COMPARISON OF BT FORMULATIONS AGAINST THE SPRUCE BUDWORM

Lew McCreery, Imants Millers and Dennis Souto, Entomologists, Forest Pest Management, USDA Forest Service, PO Box 640, Durham, NH and Bruce Francis, Director of Forestry, Passamaquoddy Indian Forestry Department, PO Box 301, Princeton, ME

SUMMARY

The Passamaquoddy Indian Forestry Department treated 40,300 acres in Maine in 1983 using Bt to protect red spruce and eastern hemlock from spruce budworm damage. The post treatment evaluation indicated that the protection objectives were achieved. In cooperation between the Passamaquoddy Indian Forestry Department and two commercial Bt suppliers, Abbott Laboratories and Zoecon Corporation, four commercial products were applied as eight field formulations. Where possible, these treatments were compared for effectiveness. The results show an average defoliation of 23 percent and population reduction from 864.5 budworms per 100 square feet of foliage to 62.5 budworms, or an average of 94 percent population reduction. The undiluted field formulations gave significantly ($P = 0.05$) less defoliation and greater population reduction than the diluted formulations. A method for spray deposit assessment using spruce foliage is presented.

INTRODUCTION

McCreery (1982) reported high spruce budworm populations and heavy past damage on about 40,000 acres of Passamaquoddy Tribal Trust lands. The Passamaquoddy Indian Forestry Department (PFD) requested and obtained spruce budworm suppression funds. USDA Forest Service, Durham Field Office staff provided technical assistance to the PFD in implementing and evaluating the suppression project. An earlier report summarized the suppression project accomplishments (McCreery and Francis 1983). In this report, various Bt field formulations used on the project are compared.

PROJECT AREA

The project was conducted in SBW-infested spruce and hemlock stands on Tribal Trust land in Townships T4ND BPP, T5ND BPP, T5R1 and Indian Township, Maine. These lands, most of which were only recently purchased by the Tribe, have been infested by SBW for many years. Only a small portion of the lands has been protected in the past.

The total area sprayed was about 40,300 acres. This area was in 26 blocks ranging from 500 to 4,000 acres. Blocks were delineated on the basis of biological need for treatment as well as topography and forest cover to aid in navigation.

METHODS

Insecticides

Four commercial preparations of Bt were used: Dipel 6L and 8L (Abbott Laboratories), and Thuricide 32LV and 48LV (Zoecon Corporation) (Table 1). All materials were applied in various field formulations from undiluted to 95 fl. oz. per acre to give 12 BIU's of active ingredient per acre. The only exception was Dipel 8L, which was applied undiluted at eight BIU's per acre (16 fl oz/acre). A sticker, RA-1990 (Rohm and Haas) was added at 2% rate of field formulation for all dilute applications.

Mixing and Loading

Mixing and loading services were provided by Chem-Pro of Oregon as subcontractors with Biegart Aviation.

Two semi-trailer tankers, each equipped with three compartments, were used to mix the insecticide. Dipel and Thuricide were mixed in separate tankers to avoid problems of incompatibility. Insecticide was unloaded from 55-gallon drums and stored in one of the compartments and water was stored in the other. The third compartment was used to mix the insecticide as needed. All liquids were metered as they were pumped to the compartments and to the aircraft. Insecticides were used within 24 hours after mixing. The sticker was added to the water before the addition of insecticide. No mixing problems occurred with the sticker.

Table 1.--Products used during the 1983 Passamaquoddy Suppression Project

Product	Rate (fl oz/acre)	Gallons Sprayed	Acres Sprayed
Dipel 6L	32[a]	935	3740
	65[a]	5277	10344
	96[a]	3000	3960
	Subtotal	9212	18044
Dipel 8L[b]	16	110	900
Thuricide 32LV	48[a]	741	1976
	64[a]	2295	4590
	96[a]	8764	11685
	Subtotal	11800	18251
Thuricide 48LV	32	782	3128
	Grand Total	21904	40323

[a] A sticker, RA-1990 (Rohm and Haas), was used with all dilute applications at a rate of two percent by volume.

[b] Dipel 8L was donated by Abbott Labs for use on this project.

Aerial Application

The aerial application was done by Precision Air of Foley, AL, as subcontractors to Biegart Aviation, Mesa, AZ. The aircraft were based at Princeton Airport, Princeton, ME. Spraying started on June 1, 1983 and was completed on June 9, 1983. The spray blocks were from 2 to 35 air miles from the airport.

Aircraft and Spray Equipment

Three aircraft each with a spray volume capacity of 300 gallons were used. One was a Thrush 600; the others were Snow Thrushes. All three were equipped with eight Mini-Micronair rotary atomizers (AU 5000). Atomizers were equally spaced along the boom, beginning 18 inches from the outboard end. Atomizer pitch was set at 45°.

Aircraft Calibration and Characterization

The aircraft were calibrated at Princeton Airport on the basis of data from spray trials in Foley, AL (O'Neal 1983). At the spray trials, Thrush 600 aircraft were flown at 110 mph, 50 feet above target at pump pressure of 40 psi. Twenty drops/cm^2 was the minimum standard for locating an effective swath at the Foley trial. Thuricide 48LV did not provide the 300 foot swath width at Foley, but later achieved that swath during tests at Princeton Airport. A swath width of 300 feet was used for all formulations.

Application

The three aircraft sprayed as a team. Team guidance was provided by a guide ship (Lincoln Air) equipped with a Loran C guidance system (Teledyne Corp.), which was used to locate team swaths. A monitor and spotter, both PFD employees, observed all applications from the monitor aircraft (Lincoln Air) 800 to 1000 feet above the terrain. The spotter called booms-on, booms-off over treatment areas. The monitor observed spray cloud behavior, team spacing, and weather conditions.

Meteorology

Weather conditions were monitored by ground personnel within treatment areas, the monitor aircraft, and through long range forecasts provided by the Maine Forest Service and Bangor International Airport Flight Service. The work plan specified these weather conditions as acceptable for Bt application:

a. Drip dry foliage within or in close proximity to spray blocks.

b. No rain forecast for four hours.

c. Windspeed >2 mph but <15 mph.

d. No inversion conditions present at or below 100 feet above canopy.

e. Air temperature forecast to be 55°F or higher within 36-48 hours.

f. Air temperature above 32°F at application time.

Larval and Bud Development

Larval and bud development were monitored at eight sites - five in the spray areas and three in the check areas. At each site, five codominant spruce were marked for development sampling. Each sample consisted of one 36-inch branch cut from the midcrown and brought to the field laboratory. Collections were made at three to five day intervals until spraying was completed. Laboratory examinations were completed on the same day as collections.

In the laboratory, all larvae (not more than 100) found on the branches were removed and their location recorded as:

1. Wandering on branches.

2. Mining in the needles.

3. Mining in the buds.

4. Other (loose in the bag, etc.).

Larval instars were determined from head capsule measurements and body coloration. Larval index was determined by the method described by Dorais and Kettela (1982). The results are summarized in Tables 2 and 3.

Bud development index is shown in Table 2. This system was developed by D. G. Mott, formerly of the PFD staff. The classes were defined as:

Class 1 - Tight buds, no green showing at the base of the bud.

Class 2 - Bud expanding, ≤2mm of green showing at the base of the bud.

Class 3 - Bud expanding, >2mm of green showing at the base of the bud.

Class 4 - Bud cap off.

Insecticide application was timed to start when most of the larvae had left needle mines (more than 50%).

Table 2.--Larval and bud index values for the Passamaquoddy Spray Project (first and last spray day), 1983

	June 1		June 9	
Location	Larval Index	Bud Index	Larval Index	Bud Index
T4ND 1	3.4	1.0	4.0	2.5
2	3.0	2.1	4.0	3.3
3	3.0	1.0	4.0	2.0
T5ND 1	3.0	1.0	3.8	1.2
2	3.5	1.5	4.6	2.5

Table 3.--Larval behavior during and after the Passamaqouddy Spray Project, 1983

	T4ND BPP			T5ND BPP		
Behavior	6/1	6/9	6/15	6/1	6/9	6/15
% Wandering	39	26	53	25	25	51
% In Needles	43	0	0	60	2	0
% In Buds	12	56	37	6	58	40
% Other[a/]	6	18	10	9	15	9
	100	100	100	100	100	100

a/ Includes larvae webbed either on or near buds or found loose in the bags.

SPRAY EFFICACY EVALUATION

Samples and Sample Clusters

A total of 45 sample clusters were established in 10 treatment blocks. Each cluster was a line of 20 dominant/codominant spruce trees spaced about 50 feet apart, across the anticipated spray swaths.

Additionally, three check blocks were established in widely separated areas at least ½ mile outside the spray blocks. Each check block had four clusters established in a manner similar to the spray blocks. Despite these precautions, Bt deposits were found in two of the three check blocks.

Prespray Survey

Prespray samples consisted of one 18-inch-long branch taken from the midcrown of each sample tree. Collections were made two to three days before spraying. The branches were bagged, labeled and delivered to a laboratory for examination. The average number of larvae per 18-inch branch was determined in the laboratory.

Postspray Survey

Postspray samples included two branches, each 18 inches long, taken from the midcrown of the sample trees. The samples were collected about 40 days after spraying when larval feeding was completed. This coincided with 10 percent adult emergence. Again, branches from each tree were bagged, labeled and delivered to the laboratory. In the laboratory, the average number of budworm per branch and the degree of defoliation were determined from 25 shoots rated in 10-percent defoliation classes.

Spray Deposit Assessment

Spray coverage was evaluated at the sample clusters in nine of the ten treatment areas and in all the check areas. Foliage samples were collected from the midcrown and from the lower crown of each sample tree. In each treatment area, deposit assessment was made for five trees in each of the selected clusters. In addition, millipore filters were exposed on 3 foot stakes near sample trees. In each treatment area, five filters were set out in each cluster. The filters were set out 8 to 12 hours before spraying and picked up within six hours after spraying. Foliage samples were taken as millipore filters were collected.

About a month later, all deposit samples were placed on tripticase soy agar plates and the spray coverage determined. For foliage samples, 20 old needles from each branch were placed on agar. After incubation, the proportion of needles producing Bt colonies were determined. Sample colonies from each dish were examined under a microscope to confirm the presence of Bt crystals. The millipore filters were handled the same way, except that the number of colonies per square centimeter was determined.

Field Laboratory

Foliage examination was done in a laboratory operated by the PFD. Personnel included experienced workers. Branches were brought to the laboratory and kept refrigerated. They were examined within a week after collection.

RESULTS AND DISCUSSION

Efficacy

The average defoliation in treated areas was 23 percent. Spruce budworm populations declined in treated areas from 865 to 62.5 budworms per 100 square feet of foliage. Thus, the average spruce budworm mortality was 94 percent.

The results for each treatment are summarized in Table 4. The differences between treatment means were analyzed using Student's Newman Keuls test ($p = 0.05$). Spruce budworm mortality was significantly higher in undiluted Dipel 6L treated blocks than in undiluted Thuricide 48LV or diluted Thuricide 32LV treated blocks. Although the differences between diluted and undiluted Dipel 6L treated blocks were not significant with the Newman Keuls test, both budworm mortality and defoliation were significantly different based on a grouped t test.

No other treatment means were significantly different. The sampling method used 20 tree lines as clusters and did not give enough samples to detect mean differences of less than 10 percent with normal field variation.

A comparison was made between diluted and undiluted treatments of Dipel 6L and Thuricide 32LV combined. The undiluted treatments had significantly lower defoliation and higher budworm mortality than the diluted treatments (Student's t test, grouped data; $p = 0.05$).

Table 4.--Spruce budworm population changes and spruce defoliation in the Passamaquoddy Spray Project, 1983

Treatment	Rate (fl oz/acre)	Clusters	Deposit % Needles cov'd	Mean No Larvae/100 ft^2 pre ± se	Mean No Larvae/100 ft^2 post ± se	% Mortality ± se	% Defol ± se
Dipel 6L	32	5	32	664 ±81.7	12.4 ± 2.3	98 ± 0.5	20 ± 3.2
Dipel 6L	32	4	65	935 ± 116	5.6 ± 3.3	99 ± 0.3	13 ± 2.9
Dipel 6L	65	7	47	1090 ±73.3	14.7 ± 2.3	98 ± 0.4	28 ± 2.9
Dipel 6L	65	4	50	1412 ±25.5	82.6 ±16.4	93 ± 1.7	25 ± 2.9
Dipel 6L	65	4	--	918 ± 318	86 ± 7.0	86 ± 4.7	21 ± 2.7
Dipel 8L	16	3	53	821 ± 137	30 ±12.2	95 ± 2.7	18 ± 0.7
Thuricide 32LV	48	4	87	921 ±73.5	32.5 ± 7.2	96 ± 0.9	19 ± 4.4
Thuricide 32LV	64	4	97	972 ± 206	69.1 ±14.0	91 ± 3.5	16 ± 3.1
Thuricide 32LV	64	4	70	1742 ± 214	87 ± 6.6	95 ± 0.5	24 ± 2.8
Thuricide 48LV	32	6	43	304 ±50.7	23.5 ± 5.3	88 ± 5.8	17 ± 2.4
Check 1		4	5	969 ±22.4	115 ±20.2	81 ± 9.3	28 ± 2.9
Check 2		4	28	314 ± 119	142 ±31.4	57 ±10.3	32 ± 5.6
Check 3		4	0	471 ± 116	174 ±76.7	50 ±21.1	32 ± 2.9

Spray Coverage

Spray deposit in the treated areas indicated good coverage (Table 5). No significant differences in deposit were found between midcrown and lower crown needle samples (60.9 percent vs. 59.3 percent of needles with Bt). On millipore filters, the average count was 48.2 colonies per cm^2. However, one block (47) had an average of 171 colonies per cm^2, suggesting multiple coverage. Without that block, the average deposit was 32.9 colonies per cm^2.

Our work with aerial application of Bt over the past three years indicate that checks need to be sampled for Bt deposits. As in the previous years, the current year's checks received some

Bt deposits. Although, the amounts are considerably less than what is found in the sprayed areas, some budworm mortality from Bt is expected, and therefore, the checks do not represent truly untreated Bt areas.

Table 5.--Spray deposit assessment for the Passamaquoddy Spray Project, 1983

Treatment	Rate (fl oz/ac)	Block No	% Needles Producing Colonies		Millipore Filters (Colonies/ cm^2)
			Mid-crown	Lower crown	
Dipel 6L	32	72	36	28	24
		43	59	70	34
Dipel 6L +2% Sticker	65	45			
		48	52	48	19
		71	51	42	15
Dipel 8L	16	49	49	56	90
Thuricide 32LV	48	46	88	86	22
Thuricide 32LV + 2% Sticker	64	44	96	97	24
		47	73	66	171
Thuricide 48LV	32	73	44	41	45

ACKNOWLEDGEMENT

The authors would like to thank D. Gordon Mott, former employee of the PFD, for his assistance during the project.

REFERENCES

Dorais, L. and E. G. Kettela, 1982. A Review of Entomological Survey and Assessment Techniques used in Regional Spruce Budworm Choristoneura fumiferana (Clem.), Surveys and in the Assessment of Operational Spray Programs. Eastern Spruce Budworm Council Report. October 1982.

O'Neal, Jerry, 1983. Physical Characterization and Droplet Assessment of Matacil, Zectran, and Three Biological Insecticides: Bactospeine, Dipel and Thuricide. Environmental Greenery Consultants, Neely. MS. May, 1983.

McCreery, Lew, 1982. Biological Evaluation of Spruce Budworm on Passamaquoddy Trust Lands in Maine. Administrative Report. USDA-Forest Service, Northeastern Area, Forest Pest Management. December, 1982.

McCreery, Lew and Bruce Francis, 1984. Aerial Suppression of Spruce Budworm with Bt on Passamaquoddy Indian Lands, Maine, 1983. Administrative Report. USDA-Forest Service, Northeastern Area, Forest Pest Management. January, 1984.