

OPERATIONAL EXPERIENCES WITH BT IN THE
EASTERN UNITED STATES

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Bacillus thuringiensis (B. t.) has been used operationally in the eastern U. S. since 1978 with most applications occurring in Maine. Changes in B. t. dosage rates, volume, cost, spray aircraft, and use patterns will be discussed. Evaluation of B. t. dosage in the east has consisted of variable results with 8 B.I.U. treatments in 1978 through 1980, to consistently good results with 12 B.I.U.'s for 1981 to 1983. Application technology has changed from high volumes in 1979 to undiluted or neat applications in 1983. Spray delivery systems have changed from boom and nozzle equipped small helicopters to small fixed-wing aircraft equipped with rotary atomizers. Improved efficacy has significantly broadened the B. t. use pattern.

Bacillus thuringiensis (B. t.) has been used as part of operational spray projects in the eastern United States since 1978. Numerous formulations and spray regimes have been employed since 1978 resulting in a substantial evolution in B. t. use patterns and spray technology. Major factors in the operational evolution of B. t. have been insecticide, dosage, volume, aircraft, spray delivery systems, spray weather guidelines, use patterns, and costs. Highlights of the evolutions of these factors in the eastern United States will be discussed in this paper.

Most operational use of B. t. in the eastern U. S. has occurred in Maine as part of the State run program or as part of other smaller operations. Most of this paper will deal with these Maine experiences. In an attempt to avoid repetition, evolution in the operational use of B. t. will be presented year by year. Changes for each of the factors mentioned above will be described for the year under consideration.

The first large scale use of B. t. in an operational program in the eastern U. S. occurred in Maine in 1978. The operation was based at Codyville in eastern Maine and covered about 22,000 acres of forest. Spraying was done with four Bell 47 series helicopters equipped with conventional booms and 80-02 nozzles. Thuricide 16B was sprayed at 8 B.I.U.'s per acre with a finished spray volume of 80 fluid ounces per acre. The operation was timed to begin at the peak of the 3rd instar, however some blocks were not sprayed until the 5th instar. The predominate host tree in the spray area was balsam fir.

Cost of the 1978 application was difficult to assess, but was certainly in excess of \$15.00 per acre; more than four times the cost of Sevin-4-Oil applied in 1978.

The treatment area near Codyville was chosen for several reasons that reflect the beginning of a B. t. use pattern. First, the infestation level, host condition and population level, was moderate. This type of area was preferred because B. t. efficacy was not expected to equal that of chemical insecticides. The Codyville blocks included many streams, ponds and marshes and relaxed buffer policies with B. t. increased forest coverage compared to a chemical operation. Small helicopters were chosen to remove B. t. from the main airport operation since operational problems were expected and because short ferry distance with helicopters was expected to lessen the impact of high spray volumes (80 ozs.) needed. Also, the low, slow helicopters were expected to provide better deposit with a highly volatile water based B. t. formulation.

Results in 1978 were acceptable foliage protection with population reduction far less (70 to 85%) than expected from chemicals (85 to 95%). Some 1978 blocks were considered to have

only fair foliage protection. The lower level of protection in these areas was thought to be the result of poor application and wet weather following spraying.

Results of the 1978 B. t. operation were good enough to promote the further use of B. t. in Maine in 1979. Operational spraying of B. t. in 1979 covered about 38,000 acres. Thuricide 16B was used at the same 8 B.I.U.'s and 80 fl. oz. volume as in 1978. Cost of the 1979 operation was very similar to the 1978 operation.

Infestation conditions in some 1979 blocks were significantly different from conditions in 1978. As in 1978, most 1979 blocks had moderate host conditions and population, however, some blocks treated in 1979 had extreme prespray host damage and high populations. These blocks, located near Old Town, were chosen to provide information about B. t. applied under more severe infestation conditions.

The 1979 program included the use of small, single engine fixed-wing aircraft to spray some B. t. blocks, although most of the B. t. operation employed Bell 47 helicopters. Use of the fixed wing aircraft and helicopters provided an opportunity to compare the two types of aircraft and, to use B. t. in a conventional airport setting rather than a remote heliport. Both helicopters and fixed-wing aircraft used in 1979 were equipped with conventional boom and nozzle spray systems.

Operational buffering standards were formalized for B. t. in 1979. Small fixed-wing aircraft and helicopters could spray B. t. to within 1/4 mile of a house whereas 1/2 mile buffers were required for the same aircraft spraying chemicals. B. t. could be sprayed to the edge of a stream or pond, but chemicals used in 1979 required a buffer of 150 to 500 feet around water. These formal criteria made B. t. use in some areas extremely advantageous and in some areas it was the only material that could provide adequate coverage.

Results of the 1979 B. t. project were extremely variable. Results on blocks in western Maine, treated with helicopters, ranged from poor to good. Poor results were blamed on rain after treatment and late application. Results with fixed-wing aircraft varied from poor to fair. All blocks with high populations and severe tree conditions had poor results. Wet weather was not the cause of failure in the Old Town areas. These failures were attributed to poor spray deposit from the fixed-wing aircraft and high budworm populations in the blocks.

Results of the 1979 project led to two restrictions for B. t. usage. First, rotor-wing aircraft were thought to provide better spray deposit and were the favored aircraft for future applications. Second, B. t. would not be recommended in areas of high budworm population or extreme tree condition.

Operational use of B. t. in 1980 covered a much larger area (200,000 acres) than 1978 or 1979. In 1980 B. t. was sprayed as a huge demonstration project sponsored jointly by the USFS and the Maine Forest Service. Technology used was basically the same as that employed in 1978 and 1979 except that the size of the project dictated the use of more productive aircraft and use of more than one insecticide.

Large jet helicopters (Bell 204, 205, and 212) were first used for B. t. in 1980. These aircraft were capable of carrying B. t. loads of 200 to 400 gallons compared to 55 gallons carried by Bell 47 aircraft. In addition to the larger capacity, these jet helicopters were faster and sprayed wider swaths. The jet helicopters were equipped with standard boom and nozzle spray systems.

Dipel 4L was used operationally for the first time in 1980. Dipel 4L was used at 8 B.I.U.'s in 80 ozs. of final volume, identical to past applications of Thuricide 16B. Thuricide was sprayed at 80 and 128 ozs. of final volume in 1980 to determine if the high volume (128 ozs.) would improve consistency of results.

Due largely to economics of scale and insecticide competition, B. t. costs decreased somewhat in 1980. Costs were \$10.07 to \$10.51 per acre for 80 oz. applications compared to a cost of more than \$15.00 in 1978 and 1979.

Blocks chosen for B. t. in 1980 were selected on the basis of proximity to human habitation, open water in spray block, proximity to sensitive areas and moderate infestation conditions.

Results of the 1980 project were disappointing. Foliage protection and larval reductions were extremely inconsistent and not all block failures could be explained. An encouraging aspect was uniformly good deposit from large jet helicopters. Tests did show that Dipel 4L produced results equivalent to Thuricide 16B. The two spray volumes of Thuricide 16B used did not produce significantly different results.

Due largely to inconsistencies with 8 B.I.U.'s in 1978 to 1980, a number of dosage variations were tried operationally in 1981 (Table 1). Products used in 1981 were Thuricide 16B and 24B and Dipel 4L. Spray volume ranged from 80 to 120 ounces. The most important change in 1981 was the use of high dosages of B. t. as a single application of 12 B.I.U.'s and two applications of 8 B.I.U.'s. Dosage was increased to obtain more consistent results from a range of weather and infestation conditions.

Several other aspects of the B. t. program did not change in 1981. Large jet helicopters were used, and B. t. blocks were selected as before. Buffers and restrictions remained the same. The B. t. area remained relatively large,

covering 126,000 acres.

Table 1. Results of B. t. Treatment Variations By Area For the 1981 Maine Spruce Budworm Control Project

Treatment	Area	Host	% Unadj. Red.	% Def.	% Fol. Saved
Dipel					
8 B.I.U.'s					
80 oz.	18-1	F	95.5	87	13
		S	91.5	36	2
	13-8	F	88.6	61	32
	22-16	F	97.4	58	30
		S	93.3	13	25
	SW*	F	95.8	14	14
		S	94.1	12	10
Thuricide					
8 B.I.U.'s					
80 ozs.	18-2	F**	87.9	71	29
		S	88.8	18	20
Dipel					
12 B.I.U.'s					
120 ozs.	17-1	F	91.8	(24)34	31
		S	85.2	(18)24	14
	5 Pl.	F	97.4	31	61
	**	S	96.9	23	58
Thuricide 24B					
12 B.I.U.'s					
96 ozs.	7 Pl.	F	95.3	26	60
		S	95.2	22	43
Dipel					
16 B.I.U.'s					
8+8					
80 ozs.	5 Pl.	F	95.7	50	42
		S	96.5	17	28

* Pre counts less than 10

** Pre counts 25 or more

Number in () represents omitting of a sample line which received heavy rain shortly after spray.

All areas sprayed with Bell 204 and 212 Helicopters.

In 1981 cost of an 8 B.I.U. application decreased to a range of \$7.37 to \$8.75 from over \$10.00 in 1980 due to stiff insecticide competition, more concentrated B. t. products, and lower application costs. The cost of a 12 B.I.U. treatment ranged from \$11.73 to \$12.89 depending on spray volume and insecticide used.

Results of the 1981 project were

encouraging (Table 1). While results in 8 B.I.U. areas varied from poor to good, results with 12 B.I.U.'s and two applications of 8 B.I.U.'s were consistently good. Two areas treated with 12 B.I.U.'s had good results even though budworm populations in these areas were high. Population reduction and foliage protection in 12 B.I.U. areas were not significantly different from similar areas sprayed with chemical insecticides.

It was first noticed in 1981 that B. t. was producing good results on red spruce especially at the 12 B.I.U. rate. Red spruce protection was a growing concern and chemical treatment had been only marginally effective.

The 1982 B. t. program was generally planned to confirm 1981 results, to re-evaluate small fixed-wing aircraft, to operationally assess Thuricide 32LV and Bactospiene, and to treat operationally sensitive areas with an environmentally safe product. About 89,000 acres were treated with spray variations listed in Table 2.

Table 2. Results of B. t. Treatment Variations By Area for the 1982 Maine Spruce Budworm Control Project

Treatment	Area	Host	% Unadj. Red.	% Def.	% Fol. Saved
Dipel 4L					
12 B.I.U.'s					
120 ozs.	M72	F	95.3	36.0	44.1
	Heli.	S	87.5	28.7	22.3
12 B.I.U.'s					
96 oz.					
Thrush					
	w/Micro.	J5	F	98.0	10.7
		S	98.4	5.7	21.6
Thuricide 32LV					
12 B.I.U.'s					
96 ozs.					
Thrush					
	w/Micro	J5	F	98.7	17.3
		S	98.9	9.7	17.6
*Bactospiene					
12 B.I.U.'s					
96 oz.					
	Heli.	B13	F	91.3	12.0
		S	91.9	8.0	21.5

* This area received rain within 4 hours of application.

Most products were applied at 96 ozs. per acre, but some Dipel 4L was sprayed at 120 ozs. per acre. Cost of a 12 B.I.U. application at 96 ozs. per acre were the same as in 1981 for

Thuricide and about \$2.00 more for Dipel 4L. Cost of applying a 12 B.I.U. treatment with a small fixed-wing aircraft rather than a jet helicopter was about \$2.00 less per acre.

Fixed-wing aircraft used in 1982 were equipped with Micronair rotary atomizers rather than boom and nozzle systems. Previous tests had shown improved B. t. deposit from this type of equipment. Spray deposit results from the 1982 Maine operations showed that deposit from Micronair equipped Thrushes and jet helicopters were similar in terms of overall block coverage and droplets per unit area.

Efficacy results for 1982 confirmed 1981 results with 12 B.I.U. applications (Table 2). All 12 B.I.U. variations evaluated had good foliage protection and population reduction was similar to reductions with chemicals. Comparisons between Dipel 4L and 32LV showed no significant efficacy difference. Results with Bactospiene were inconclusive due to poor spray weather.

The effect of spray volume was compared in 1982 using Dipel 4L at 120 and 96 ozs. of final spray volume. No significant difference was found between the two volumes.

Protection of red spruce with B. t. was evaluated in 1982. Single 12 B.I.U. applications of Dipel 4L or Thuricide 32LV were found to be comparable to split applications of Sevin-4-Oil for protection of red spruce. B. t. applications were able to prevent about half the defoliation expected on the red spruce assessed.

Efficacy in 1982 on blocks treated with Micronair equipped small fixed-wing aircraft was equal to efficacy achieved with boom and nozzle equipped jet helicopters. Fixed-wing results in 1982 led to a change in the favored status held by helicopters. The decision was made to choose 1983 aircraft on the basis of price. Rotary atomizers would also be required.

A new material, volume changes, and additional evaluation of B. t. efficacy on spruce were considered during the 1983 Maine program. In addition to the 119,000 acre State run program, B. t. was applied on lands owned by the Penobscot and Passamaquoddy Indian Tribes and as a part of a large private project.

Maine added Dipel 6L to its list of operational materials (Table 3). Spray volume was reduced to 64 ounces or less for all insecticides used by the State except Thuricide 24B. Dipel 4L, Dipel 6L, and Thuricide 32LV were also applied undiluted at 48, 32, and 48 ozs. respectively. International Paper Company applied Dipel 6L and 8L undiluted in about 25% of their 1983 project. Baskahegan Company used Thuricide 32LV on their private project. The Penobscot and Passamaquoddy Indian Tribes used a variety of B. t. products on a 40,000 acre project. Finally, the State of Vermont conducted a 1,700

acre project using Thuricide 32LV, Bactospiene, and Dipel 6L. All 1983 applications in the eastern U. S. were at 12 B.I.U.'s. All applications in Maine were done with small fixed-wing aircraft at costs varying from \$5.00 to \$8.00 per acre. Cost reductions were greatest in small private projects primarily due to low project overhead. Insecticide costs were significantly lower in 1983 due to competition.

Table 3. Results of B. t. Insecticide Treatment Variations by Area For the 1983 Maine Spruce Budworm Control Project

Treatment	Area	Host	% Unadj. Red.	% Def.	% Fol. Saved
Dipel 6L					
12 B.I.U.'s					
64 ozs.	G46	F	73.0	47.1	25.7
		S	85.5	58.7	13.5
	M82	F	93.6	44.6	43.6
		S	97.4	26.0	45.3
		H	89.3	34.1	33.8
	M72	F	81.3	12.3	18.1
		S	90.4	13.8	16.6
	M121	F	78.7	26.1	33.4
		S	79.7	20.0	41.6
		H	97.8	6.3	26.4
Dipel 4L					
12 B.I.U.'s					
48 ozs.					
Undil.	M 5	F	94.5	15.1	36.1
		S	96.4	16.4	16.4
Dipel 6L					
12 B.I.U.'s					
32 ozs.					
Undil.	M10	F	87.5	28.4	22.8
		S	86.6	20.9	11.9
Thuricide 32LV					
12 B.I.U.'s					
64 ozs.	G26	F	91.3	52.2	20.6
		S	97.4	34.1	38.1
	B5	F	88.6	45.6	27.0
		S	93.7	59.1	13.1
Thuricide 32LV					
12 B.I.U.'s					
48 oz.					
Undil.	B13	F	85.4	56.9	34.3
		S	96.9	24.3	47.9
Thuricide 24B					
12 B.I.U.'s					
96 ozs.	J12	F	91.2	33.4	45.6
		S	91.8	13.1	38.0

Table 3 Continued.

Treatment Area	Host	% Unadj. Red.	% Def.	% Fol. Saved	
<u>Bactospiene</u>					
12 B.I.U.'s					
64 ozs.	G27	F	86.7	45.6	27.2
		S	81.9	42.8	29.4

All areas were treated with Thrushes or M18 aircraft with Micronairs

Efficacy of all 1983 budworm treatments was down because of poor spray weather and unusual larval/host synchrony. However, nearly all B. t. applications conducted in 1983 were successful. Results of the Maine B. t. treatments (Table 3) were again comparable to chemical treatments. Some blocks received only fair foliage protection, but these blocks were sprayed late when much defoliation had already occurred.

Undiluted applications of Dipel 4L and 6L and Thuricide 32LV were as effective as 64 oz. applications made under similar conditions. Spray deposit with undiluted materials was comparable to deposit with 64 oz. applications.

Protection of red spruce with B. t. was good for the third consecutive season. Defoliation on spruce was unusually severe in Maine in 1983, but B. t. applications were able to reduce defoliation to 50% of expected in most blocks.

To summarize, the six years of operational B. t. usage have led to substantial changes in B. t. usage patterns in Maine. It seems appropriate to end this paper with the current status of B. t. application in Maine and the eastern U. S..

Dosage - The 12 B.I.U. dosage is generally accepted in Maine and the eastern U. S.. This rate has a nearly perfect record of success over three years of use. A change from 12 B.I.U.'s to a lower rate would require significant evidence.

Material - Currently available materials favored for use in the eastern U. S. are Bactospiene, Dipel 4L, 6L, and 8L, and Thuricide 32LV and 48LV.

Volume - Low spray volume is generally accepted. Volumes of 64 ozs. have been proven as effective as high volumes used in the past. The Maine State program favors undiluted applications at 48, 32, or 24 ounces depending on which product is used.

Cost - B. t. costs have shown large reductions since 1978 due to competition, concentrated products, and lower emission rates which

lower application costs. B. t. costs are now close to the cost of Sevin-4-Oil, but remain significantly higher than the cost of Matacil or Zectran.

Aircraft - Small fixed-wing aircraft are now preferred as a less expensive, but effective alternative to helicopters.

Spray Delivery System - Micronair atomizers are preferred to boom and nozzle systems.

Efficacy - Foliage protection and population reductions on spruce with 12 B.I.U.'s of B. t. have been comparable to chemical results. Results with B. t. on fir are not usually different from chemical results, but in an exceptional year, chemical results of fir can be significantly better.

Timing - B. t. has been effective from the mid 4th to early 6th instars. Early timing is restricted by need for bud expansion to provide a foliar target. Spray applications during late instars are restricted by the amount of prespray damage.

Operational Considerations - Undiluted B. t. materials do not present any unusual operational problems. However, bulk shipment would be an improvement.

Usage Patterns In Maine

1. Can be used on any level of budworm population
2. Often favored on areas with a high spruce content (70% spruce)
3. Not favored on fir in critical condition
4. Favored in wet areas where chemical buffers hinder spray coverage
5. Favored near environmental hazards
6. Favored near human habitation
7. The percentage of the Maine spray project treated with B. t. has shown a gradual increase since 1978.

Year	Approximate Acreage	Percentage of Operation
1978	20,000	1
1979	38,000	2
1980	200,000	15
1981	126,000	11
1982	89,000	10
1983	119,000	14
Planned		
1984	250,000	30

Operational Weather Guidelines

1. Should not be sprayed when cool, wet weather is predicted shortly after spray
2. Best results are expected when warm, dry conditions are expected for a day or two after spray
3. Weather requirements are more restrictive than those for contact chemicals due to the quicker action of chemicals