1989 WESTERN SPRUCE BUDWORM PILOT PROJECT, WALLOWA-WHITMAN NATIONAL FOREST HALFWAY, OREGON

H6

draft

by

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INTRODUCTION

Western spruce budworm (Choristoneura occidentalis Freeman) ~~outbreaks in the Pacific Northwest caused defoliation~~ defoliation was detected on about 3 million acres of mixed conifer forests in the Pacific Northwest in 1988. Defoliation had declined significantly from 1986, when 6 million acres were defoliated. The expectation is that western spruce budworm will continue to be one of the most important defoliators of western conifer stands, and that use of insecticides ~~application projects~~ to suppress budworm ~~outbreaks~~ populations will be considered as a management ~~approach~~ short-term option.

In 1989, the Regional Forester of the Pacific Northwest Region selected application of insecticides, with a clear preference for a biological insecticide with Bacillus thuringiensis as an active ingredient, ~~Bt~~ over carbaryl, as the preferred alternative for suppressing current spruce budworm outbreaks that were determined to be causing unacceptable damage to forest resources. This decision was made based upon a final environmental impact statement on management of western spruce budworm in Oregon and Washington (USDA-FS 1989).

In 1988, the USDA Forest Service resumed pilot testing of biological insecticides for control of western spruce budworm . This was done because several commercially available formulations of insecticides containing Bacillus thuringiensis (~~Bt~~ Bb, Bt) had not been ~~tested~~ evaluated under operational conditions to determine their effectiveness in ~~controlling~~ suppressing western spruce budworm ~~outbreaks~~ populations. Only insecticide formulations demonstrating acceptable effectiveness in controlling populations will be used on future operational suppression projects by the Forest Service.

The Forest Service developed a set of priorities for pilot testing ~~biological~~ insecticides for ~~control of~~ suppression of western forest defoliators. Top priorities for western spruce budworm were to focus on applications of undiluted aqueous formulations of ~~Bt~~ Bb, and to compare ~~volumes per acre~~ application rates of 42.7 ounces to 64 ounces per acre. In past projects, 42.7 ounce/acre applications had yielded inconsistent

results against
control of western spruce budworm populations, while 64 ounce applications gave was
consistently better control. more effective However, there had never been direct comparisons
of the two volumes using the same BT formulations in a pilot test. The 1989 the two rates
Western Spruce Budworm Pilot Test conducted at Halfway, Oregon, was designed to
test these treatments.

OBJECTIVE

To compare effectiveness of an aqueous B.t. formulation. measure the efficacy of Foray® 48B applied undiluted at the rates of 16 (billion international units) BIU's in volumes of 42.7 ounces (1/3 gallon) and 64 ounces (1/2 gallon) of formulation per acre, in suppressing populations of western spruce budworm.

PROJECT DESCRIPTION AND DESIGN

DESCRIPTION OF PROJECT AREA

The pilot project test was done conducted on the Wallowa-Whitman National Forest in Oregon. The initial project boundary was limited to the Pine Ranger District at elevations less than 6,000 feet above sea level. It became clear after intensive reconnaissance of this area that the western spruce budworm populations were too widely scattered to locate enough test blocks in this area (spotty and too low to do the pilot test) Surveillance of adjacent Districts revealed the likelihood of finding populations high enough for testing. A supplement was made to the 1989 Environmental Assessment- Western Spruce Budworm Management in Oregon and Washington in 1989, adding portions of these Districts. The expanded pilot test boundary extended from the Big Creek drainage and Balm Creek Reservoir area on the LaGrande Ranger District eastward to the Duck Creek drainage in the Hells Canyon National Recreation Area. Twelve test blocks were set up within this expanded area (Figures 1,2, and 3).

Stand composition within the blocks was predominantly grand fir with lesser amounts of Douglas-fir, Englemann spruce, ponderosa pine, western larch, lodgepole pine, and subalpine fir.

PROJECT DESIGN

~~four treatments replicated five times.~~

The pilot test was originally planned to compare western spruce budworm population densities in unsprayed untreated check blocks to those in blocks receiving three treatments. The treatments, shown by priority, were as follows:

1. Foray® 48B applied at 42.7 16 BIU's in ounces per acre.
2. Foray® 48B applied at 64 16 BIU's in ounces per acre.
3. SAN® 415 SC LV applied at 64 16 BIU's in ounces per acre.

All treatments were to be made applied at 16 BIU per acre. Each treatment and the untreated unsprayed check blocks were to be replicated five times, in a completely randomized design.

When it became apparent that 20 blocks with western spruce budworm populations high enough to qualify for treatment (at least block means of 12 larvae/ 45cm long branch with 90% confidence) could not be located in the pilot test area a decision was made to drop the SAN 415 treatment. Twelve blocks with qualifying populations were established. The two Foray treatments and the unsprayed checks were assigned at random to these blocks. Each treatment was replicated four times.

Separate batch trucks and application helicopters were used to store, transport, and apply the Foray 42.7 ounces/acre and Foray 64 ounces/acre

V produced by Sandoz Lab., - - - (State).

treatments. Both Foray treatments were applied to their assigned blocks on the same days and matched with an unsprayed check block released for ~~testing~~ at the same time. larval population samples

BLOCK LAYOUT

Twelve ~~test~~ blocks averaging 500 acres each were established within the project boundary on the Wallowa-Whitman National Forest. These blocks were located by first examining 1988 western spruce budworm defoliation maps and stand type maps to delineate areas with suitable spruce budworm host trees. Areas with ~~motor vehicle access restricted because of~~ sensitive elk calving sites were eliminated, as were long-term research plots used for monitoring ~~insects~~. Douglas-fir tussock moth & western spruce budworm populations.

Criteria used to further aid in block location were:
1. Presence of defoliation caused by western spruce budworm in 1988 over most of the 500 acres.
2. Adequate number of host trees suitable for sampling.
3. Less than 500-foot difference between the highest and lowest elevations in the block.
4. Enough distance from other blocks to prevent contamination by drift.
5. ~~Only National Forest administered land.~~ Land administered by National Forest system only.
6. Good motor vehicle access.
7. Prominant landmarks visible from helicopters.

A total of 27 blocks meeting these criteria were located within the test boundaries. Most of the blocks were initially located by reconnoitering the pilot test area from a helicopter, followed by ground visits ~~to promising looking block sites~~. Recent color aerial photography of the Wallowa-Whitman National Forest proved to be an excellent aid for block location.

Fourteen of the blocks did not qualify for the test because early larval densities were less than 12 larvae per 45cm branch. One block was eliminated because of limited motor vehicle access.

Eight of the blocks assigned ~~Foray~~ Sev treatments were marked for spraying by placing orange fluorescent panels on the ground in openings along the boundaries and orange streamers in the tops of trees. Features that could be easily distinguished from low flying helicopters, such as roads, streams, and ridges, were also used to define block boundaries. Check blocks were not marked with panels or streamers.

PROJECT LOGISTICS AND ADMINISTRATION

INSECTICIDES

Foray 48B Flowable Concentrate® contains the HD-1 strain of Bacillus thuringiensis Berliner var. kurstaki as the active ingredient. ~~The insecticide~~ It is produced and marketed by Novo Laboratories, Inc. Foray is an aqueous formulation that can be applied by aircraft, either undiluted or diluted with water. It contains 48 BIU of Bt per gallon. The insecticide is brown in color and does not contain any dye. Foray is labelled for use against western spruce budworm under EPA registration number 58998-7.

The Forest Service purchased 1760 gallons of Foray 48B, plus 440 gallons of Foray 48B inactivated by autoclaving. The insecticide was shipped to Baker, Oregon in 55 gallon drums and turned over to the application contractor for storage and handling.

The 42.7 ounce per acre application was made by transferring an appropriate amount of insecticide from the 55 gallon containers into the contractor's batch truck. It was then pumped into the application helicopter during the mornings spraying was done.

The finished spray used for the 64 ounce per acre applications was made by adding one-half gallon of inactivated Foray to each gallon of active Foray and mixing in a separate batch truck. No dye was added to insecticide sprayed on the test blocks.

APPLICATION EQUIPMENT

CONTRACTOR A Request For Proposals approach was used to negotiate and award the application and observation contract. Three contractors submitted proposals. Western Helicopter Services from Newberg, Oregon was awarded the contract on the basis of the best combination of technical approach and price.

SPRAY EQUIPMENT Western Helicopters provided two Hiller-Soloy helicopters for ~~spraying~~ insecticide application. The helicopter spraying systems consisted of Simplex tanks, Sorenson gear pumps, and six Beecomist 360A rotary atomizers on each aircraft. The atomizers were mounted within 3/4 of the main rotor radius on the booms. Thirty mesh screens were used. Crophawk monitors were used to monitor flow rates.

Two 10-wheel batch trucks equipped with paddle agitators were used to store, transport, and disperse insecticide, fuel, and water to the spray helicopters.

CALIBRATION AND CHARACTERIZATION Calibration of the spray aircraft was done at Western Helicopter's headquarters in Newberg. The first attempts to calibrate the helicopters were not successful because the centrifugal pumps were not able to pump Foray 48B, due to cavitation. The centrifugal pumps were replaced with Sorenson gear pumps and calibration proceeded smoothly.

The spray aircraft were calibrated to produce an effective swath of 100 feet with a density of 20 drops per square centimeter at an airspeed of 60 MPH.

A small quantity of the insecticide was dyed with Rhodamine B WT to characterize the aircraft spray pattern. Kromekote cards were placed 10 feet apart on a line 300 feet long. The helicopters were flown perpendicular to the line at a height of approximately 50 feet. The cards were examined with 7X magnifiers to determine droplet diameter. Using the D-Max system, the VMD for effective swaths for both aircraft was estimated to be 150 to 180 micrometers

OBSERVATION AIRCRAFT Two Bell Jet Ranger 206's were provided to serve as the observation and administrative use aircraft. They carried Forest Service personnel who ~~observed~~ followed the spray helicopters for spray dispersal and movement and monitored.

EQUIPMENT AND SUPPLIES

Following the large western spruce budworm suppression projects in 1988, Forest Pest Management worked with the Redmond Fire Cache on the Deschutes National Forest to inventory, store, and manage a large and costly quantity of equipment and supplies needed for forest defoliator suppression projects. More than 600 separate types of supplies, worth more than $250,000 were stored. These items were incorporated into the National Fire Equipment System. The Redmond Fire Cache put together a catalog of supplies, along with instructions on ordering. This system for ordering supplies was used for the first time on the ~~Halfway~~ this ~~pilot test~~ project, with excellent results. Practically all equipment needed was ordered several weeks before ~~the pilot test~~ project personnel reported to Halfway. The supplies, valued at $93,000, arrived in excellent condition in a large trailer truck and van. Complete inventories accompanied the supplies. Having all the supplies arrive at the same time saved much time compared to previous projects. Equipment and supplies not consumed on the pilot test were returned to the Redmond Fire Cache for storage and repair.

PROJECT ORGANIZATION

The ~~pilot test organization~~ Pilot project test organization used the Incident Command System modified to fit a small aerial application project (Fig. 4). The test was administered by personnel from the Forest Pest Management staff of the Pacific Northwest Region and the Wallowa-Whitman National Forest. Individuals from several National Forests in the Pacific Northwest Region, the Boise Field Office of Forest Pest Management, and the Boise Inter-Agency Fire Center participated. The majority of the Biological Aides were local residents hired by the Wallowa-Whitman National Forest. Because of the relatively small size of the ~~test~~ project it was possible to have some people serve in more than one position. This worked well; ~~in that~~ people were always busy and they ~~got to~~ experienced a variety of tasks.

SAFETY

Safety was a major consideration for all phases of the ~~pilot test~~ project. ~~Project~~ personnel were given a daily safety message. Training was provided in first aid and defensive driving. Safety hazards encountered within the (test) project boundaries were displayed on ~~pilot test~~ maps. All aerial operations were carried out according to Federal Aviation Administration and Forest Service regulations. An emergency procedures guide was prepared, covering motor vehicle accidents, injuries, aircraft accidents, and spills. This guide was provided to all ~~test~~ personnel, and placed in each vehicle. The goal was to avoid any ~~lost time due to~~ injuries and ~~avoid motor vehicle~~ accidents by continuously emphasizing safe working procedures. This goal was not met. One employee suffered a ~~fractured~~ bone and ~~bone when he fell off a rock~~. One vehicle sustained damage. There were no aircraft accidents or spills.

BUDGET

The pilot ~~test~~ project was funded by Forest Pest Management. Table 1 displays ~~pilot test~~ project costs.

Budget for the project

Table 2. 1989 Western spruce budworm pilot ~~test budget~~.

←Application Contract	
Western Helicopters	$136,477
Insecticide	
Novo Laboratories	$19,800
Supplies and Equipment	
Redmond Cache	$3,500
Vehicle Rental	$50,000
Fuel, Tires	$5,500
Rent	$2,800
Trailer Lease	$3,985
Telephone	$600
Electricity	$650
Services	$1,100
Misc Supplies	$7,100
Project Personnel	
Salaries	$165,000
Per Diem	$40,000
Administrative Flights	$21,000
TOTAL	$457,512

Application Dates & Weather

~~APPLICATION~~ CONDITIONS

Treatment assignments and application dates are shown in Table 2.

Table 1. Treatment assignments and date of treatment.

Replicate No.	Date Treated	Block	Treatment
1	June 18	10	Check
		14	FORAY @ 42.7
		11	FORAY @ 64
2	June 19	16	Check
		19	FORAY @ 42.7
		18	FORAY @ 64
3	June 21	20	Check
		21	FORAY @ 42.7
		17	FORAY @ 64

		25	Check
4	June 23	26	FORAY @ 42.7
		27	FORAY @ 64

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Spraying was done on June 18, 19, 21, and 23. All spraying was accomplished between the hours of 5:00 AM and 7:00 AM. Weather conditions during the spraying were as follows:

Date	Relative Humidity	Temperature	Wind Speed
June 18	70-80%	40-41	0-1
June 19	80-90%	44-45	0-1
June 21	76-90%	36-39	1-2
June 23	75-80%	43-50	2-6

SPRAY DEPOSIT ASSESSMENT

Spray deposition was assessed by placing Kromekote and water sensitive cards in plastic holders on the ground in the treatment blocks. A spray card line consisting of 20 cards, spaced approximately 10 feet apart, was established in each block that ~~got~~ was sprayed. An attempt was made to place the cards in openings as much as possible. In addition, spray cards were also placed around several of the trees used for post-spray population assessment. Cards were collected approximately 30 minutes after the entire block had been sprayed.

Spray drop density on the spray cards was determined with a dissecting microscope. One person read all cards. Cards were placed into four drop density classes, 0 = no drops, 1 = 1-5 drops /~~CM2~~ sq cm, 2 = 6-14 drops/~~CM2~~ sq cm, 3 = 15+ drops/~~CM2~~ sq cm.

Undyed Foray could be detected on the white Kromekote® spray cards ~~with relative~~ fairly easily. ease. The insecticide caused blue-green spots where it impacted on the water-sensitive cards. The water-sensitive cards were not useful for assessing spray deposit because their entire exposed surfaces turned blue-green in the high relative humidity.

~~Spray deposit was measured in each block sprayed. Cards were placed near several sample trees used for budworm population estimation. Each block also had a cardline consisting of 20 Kromekote cards placed in relatively open areas.~~ Results of spray deposit measurements are shown in Table 3.

With the exception of Block 26, spray deposit measured on the cards was good to excellent. Winds were gusting up to 6 MPH, measured at the ground when Block 26

was sprayed. It is likely the wind caused many of the drops to move out of the block.

Table 3. SPRAY DEPOSITION DENSITY MEASUREMENTS, WESTERN SPRUCE BUDWORM PILOT TEST, HALFWAY, OREGON.

OZ/ACRE	BLOCK	DROP DENSITY RATING	CARD LOCATION	
			SAMPLE TREE	CARDLINE
42.7	14	0 *	1(4%) **	0(0%)
		1	8(32%)	2(10%)
		2	9(36%)	17(85%)
		3	7(28%)	1(5%)
42.7	19	0	4(9%)	0(0%)
		1	31(72%)	4(20%)
		2	7(16%)	14(70%)
		3	1(2%)	2(10%)
42.7	21	0	0(0%)	0(0%)
		1	15(31.2%)	1(5%)
		2	17(35.4%)	2(10%)
		3	16(33.3%)	17(85%)
42.7	26	0	5(10.6%)	0(0%)
		1	42(89.4%)	5(25%)
		2	0(0%)	9(45%)
		3	0(0%)	6(30%)
64	11	0	0(0%)	0(0%)
		1	6(18.7%)	3(15%)
		2	12(37.5%)	4(20%)
		3	14(43.7%)	13(65%)
64	17	0	2(10%)	0(0%)
		1	12(60%)	0(0%)
		2	6(30%)	3(15%)
		3	0(0%)	17(85%)
64	18	0	0(0%)	0(0%)
		1	7(35%)	0(0%)
		2	9(45%)	8(40%)
		3	4(20%)	12(60%)
64	27	0	0(0%)	0(0%)
		1	19(43.2%)	0(0%)
		2	18(40.9%)	9(45%)
		3	7(15.9%)	11(55%)

* Deposit rating 0= no drops, 1=1-5 drops/cm2, 2=6-14 drops/cm2, 3=15+ drops/cm2.

** First number is the number of deposit cards, second number is percent of total deposit cards.

ENTOMOLOGICAL PROCEDURES

INTRODUCTION Entomological sampling was used to: (1) qualify blocks for treatment; (2) release blocks for treatment at the appropriate time, and; (3) evaluate the results of BT application in terms of population reduction and foliage protection. 6 treatments.

Each treated (8) and untreated (4) block included as part of the project was sampled according to the following multiple-stage sampling scheme:

Sampling Stage	Unit Sampled	No. Units Sampled per Sampling Stage
1	Cluster Plots	25
2	Trees	3
3	Branch-tips	Pre-treatment 1 Post-treatment 1

This sampling was done to determine pre- and post-treatment budworm densities for each replicate. Pre-spray sampling was done by clipping mid-crown branches with a pole pruner equipped with a catch basket. Post-spray sampling was also done by mid-crown pole pruning.

The types of sampling and entomological activities conducted on the Pilot Project are shown in the following list. Details are presented later in this document.

1. Degree day measurements
2. Early larval density sampling
3. Larval development sampling
4. Pre-treatment larval density sampling
7. Post-treatment larval density sampling
8. Larval and pupal rearing
9. Adult trapping
10. Post-treatment defoliation sampling

DEGREE DAY MEASUREMENTS An Omnidata biophenometer was placed at each of three elevations (3,800, 4,600, and 5,400 feet) within the area of the potential treatment sites on May 19, 1990. Biophenometers were calibrated and checked prior to placement in the field. Set-point minimum and maximum threshold

temperatures were 42 F and 110 F, respectively. Each biophenometer was housed in a small instrument shelter and located out-of-sight from roads, in clusters of dominant to codominant budworm host trees. Each instrument shelter was attached to a metal fence post driven into the ground at least 50 feet from the nearest tree. Shelters were positioned so that they received partial exposure to the sun throughout the day.

Biophenometers were read every 2 to 6 days through July 11 when they were removed.

EARLY LARVAL DENSITY SAMPLING Sampling of early instar larvae was done in order to estimate population densities for each block. To qualify for treatment, each block was required to have, with 90% confidence, a budworm population density of at least 12 larvae per 45-cm (17.7-in) branch. A t value was calculated for each block using early larval density data. This value was then compared to the appropriate value for n samples and the 90% confidence level for a one-tailed test.

Early Larval Density Plots were located at or near the same sites as the Pre- and Post-treatment Evaluation Plots. The sample trees at each plot consisted of three Douglas-firs or three true firs. The trees were open-grown, relatively full crowned with bud-bearing branches in the mid-crown, 20 to 45 feet tall, and exposed to full sun most of the day. In mixed stands, sample trees were selected from the predominant host species.

One 45-cm (17.7-in) apical or outside branch was obtained from the mid-crown of each sample tree. Each branch was clipped with a pole pruner and collected in the cloth collecting basket attached just below the cutting head. Each branch, plus any larvae that had fallen into the basket, was placed into a labeled paper bag. The three bags from each plot were then stapled together, placed into a cardboard box, and transported to the laboratory.

At the laboratory, samples were put into a walk-in cooler at 40°F until they could be examined, usually within 24 hours after collection. Numbers of budworm larvae, new shoots or buds, and other lepidopterous larvae were recorded for each branch.

LARVAL DEVELOPMENT SAMPLING Each set of three blocks (i.e., two treated and one untreated) was released for treatment when observations indicated that at least 95 percent of all buds had unfurled (i.e., the budcap was gone, the bud sheath had broken, the shoot had elongated, and the needles were no longer bunched) and less than 15 percent of the budworm larvae were in 2nd and 3rd instars combined.

Once a block qualified for treatment, development plot sites were identified and the original plan was to visit these plots intermittently until the first buds begin to burst, and then to sample the plots at least twice weekly until buds opened and the foliage began to expand. Depending on weather and rate of development, samples were then to be taken as often as necessary until release criteria (i.e., less than 15 percent in 2nd plus 3rd instars and 95 percent of

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Criteria
~~buds unfurled~~) were met, ~~for a set of blocks and the blocks were released for treatment~~.

~~When~~ development samples (were collected) (on a) block, (they) were collected in the following manner: Samples were collected at six to twelve sampling locations on the Pilot ~~Test~~ Project blocks. These sampling locations were selected such that they best characterized the range of both elevational and aspect differences within the block. Development plots were located at the same sites as Evaluation Plots; however, development samples were <u>not</u> taken from Evaluation Plot trees.

At each of the development plots one branch was clipped from the lower crown of each of 4 trees. Sample trees conformed to the same criteria established for the Early Larval Density Sampling described in the previous section. In stands with only one host species, all 4 sample trees were of that species. In a mixed species stand, 2 Douglas-firs and 2 true firs were sampled since development rates may differ among host species that occur at the same location (Williams et al. 1985). Samples were obtained by clipping one 45-cm apical branch tip with developing shoots from the lower crown of each sample tree. For each branch sampled, total number of new shoots, number of unfurled shoots, and number of larvae were tallied. At least 25 budworm larvae were collected at each development plot for instar determination.

* insert.

<u>PRE-TREATMENT LARVAL DENSITY SAMPLING</u> Pre-treatment larval samples were collected in each block after it had been released for treatment and within 24 to 48 hours before insecticide application. Three trees were sampled in each of 25 plots in each block. Sample trees were selected using the following criteria:

(1) Species were the same as the predominate host type in the surrounding stand.

(2) Trees contained current-year's shoots (new shoots) in the mid-crown.

(3) Trees were reasonably open-grown, full-crowned, and exposed to full sun most of the day.

(4) Trees were 20 to 45 feet tall.

The sample trees on each plot were located within a 1-acre area. One apical, 45-cm branch tip was clipped from the mid-crown of each of the three sample trees using a pole pruner equipped with a collecting basket. Each branch had at least six new shoots. To help insure that population density estimates were reliable and unbiased, the following precautions were taken:

(1) Branches other than the one being collected were not disturbed so as to avoid having larvae from these branches drop into the collecting basket.

(2) If other branches were accidentally disturbed, all budworm larvae were removed from the basket and another sample branch clipped.

(3) The sample branch was not disturbed with the pole pruner until the collecting basket was situated below the branch. This helped insure that

larvae which fell off the branch during the clipping procedure were collected in the basket.

Each branch, plus any larvae that had fallen into the basket, were placed into a labeled paper bag. The three bags from each plot were then stapled together, placed into a cardboard box, transported to the laboratory, and placed into a cooler at 40°F until branches could be examined. Branches were always examined within 24 hours of collection. Numbers of new shoots, budworm larvae in each developmental stage, and other larvae were counted and recorded for each branch.

POST-TREATMENT BUDWORM DENSITY SAMPLING Post-treatment density samples were collected from each evaluation plot no sooner than 14 days after treatment, but after pupae were first detected in the block. Sampling was (done) completed no later than 21 days after treatment, even if no pupae had been detected in the block by that date.

Post-treatment samples were collected from the same plots and trees as the pre-treatment samples. One 45-cm mid-crown branch tip was collected from each plot tree for individual processing. Care was taken to avoid sampling branches adjacent to those removed during pre-treatment sampling.

(Processing of) Post-treatment evaluation samples (was done) were processed in the field at time of collection. After being clipped, each branch sample plus the contents of the collecting basket were carefully removed and placed into a beating box on top of a white drop cloth. All new shoots, live larvae, live pupae, and pupal exuviae were counted and recorded. All live budworm larvae and pupae were collected for rearing. These insects were placed individually into plastic petri dishes, put into a styrofoam cooler, and transported to the laboratory.

LARVAL AND PUPAL REARING Each petri dish containing a live budworm larva or pupa was numbered and the stage of the insect recorded. ~~Fresh artificial budworm medium was put into each dish containing a larva.~~ Fresh artificial budworm diet was put into each dish containing a larva. Larvae and pupae were checked daily to determine the need for food or to detect mortality. Dishes containing larvae that died, or pupae which had not transformed into adults after 14 days in the pupal stage, were saved for further assessment and any remaining diet removed from the dish. Dead larvae and pupae were cultured on bacteriological media and diagnosed, with the assistance of personnel from the PNW Forestry Sciences Laboratory in Corvallis, for presence of Bacillus thuringiensis.

ADULT PHEROMONE TRAPPING One pheromone trap was deployed at each of 10 randomly selected plots in each block at about the time that pupation commenced. Each trap was hung on the end of a lower crown branch, ~~at~~ at about head height ~~head-height or higher~~, of an open-grown host tree. Traps were hung perpendicular to the branch axis, near the end of the branch, so as not to block the trap entrance. Traps were of the delta sticky trap type, and were baited with a 92:8 mixture of the principle components of the naturally occurring western spruce budworm pheromone (E-11 and Z-11 tetradecenal) at a strength of 0.0001 percent by weight in a PVC pellet. Traps were left without

servicing through moth flight and retrieved as soon as possible after moth flight. Numbers of budworm moths was counted and recorded for each trap.

POST-TREATMENT DEFOLIATION ESTIMATES Post-treatment defoliation measurements were made at the same time that post-treatment samples were collected. ~~We~~ It was assumed that the amount of feeding that occurred after this date would be an insignificant amount. Twenty new (current year's) buds or shoots on each midcrown branch sample were rated for defoliation using the following index:

Defoliation Index	Percent Defoliation
1	0
2	1-25
3	26-50
4	51-75
5	76-99
6	100

ENTOMOLOGICAL SAMPLING RESULTS

DEGREE-DAY MEASUREMENTS Accumulated degree-days are shown in Figure 5. Since the biophenometers were not placed in the field until May 19, the recorded accumulated degree-days were less than the actual number of degree-days accumulated. The 5,400 biophenometer site was very close to an Agriculture and Soil Stabilization Service SNOTEL site which is used for measuring various weather parameters. Information was used from the SNOTEL site to calculate the number of degree-days accumulated before the first biophenometer reading and added to this total to get the actual total for the 5,400-foot site (Figure ~~6~~). The first set of blocks was treated on June 18 when the accumulated degree-days were 369, 275, and 237 at 3,800, 4,600, and 5,400 feet respectively. Even with additional degree-days added due to the late placement date, these numbers appear to be lower than that required for nominal fifth instar (556 $\pm$ 35.5) as reported by Wickman (1988). Our degree-day estimates also seemed low in comparison with additional unpublished data from northeastern Oregon (personal communication, T.R. Torgersen, Pacific Northwest Research Station, LaGrande, OR). We do not have an explanation for these apparent differences.

EARLY LARVAL DENSITY SAMPLING The first 9 blocks sampled did not qualify for treatment, with mean larval densities ranging from 2.6 $\pm$ 0.4 to 9.1 $\pm$ 1.6 larvae per 45-cm branch. The first two blocks to qualify (Blocks 10 and 11) were sampled on June 7. The last early larval density samples were collected from Block 27 on June 16. Of the 28 blocks delineated, early larval density samples were collected on 25 of them, with 13 of them not qualifying for treatment. Most of those not qualifying for treatment were at the lower elevations. Maximum and minimum elevations of those qualifying for treatment are shown in Table ~~5~~ 4.

LARVAL DEVELOPMENT SAMPLING The amount of larval development sampling was less than planned due to the time it took to collect early density samples in the 13 blocks that did not qualify for treatment, in addition to the 12 that did qualify. Larval development samples, as called for by the entomological sampling plan, were collected once on 6 blocks (14, 16, 17, 18, 20, and 21), twice on 3 blocks (25, 26, and 27), and not at all on 3 blocks (10, 11, and 19). In lieu of sampling as planned, determination of when a block should be released for treatment was made by driving throughout the block, observing foliage development, and stopping to look at budworm larvae at several points (including highest and lowest elevations) within the block. In all blocks, all true fir shoots were unfurled and all Douglas-fir shoots, with the exception of some on an occasional tree, were unfurled when scheduled for pre-treatment larval sampling and released for treatment. At this time, shoots checked within a block yielded primarily 5th instar budworm larvae, with an occasional 6th instar.

PRE-TREATMENT SAMPLING Pre-treatment samples were taken within 48 hours of insecticide application on all blocks (Table 3). The target of less than 15% of the larvae being in second and third instars combined was met (Table 4) on all blocks, and almost all new shoots had unfurled at time of treatment. Larval densities for the 12 blocks used in the pilot test ranged from 16.8 to 30.5 larvae/45-cm branch, with pre-treatment mean densities of 26.6, 23.0, and 24.0 for Foray 42.7, Foray 64, and untreated, respectively (Figure 7). Analysis of variance shows (Table 4) that there are no significant differences (F=0.32, p=0.738) among the average pre-treatment larval densities for the three treatments.

$\bar{X}$ = 24.8

POST-TREATMENT BUDWORM DENSITY SAMPLING Post-treatment samples were collected 19 days after insecticide application on all blocks (Table 3). Mean larval densities for the 8 blocks treated with insecticides ranged from 1.2 to 6.9 larvae/45-cm branch, with post-treatment means of 4.8 and 3.5, for Foray 42.7 and Foray 64, respectively (Figure 7). Mean larval densities for the 4 untreated blocks ranged from 9.2 to 16.1, with a treatment mean of 13.5 larvae/45-cm branch. The analysis of variance of randomized complete block design was used to test the null hypothesis that there is no difference among the three treatments. The analysis included two planned single degrees of freedom contrasts: Foray 42.7 + Foray 64 vs untreated; and Foray 42.7 vs Foray 64. The differences among the three treatment means are significant (F=24.6, p=0.001) as are the means for the planned contrast, Foray 42.7 + Foray 64 vs untreated (F=48.5, p<0.001)(Table 5). However, the analysis indicates that there is no difference between the two insecticide treatments (F=0.7, p=0.42).

$\bar{X}$ = 4.15

The two insecticide treatments resulted in population reductions of 81.8% and 84.7% for Foray 42.7 and Foray 64, respectively (Figure 8). The population reduction attributed to natural mortality in the untreated blocks was 43.8%. Population reductions, when corrected for natural mortality using Abbott's (1925) formula, were 67.7% for Foray 42.7, and 72.9% for Foray 64.

We feel that a residual (i.e., post-treatment) population of no more than one budworm per 45-cm midcrown branch is ideal for having a low probability of population resurgence for the remainder of an outbreak period. Even though residual populations of 4.8 and 3.5 budworms per 45-cm branch (Table 5) are not

ideal, the adverse effects on host trees should be reduced (when compared to untreated areas) for at least a year or two in an operational project situation. With the levels of population reduction shown in this test (Table 5), pre-treatment population levels would need to be about 6 larvae per 45-cm branch to achieve ideal post-treatment levels.

LARVAL AND PUPAL REARING A total of 6,403 budworm larvae and pupae were reared from post-treatment collections to estimate the amount of additional mortality as a result of B.t. infection or parasitization (Table 6). All larvae and pupae that died of causes other than parasitization were diagnosed for presence of B.t. Half of the diagnosed specimens from the untreated blocks showed B.t. to be present. We can only speculate as to why this occurred. Two possibilities are contamination during the rearing process or problems with the B.t. diagnosis technique. Because of this, B.t.-caused mortality cannot be separated accurately from mortality due to causes other than parasitization. The treated areas did show a little over twice as much other mortality as the untreated areas (Table 6). This suggests that there was some effect on mortality of reared insects due to the B.t. treatments.

Parasites emerged from 18.2%, 12.2%, and 16.9% of the reared budworms from Foray 42.7, Foray 64, and untreated blocks, respectively. In all treatments a little over 80% of the parasites were comprised of two hymenopterous species (Apanteles fumiferanae and Glypta fumiferanae) and one dipterous species (Winthemia fumiferanae). The remaining parasites were comprised of nine hymenopterous and nine dipterous species (Table 7).

ADULT PHEROMONE TRAPPING Average numbers of moths caught per trap ranged from 25.0 to 43.8 for the 12 blocks, with averages for the 3 treatments of 36.7, 36.5, and 33.4 for Foray 42.7, Foray 64, and untreated, respectively. Analysis of variance showed no differences (F=0.53, p=0.64) among average numbers of moths caught per trap for the three treatments (Table 8). This suggests that male moths dispersed equally throughout the 500-acre blocks regardless of treatment, and that little difference in 1991 defoliation levels should be expected among treated and untreated blocks.

POST-TREATMENT DEFOLIATION ESTIMATES Post-treatment defoliation estimates for each block and treatment were compared using the proportion of shoots which fell into each of the six defoliation classes. Figures 9-11 show average proportions for each treatment as well as proportions for each block. As shown by Figure 11 the untreated blocks had a greater proportion of shoots in the heavier defoliation classes, indicating that the treatments did have some effect on the amount of current year defoliation.

DISCUSSION

The objective of measuring the efficacy of undiluted Foray 48B applied at 16 BIU, in volumes of 42.7 and 64 ounces per acre was met. Statistically, there was no difference in the post-spray budworm population densities between the two treatment rates. Post-spray population densities in both ~~spray~~ treatments were statistically different from the (no treatment) blocks.

Two of the (sprayed) blocks with the highest post-~~spray~~ population densities, Blocks 26 and 27, were sprayed when winds measured on the ground were gusting up to 6 MPH. This was within the treatment criteria, but it is likely the winds transported considerable quantities of the insecticide away from the spray blocks, thus reducing the amount available for consumption by budworm larvae. Spray deposit card measurements showed lower drop ~~density~~ for these blocks than other spray blocks.

In recent operational suppression projects conducted by the Forest Service in Oregon and Washington, the goal was to reduce the population to one or fewer budworms per average branch sample. Entomologists believe populations reduced to that extent will not resurge to outbreak levels for many years, if treatment blocks are large enough to avoid rapid reinfestation from adjacent untreated outbreaks. That degree of control was not achieved on any of the pilot test treatment blocks.

Budworm population densities in the test blocks were higher than has been experienced in most recent (control) projects conducted in the Pacific Northwest. The percent larval mortality accomplished by both treatments, 81.8% for Foray @ 42.7, and 84.7% for Foray @ 64, is similar to population control achieved with four other BT insecticides used for budworm control in 1988 against lower density populations in other locations in Oregon. It is not possible to statistically compare results from this pilot test to the other operations, however, it appears that Foray is as effective in controlling western spruce outbreaks as the other BT products used in recent years.

Aside from the inability to pump undiluted Foray with centrifugal pumps no other operational problems were experienced with the insecticide. In fact, Western Helicopter representatives who have sprayed almost all commercial BT products used in forestry in the United States, commented that Foray 48B "was the easiest BT product" they had used. The contractor liked Foray because there was little to no residue left in the spraying systems, including atomizer screens, and the ease with which it could be cleaned from surfaces on the ~~spray~~ helicopters.

RECOMMENDATIONS

1. OPERATIONAL USE OF FORAY 48B Although the residual population of western spruce budworm was higher than desired in the treatment blocks, we recommend Foray 48B be included with Thuricide 32LV, Thuricide 48LV, Dipel 6L, and Dipel

6AF, as available for use by the Forest Service in controlling budworm outbreaks.

2. PILOT TEST PLANNING The decision to do this test was made in December 1988. It was not possible to evaluate the budworm population in the pilot ~~test~~ Project area until May 1989 when the test blocks were being established. In the future, planning for pilot ~~tests~~ projects should begin approximately 15 months prior to the time spraying would be anticipated. This would allow time to carefully assess the outbreak population for density and health and select stands that offer the best potential for locating test blocks.

rates recommend

3. PILOT TEST STANDARD Future pilot tests of ~~BT~~ insecticides for control of western spruce budworm should include as a standard treatment, Thuricide 32LV applied undiluted at 64 ounces per acre. This product has consistently provided good control of budworm outbreaks. Control achieved by the test product would be compared to that achieved by Thuricide 32LV.

don't use

REFERENCES CITED

Abbott, W.S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265-276.

Wickman, B.E. 1988. Seasonal variation of degree-day accumulation in relation to phenology of western spruce budworm, Douglas-fir tussock moth, and the host trees in northeastern Oregon. USDA Forest Service, Pac. Northwest Res. Sta., Res. Note PNW-RN-482. 11p.

Williams, C.B., D.A. Sharpnack, L. Maxwell, P.J. Shea, and M.D. McGregor. 1985. Guide to testing insecticides on conifrous forest defoliators. USDA For. Serv. Gen. Tech. Rep. PSW-85, 38p., Pac. Southwest For. and Range Exp. Sta. Berkeley, CA.

USDA-FS- 1989, ~~FEIS~~ Final Environmental Impact ~~Statement~~ & Management of Western Spruce Budworm - Oregon and Washington. ~~&~~ USDA Forest Service, Forest Pest Managent, Pacific N.W. Region.