check
Acres Treated	10,494	10,176	10,622	9,207	480	
Application Equipment						
Aircraft	Ayers Turbo Thrush	Ayers Turbo Thrush	Hiller 12E Soloy	Hiller 12E Soloy	Hiller 12E Soloy	
Nozzles	Unimizer	Unimizer	Beecomist 360A	Beecomist 360A	Beecomist 360A	
Targeted Droplet Size (VMD)	80 - 100	80 - 100	125	125	125	
Release Parameters	larvae 50% in the fifth instar or larger					
Efficacy						
avg. larvae/branch 1/ - prespray	10.53 ± .68	9.91 ± .75	11.03 ± .92	10.31 ± .72	8.4 ± .70	8.60 ± .72
avg. larvae/branch - postspray	1.17 ± .18	1.12 ± .21	.97 ± .12	.64 ± .12	.40 ± .18	2.69 ± .29
percent defoliation class 2/						
Spray Deposit Assessment						
avg. drops/cm2	6.61 ± 1.19	7.31 ± 1.10	3.85 ± .54	25.91 ± 3.46	2/	

1/ Branch is a 45 cm branch tip.

2/ Information not available.

Some of the conclusions from that project were:

1. Fixed wing aircraft (Turbo Thrush type) could be used on some types of terrain in the Pacific Northwest. However, there are other areas where application should be with helicopter.

2. Fixed wing aircraft are not necessarily less expensive to operate. Additional speed and carrying capacity may be negated by additional ferrying time, since acceptable airstrips may not be in close proximity to the treatment area. Heliports can be set up within or very near a treatment area.

3. Oil base formulations must be diluted at a rate of more than one part water to decrease the risk of inversion problems.

4. With the exception of the 64 oz. 15 BIU application, the standard 12 BIU 96 oz. application performed best.

5. Additional information should be obtained on the ultra low volume, small drop applications under western conditions.

6. It was difficult to assess spray deposits with the undyed formulations.

7. Some B.t. formulations can perform as well as chemical insecticides under operational conditions.

(Ragenovich, unpublished data)

1986

No spray projects for control of western spruce budworm were conducted in 1986.

1987

An environmental analysis and assessment was conducted for western spruce budworm for 1987, and 500,000 acres were selected for treatment with B.t.. Funding for about 250,000 acres was available. There were three treatment units; one was located in Washington on the Wenatchee NF, west of Yakima, and referred to as the Rimrock Unit. The other two units were located on the Malheur NF in eastern Oregon and referred to as the North and South Units. Since there were still unanswered questions about the use of low volume, undiluted applications and the performance of small droplets under western conditions, it was felt that for an operational project, the standard 12 BIU, 96 oz. application should be used. There were, however, 8000 acres identified to be treated on an operational basis with the undiluted 16 BIU, 64 oz. application rate. Ultimately, this treatment was not applied because there was no material meeting those specifications available; and the 12 BIU, 96 oz./acre rate was applied to all acres treated.

Due to environmentally sensitive issues, it was specified that an aqueous formulation of B.t. be used on the Rimrock Unit, which surrounded Rimrock Lake, and on a watershed within the North Unit on the Malheur NF; otherwise, either an aqueous base or oil base formulation was acceptable.

The 1987 projects were unusual from the standpoint that these were the first spray project contracts to be awarded on a negotiated bid process.

The possible additional efficacy of higher potentcy applications, and the option of undiluted applications continued to be an attractive option; therefore, in addition to the operational projects, a field test done in cooperation with the PNW Research Station, was conducted in central Oregon, near Burns. The purpose of this project was designed to compare the efficacy of 12 and 16 BIU applications, and of 16 BIU diluted and undiluted applications.

The following are dicussions of each of the projects conducted in 1987:

Rimrock Unit

One of the main concerns for the Rimrock Unit was the impact of the western spruce budworm on the visual resource. The objective of the project was to reduce the population to a level of less than one larvae per branch; this population reduction would subsequently result in minimal feeding damage in following years. The project area included Rimrock Lake, Clear Lake, and the Tieton River; as a result, this was considered a sensitive area and it was stipulated in the contract that an aqueous based formulation be used in the treatment.

Table 4 summarizes the Rimrock B.t. project.

The contract for the Rimrock Unit was awarded with a resonable amount of lead time, and the contractor was able to report, and have the material delivered, and on-site, prior to the release of the spray blocks.

The B.t. formulation used on this project was Thuricide 48LV diluted with two parts water to one part B.t. and applied at 12 BIU's and 96 oz. per acre. Results of the project show that the target of less than one larvae per branch was achieved. The formulation met all expectations in regard to mixability, flowability, atomization, and biological performance. The dye in the formulation made spray deposit assessment relatively easy.

(Scott, draft progress report, 1988)

Table 4: Summary of the 1987 Rimrock Unit B.t. project.

Parameters	Treatment
Formulation	Thuricide 48LV
Application Rate (per acre)	diluted/12 BIU/96 oz.
Acres Treated	44,031
Application Equipment	
Aircraft	Hiller 12E Soloy Hughes 500D Lama SA 315B
Nozzles	Beecomist 360
Targeted Droplet Size (VMD)	100-150 microns
actual droplet size	83 microns
Release Parameters	95% buds unfurled 50% larvae in the 5th instar or greater
Efficacy	
avg. larvae/branch 1/- early density	5.9 ± 0.82
avg. larvae/branch-postspray (beginning of pupation)	0.89 ± 0.10
percent defoliation class	1-25 percent
Spray Deposit Assessment drops/cm2	11.05 ± 1.7

1/ Branch is a 45 cm. branch tip

Malheur North and South Units

A number of problems on the Malheur Units contributed to less than acceptable results in 1987. An unusually warm, dry winter and spring resulted an early insect development as much as 3 to 4 weeks ahead of normal. Delays in awarding the contract also affected the ability of the contractor to treat all the acres.

Both fixed wing and helicopter application aircraft were used on the project. A total of 85,922 acres were treated on the Malheur NF.

Originally, the primary insecticide on the two Malheur Units was an oil base formulation, Dipel 6L. A small area within a watershed was designated to be treated with an aqueous base formulation, Dipel 6AF. Early in the project, the contractor began to experience problems with the mixing and application of the oil base product. Due to the size of the project, it was necessary to mix several thousand gallons of formulation the day prior to treatment. However, it was found that once the Dipel 6L was mixed with water, it began to separate into three layers; water, oil, and a mixture that had the appearence of a partially inverted emulsion. This mixing problem also affected the ability to provide a proper application. The insecticide manufacturer recommended an additive to keep the mixture in solution. The additive, however, caused the material to break up into very fine drops that did not deposit on spray assessment cards during characterization trials. As a result the effective swath width of the application aircraft was reduced by almost half. After several days of attempting to solve the mixing problem, the Forest Service rejected the Dipel 6L product on the basis that it was unacceptable and could not meet specifications. The contractor then obtained Thuricide 48LV to replace the Dipel. However, by that time, the insect development had advanced beyond the initial targeted release date, especially on the South Unit, which was a lower elevation. Approximate acres treated with each product were: Dipel 6L - 26,601; Dipel 6AF - 2,500; and Thuricide 48LV - 54,850.

Early insect development, delays in contract award, and application time lost in trying to solve the mixing problem, and having to obtain an alternative pesticide all combined to result in a shortfall of about 96,500 acres.

Table 5A and 5B summarize, to the extent possible, the results of the Malhuer North and Malheur South projects, respectively.

It is extremely difficult to draw conclusions from 1987 Malheur project. The advanced insect development, late contract award, and unacceptable insecticide product all contributed to a number of variables in the data. Each of the treatment units received a combination of treatments. The entomolgical sampling proceedures were designed to sample the effectiveness of the treatment on the Units as a whole; therefore, any attempt to compare results between the formulations of B.t. would be invalid. Based on the 14-day postspray sample; neither of the Units acheived the objective of less than one larvae per branch. The post spray sample represents the larval populations in only those parts of the units that were treated.

Table 5 A. Summary of the 1987 B.t. Projects on the Malheur NF.

NORTH UNIT

Parameters	Treatment			
Analysis Unit	Flat		Dixie	
Formulation	Dipel 6L Thuricide 48LV	Check	Dipel 6AF Thuricide 48LV	Check
Application Rate (per acre)	diluted/12 BIU/96 oz.		diluted/12 BIU/96oz.	
Acres Treated	11,373 20,700		2,520 9,431	
	35% 65%		21% 79%	
Application Equipment				
aircraft	Turbo Ag Cat Turbo Thrush Bell 205		Bell 205	
nozzles	Beecomist 360A			
Targeted Droplet Size (VMD)	100 - 150 microns		100 - 150 microns	
Release Parameters - targeted	50% fifth instar		50% fifth instar	
Release Parameters - actual	> 91% in 5th instar		> 80% in 5th instar	
Efficacy per Analysis Unit				
avg.larvae/branch 1/ - early density	6.28 ± 0.64		11.28 ± 1.04	
avg.larvae/branch - postspray(14 days)	1.11 ± 1.19	2.59 ± 0.49	1.79 ± 0.24	2.82 ± 0.35
defoliation class	26 - 50%	26 - 50%	51 - 75%	26 - 50%
Spray Deposit Assessment drops/cm2	9.37 ± 0.25		6.48 ± 0.28	

1/ Branch is a 45 cm. branch tip

Table 5 B. Summary of the 1987 B.t. Projects on the Malheur NF.

-SOUTH UNIT

Parameters	Teatment							
Analysis Unit	Lost Cabin			Canyon			Starr	
Formulation	Dipel 6L	Thuricide 48LV	Check	Dipel 6L	Thuricide 48LV	Check	Dipel 6L	Check
Application Rate (per acre)	diluted/12 BIU/96oz.			diluted/12 BIU/96oz.			diluted/12 BIU/96oz.	
Acre Treated	11,337	7,469		4,806	17,986		300	
	60%	40%		21%	79%			
Application Equipmwent								
aircraft	Turbo Thrush Bell 205			Bell 205			Bell 205	
nozzles	Beecomist 360A			Beecomist 360A			Beecomist 360A	
Targeted Droplet - Size (VMD)	100 - 150 microns			100 - 150 microns			100 - 150 microns	
Release Parameters - targeted	50% fifth instar			50% fifth instar			50% fifth instar	
Release Parameters - actual	> 80% in 5th instar			> 81% in 5th instar			> 75% in 5th instar	
Efficacy per Analysis Unit								
avg.larvae/branch 1/ - early density	4.03 ± 0.32			5.83 ± 0.32			5.30 ± 3.55	
avg.larvae/branch - postspray (14 day)	2.18 ± 0.26	3.95 ± 0.48		3.12 ± 0.71	4.70 ± 0.32		4.58 ± 0.58	2.46 ± 0.57
defoilation class	1 - 25%	26 - 50%		1 - 25%	51 - 75%		1 - 25%	1 - 25%
Spray Deposit Assessment drops/cm2	9.37 ± 0.25			3.75 ± 0.16			2.14 ± 0.34	

1/ Branch is a 45 cm. branch tip.

Following the conclusion of the Malheur project, a review was conducted to determine the reasons for the problems that resulted in the shortfall of acres. The review identified funding, contracting, quality of forest type data, early insect development, environmental assessment, and quality of insecticide, as primary contributing factors for the shortfall of acres.

(USDA Forest Service Review, 1987; unpublished data, 1987)

Burns Field Test

In addition to the operational project, Forest Service personnel decided to continue to explore the efficacy of higher potency applications (16 BIU's/acre), and the option of undiluted applications. The decision to use Dipel 6L for this project was based on availability of material, and because this product was the one originally intended to be used on most of the operational project on the Malheur NF. There were three treatments plus a check. The treatments were 12 BIU's diluted and applied at 96 oz. (the standard application rate), 16 BIU's diluted and applied at 96 oz., and an undiluted application of 16 BIU's applied at 42.7 oz. per acre. All treatments were replicated three times and applied on three separate days. In addition to the efficacy data, a foliage bioassay was conducted. Table 6 is a summary of the preliminary results of this field test.

Preliminary conclusions are that the mean population reduction was not adequate in any of the treatments to consider them a success. All were considerably higher than the operational target of one larvae per 45 cm. branch tip. The lack of success appears to be a problem of proper coverage, which was supported by the bioassy. The 0-hour collection made within 1-hour of treatment should have had a much higher percentage of kill. The percentage of 0's (no kill) illustrated the lack of proper coverage by spray despite being within the proper wind and humidity conditions. During the application, the pilot had reported that the material did not appear to be coming down (Beckwith, personal communication). Another indication of the poor coverage is the mean number of *B.t.* colonies/branch. These numbers were very low. The highest counts, which were on the 16 BIU diluted application, were about half of what would normally be expected. The undiluted 16 BIU application represented the fewest colonies to be recovered.

One of the problems encountered was that the undiluted treatment had difficulty in flowing through the spray system at the early morning temperatures of 34° to 40°.

(Beckwith, in-service letter 4500, 1987; personnel communication)

Table 6. Summary of the preliminary data for the B.t. Field Test near Burns, OR.

Parameters	Treatment			
Formulation	Dipel 6L	Dipel 6L	Dipel 6L	Check
Application Rate (per acre)	diluted/12 BIU/96oz.	diluted/16 BIU/96oz.	diluted/16 BIU/42.7oz.	
Acres Treated	120	120	120	
Application Equipment				
aircraft	Hiller 12E Soloy	Hiller 12E Soloy	Hiller 12E Soloy	
nozzles	Beecomist 360A	Beecomist 360A	Beecomist 360A	
Targeted Droplet Size (VMD)	100 - 150 microns	100 - 150 microns	2/	
Efficacy				
avg. larvae/branch 1/-prespray	6.2	3.8	8.1	5.5
avg. larvae/branch - postspray	3.1	3.0	3.6	5.4
mean no. B.t. colonies obtained from branch samples following spraying	6.64 ± 2.01	16.27 ± 4.90	4.09 ± 1.84	
Defoilation class - 2/				
Spray Deposit Assessment drops/cm2 2/				

1/ Branch is 45 cm. branch tip.

2/ Information not available.

CONCLUSIONS

This paper provides a synopsis of the use of B.t. formulations on western spruce budworm in the Pacific Northwest from 1983-1987. Over the past several years there have been significant changes in the B.t. formulations manufactured for western spruce budworm control. In addition, there have been new developments in the area of spray technology. This summary of the projects in the Pacific Northwest demonstrates how some of these formulations and technologies have been incorporated into an operational program, often without previous evaluation. A variety of formulations, application rates, and spray technologies were used; and the results of these projects are as variable. Although results have been variable, most problems have often been associated with the application aspects; and B.t. is still considered a viable option for western spruce budworm suppression.

The trend for the use of B.t. against western spruce budworm is toward higher potency, and undiluted lower volume formulations. Inherent with those formulations are differences in spray technology and application that have not been properly evaluated in conditions, such as mountainous terrain, that occur in the West. The program of evaluating the new formulations and spray technology has not kept pace with their development. One significant conclusion that can be drawn from the projects in the past 5 years, is that a systematic and planned approach to evaluating and keeping abreast of the B.t. and other insecticide products, and spray technology is needed.

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