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FOREST SERVICE
U.S.DEPARTMENT OF AGRICULTURE

Control of Douglas-fir Tussock Moth by Aerially Applied Dimilin (TH 6040)

John S. Hard James D. Ward Steven Ilnytzky

RESEARCH PAPER PSW-130

The Authors

JOHN S. HARD was formerly an entomologist with the Station's research unit doing field evaluation of chemical insecticides, with headquarters in Davis, Calif. He is now assigned to the Forest Service's Northern Region, Missoula, Mont. He earned a forestry degree (1960) and a master of science degree in forest entomology (1962) at State University of New York, Syracuse. **JAMES D. WARD** is a supervisory entomologist in charge of the aerial survey team office, State and Private Forestry, Southeastern Area, Forest Service, Doraville, Ga. He was graduated from East Tennessee State University (B.A. degree in science, 1965) and Duke University (M.F. degree, 1967). He joined the Forest Service in 1967. **STEVEN ILNYTZKY,** formerly a research scientist in the Canadian Forestry Service, is a consultant, in Victoria, B. C. He attended Michigan State University, where he received a forestry degree (1959) and a master's degree in entomology (1962), and McGill University, where he received a doctorate in economic entomology (1969).

ACKNOWLEDGMENTS

We thank Richard Orchard, U.S. Forest Service, Corvallis, Oregon, for developing and installing the spray monitoring device in the spray aircraft and mixing and loading the spray formulations; and Harold Ayer, U.S. National Weather Service, Portland, Oregon, for daily weather forecasts and meteorological monitoring on the experimental plots during spray application. Both contributed substantially to the success of the experiment. We also thank the British Columbia Forest Service for providing study areas and general support for the experiment.

The work leading to this publication was funded in part by a U.S. Department of Agriculture sponsored program titled "Expanded Douglas-fir Tussock Moth Research and Development Program."

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Pacific Southwest Forest and Range Experiment Station
P.O. Box 245
Berkeley, California 94701
1978

IN BRIEF...

Hard, John S., James D. Ward, and Steven Ilnytzky.
1978. **Control of Douglas-fir tussock moth by aerially applied Dimilin (TH 6040).** Res. Paper PSW-130, 6 p., illus. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

Oxford: 145.7x18.77 *Orgyia pseudotsugata:* 453—414.12 Dimilin: (711)
Retrieval Terms: tussock moth, Douglas-fir, insecticides, performance tests, Pacific Northwest, British Columbia.

Tests were made in 1976 on epidemic Douglas-fir tussock moth populations in the North Thompson River Valley north of Kamloops, British Columbia, to determine the minimum effective amount of Dimilin required for tussock moth population control. Three dosages of Dimilin per gallon of water, 2.0 oz, 1.0 oz, and 0.5 oz, were aerially applied with fixed-wing aircraft at about 1 gallon per acre in a randomized block experiment. The nine treated plots and three check plots ranged from 50 to 81 acres in area and 2300 to 2900 feet in elevation. Larval populations were monitored 1 day before spray application and 7, 14, 21, 28, and 35 days after spray application to determine (a) the effect of treatment on larval mortality, and (b) the incidence of naturally occurring tussock moth virus infection in the experimental plots.

Mean numbers of surviving larvae per 1000 in^2 at 35 days postspray in the 2.0-oz, 1.0-oz, and 0.5-oz, and check plots were 1, 15, 22, and 60 larvae, respectively. Mean percent unadjusted mortalities at 35 days postspray were 99.7, 92.2, 89.7, and 61.1 percent. Numbers of surviving larvae per 1000 in^2 were significantly different at 35 days postspray between (a) the 2.0-oz treatment and (b) the 1.0-oz and the 0.5-oz treatments, and at 28 and 35 days postspray between (c) the three Dimilin treatments and (d) the untreated checks. Analysis of percent unadjusted mortalities showed significant differences between (a) the 2.0-oz treatment and (b) the 1.0-oz and 0.5-oz treatments at 14, 21, 28, and 35 days postspray.

Virus infection did not cause high larval mortality in the experimental areas until after the experiment was terminated. The tussock moth outbreak collapsed, however, during the late larval period; the collapse is attributed to a combination of virus, late larval and pupal parasitization, and unusually cool, wet weather in August.

Sample trees were heavily defoliated only in untreated and 0.5-oz treated plots. We recommend, however, that no less than 2.0 oz of Dimilin per acre be pilot-control tested for Douglas-fir tussock moth population control during the rising phase of a tussock moth outbreak.

When ingested by insects and other arthropods, Dimilin (1-(4-chlorophenyl)-3-(2,6-difluorobenzoyl)-urea), causes mortality by interfering with cuticle deposition during molt (Post and Vincent 1973). This highly water-insoluble chitin-formation inhibitor is an insect stomach poison; its toxicity increases inversely with suspended particle size (Mulder and Gijswijt 1973). It is rainfast,[1] and has a residual life on sprayed foliage in the field of at least 3 to 4 weeks (Granett and Dunbar 1975, Pree 1976) and up to 4 months (Skatulla 1975). Because of its mode of action, its toxicity to vertebrates is extremely low.

Dimilin has been tested and proven effective against a variety of forest insect pests (Skatulla 1975), and is considered to be quite safe environmentally. It caused molt inhibition of gypsy moth larval parasitoids when host larvae were fed Dimilin-treated leaves (Granett and Weseloh 1975); however, in a later study (Granett and others 1976) percent *Apanteles* emergence differed significantly between treated and untreated gypsy moth hosts only when these were treated during the first and second larval stadia. It also adversely affected reproduction in a species of brine shrimp (Cunningham 1976).

An aerial application in 1975 of 4.0 oz a.i. (active ingredient)/gal/acre (280.1 g a.i./9.3 l/ha) reduced larval populations of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), 100 percent over 21 days, but was considered to be an overdose (Neisess and others 1976). This report describes the results of an aerial test in 1976 of three reduced Dimilin dosages applied to a declining tussock moth population to determine the minimum application rate effective for Douglas-fir tussock moth control. Procedures are described in detail so that the experiment can be reproduced on rising tussock moth populations, if desirable.

MATERIALS AND METHODS

Four rectangular plots were established in each of three areas in the North Thompson River Valley at elevations ranging from 2300 to 2900 ft (700 to 900 m) approximately 12 mi (20 km) north of Kamloops, British Columbia. A total of 300 nondefoliated, egg mass-bearing, open-grown Douglas-fir, [*Pseudotsuga menziesii* (Mirb.) Franco], 30 to 50 ft (9.1 to 15.2 m) tall were selected, 25 per plot, for tussock moth larval sampling.

A randomized block experimental design was used, with one replicate of each of four treatments in each block. Treatments were aerially applied Dimilin W-25 (25 percent wettable powder)[2] water suspensions of 2.0 oz a.i./gal (15.0 g a.i./l), 1.0 oz a.i./gal (7.5 g a.i./l), 0.5 oz a.i./gal (3.75 g a.i./l) and untreated checks. Treated plots were sprayed with about 1 gal (3.8 l) of formulation per acre (0.41 ha). The water-based formulations contained 10 percent ethylene glycol by volume to achieve finer spray atomization than an unadulterated water carrier provides. All formulations contained 7.56 g/gal (2 g/l) of Rhodamine B Extra S (GAF) dye for spray deposit assessment.

Plot treatments in each block were randomly assigned but in block 1 the 0.5-oz and the 2.0-oz treatment assignments were reversed because of potential spray drift from the upper plot to the lower plot. We felt that if drift was to occur, drift of 0.5-oz formulation onto a 2.0-oz treated plot would have less chance than the reverse drift of obscuring treatment effects.

Plots were sprayed as soon as weather permitted after 100 percent of monitored egg masses on the plots hatched and all larvae were dispersed from the egg masses. When treated, most larvae were in the second instar. All treated plots within a block were sprayed on the same day, but each block was treated on a separate day — June 13, June 17, and June 18 — so that date of treatment was the blocking factor.

The order of application of each formulation was changed on each day of treatment to prevent bias that might be introduced by variation in meteorological conditions during the hours that spray was applied. This restriction of randomization had no apparent effect on results of significance tests because time of day when spray was applied proved unimportant. Temperature, relative humidity, wind speed, and direction of airflow were monitored and recorded in each block by a professional meteorologist during spray application *(see Appendix, table 3)*.

Formulations were mixed the morning they were to

[1]Robertson, J.L. 1976. *Bioassays to provide supporting data for the design and execution of field tests and screening new candidate materials.* (Report on file, Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.)

[2]Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

be sprayed. They were applied in 100-ft (30 m) swaths from a Cessna Ag Truck flying 100 ft (30 m) above the trees, using a wind-driven pump and conventional spray boom with 22 evenly spaced flat fan tips (Spray Systems, Wheaton, Ill., T8010). Colored treetop banners were used to mark plot corners and midpoint of the end of each plot. The pilot was instructed to apply 13 evenly spaced spray swaths to each plot, parallel to the long plot axis. An aerial observer having radio contact with the spray pilot flew in a helicopter above the spray aircraft to insure that spray swaths were distributed evenly across each plot. Spray parameters *(see Appendix, table 4)* were recorded by an electronic device mounted in the spray aircraft. Plot areas were measured on the ground after all plots were treated.

One 4- by 4-in (10.2- by 10.2-cm) Kromekote card was placed in the open at ground level near each sample tree on treated plots to sample spray deposit. Kromekote cards were placed in untreated plots to detect spray drift from treated plots. A Quantimet Image Analyzer was used to determine spray droplet volume median diameter and mean number of droplets per square centimeter for each treated plot.

Larval populations were sampled at 1 day before spray, and 7, 14, 21, 28, and 35 days postspray. The last 35-day sample was taken on July 23 in block 3. Two midcrown branch samples were removed from each tree at each sample date. Branch length, width, and number of live tussock moth larvae were recorded for each sample. An additional subsample of two or four live larvae was collected from each tree at each sample date, and the larvae were reared singly in the laboratory on artificial media[3] to determine incidence of virus infection during the experiment. Larvae that died in rearing were examined microscopically to determine cause of death.

Larval population data transformed to number of larvae per 1000 in^2 (6452 cm^2) of foliage, and percent unadjusted mortality at each sample date, were treated as independent samples and were subjected to analyses of variance. Technically, however, the samples are a time series of nonindependent measurements because the same trees were sampled repeatedly. Appropriate orthogonal contrasts were computed at postspray sample dates to test significance of differences among treatments. Contrasts for percent mortalities were computed only for treated plots because percent mortality variances were unequal between treated and untreated plots. Pooled variances of percent mortality in all treated plots were computed for all postspray sample dates, and the power of the experiment to detect significant differences in mortality was calculated (Pearson and Hartley 1951).

Percent unadjusted mortality of each treated plot and residual number of live larvae at 35 days postspray were both plotted against applied dosage rates [a.i. applied per acre = (spray flow in gal X oz a.i. per gal formulation) /plot area in acres] and linear models were computed.

Amount of crown completely defoliated on each sample tree was estimated and recorded in October 1976.

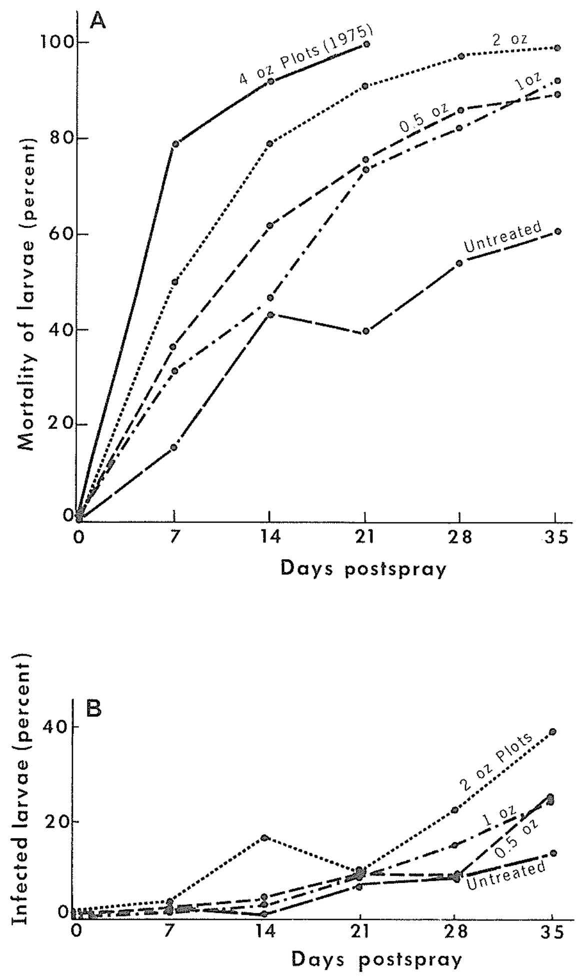

Figure 1—Larval populations of Douglas-fir tussock moth were sampled periodically in 1976 on plots aerially treated with Dimilin at several dosages (oz. a.i./gal). (A) Mean percent larval mortality increased more in treated plots than in untreated plots following treatment. Mortality found in 1975 by Neisess and others (1976) is graphed for comparison. (B) Mean percent virus infection of live larvae collected on the same sampling dates, and reared in the laboratory, increased during the experiment.

[3]Thompson, C.G. 1966. *Douglas-fir tussock moth virus test, Phase 3. Simulated field test to determine virus dosages and concentrations.* (Report on file, Pacific Northwest Forest and Range Exp. Stn., Portland, Oreg.)

RESULTS AND DISCUSSION

Spray deposit on all treated plots was adequate *(see Appendix, table 5)* and Kromekote cards set out in untreated plots revealed no spray drift from treated plots. As expected, however, an extremely small amount of 0.5-oz a.i./gal spray drifted onto the 2.0-oz a.i./gal treated plot on June 13 because of downslope air drainage.

The 2.0-oz treatment resulted in almost 100 percent tussock moth control at 35 days, and is comparable to control on the 4.0-oz plots at 21 days in 1975 *(fig. 1A)*. Results of the experiment were not obscured by virus because virus infection *(fig. 1B)* did not cause high mortality in the plots until after the last population sample was taken.

Analysis sensed significant larval population differences at 28 and 35 days postspray between treated and untreated plots, but only at 35 days postspray between the 2.0-oz and lower dosage plots *(table 1)*. Analysis of percent mortality, among treated plots only, appeared to sense significant differences between 2.0-oz and lower dosage plots at 14, 21, 28, and 35 days postspray *(table 1)*. Estimates of experimental power, calculated from pooled variances of percent mortality, indicated that these apparently significant differences were truly detectable at these postspray periods *(see Appendix, table 6)*. If the corresponding differences for the 7-day period were also truly significant, they would not have been detectable without more replications.

Table 1 — *Significance*[1] *of numbers and percent mortality of tussock moth larvae on treated plots of Douglas-fir, British Columbia*

Dimilin treatment (oz a.i./gal)	Number of days postspray: 0	7	14	21	28	35
	Mean number of larvae/1000 in²					
2.0	314	165	66	30	7	1
1.0	193	132	106	52	34	15
0.5	276	194	126	65	37	22
Untreated	155	130	86	89	72	60
	Mean percent mortality					
2.0		49.9	79.4	91.4	97.9	99.7
1.0		31.3	46.2	73.9	82.1	92.2
0.5		36.3	61.0	75.8	86.1	89.7
Range		18.6	33.2	17.5	15.8	10.0

[1]Means not connected by a bar are significantly different at the 95 percent level.

Regression of percent unadjusted mortality at 35 days postspray over ounces of Dimilin applied per acre indicates that 1.5-oz a.i./acre would have caused 93.5 to 97.5 percent mortality *(fig. 2)*, and would have allowed a residual population of 4 to 15 larvae/1000 in² to survive *(fig. 3)*. This degree of control may be inadequate during the rising phase of an outbreak to prevent substantial damage from occurring the following year. Therefore we recommend no less than 2.0-oz a.i./acre for control of rising tussock moth populations.

Defoliation of current-year needles occurred on most sample trees in all plots, but heavy losses of both new and old foliage occurred only on sample trees in untreated and 0.5-oz treated plots *(table 2)*. Application of 1.0-oz a.i./acre may provide adequate foliage protection from collapsing larval populations, but probably not to treated stands containing a residual population of 10 to 21 larvae/1000 in² *(fig. 3)* with low levels of virus infection and parasitization.

Tussock moth populations in the Kamloops area collapsed by late summer of 1976. No egg masses were found on any of the experimental plots in October. A combination of virus, late larval and pupal parasitization, and adverse weather appeared to be the major

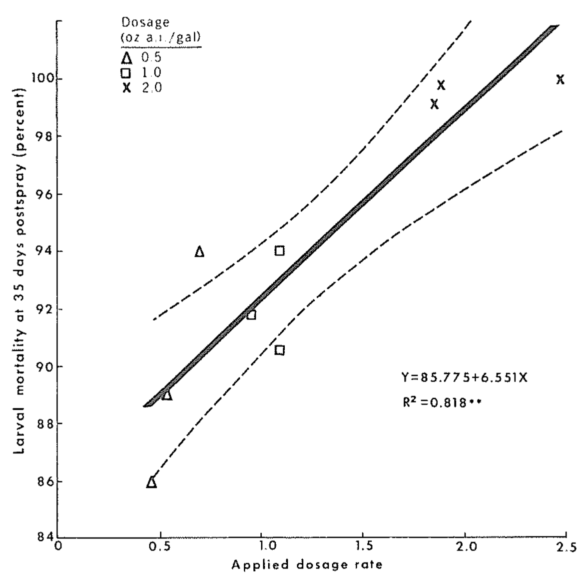

Figure 2—Douglas-fir tussock moth larval mortality, in mean percent per plot at 35 days postspray, is highest in plots treated with 2 ounces of Dimilin per gallon of spray. Applied dosage rate is calculated as a.i. applied per acre = (spray flow in gal) (oz a.i. per gal formulation)/ plot area in acres. Dotted lines show 95 percent confidence limits; ** = significant at 1 percent level.

cause of collapse of the outbreak. Watt (1968), in a computer analysis comparing tussock moth population fluctuations in interior British Columbia with weather variation, concluded that July and August mean temperatures were the first and second most important factors regulating tussock moth abundance there. Although the summer of 1976 was cooler than normal in Kamloops, exceptionally adverse weather did not occur until August *(see Appendix, table 7)*. As the field test was terminated on July 23, we suspect that direct effect of adverse weather on differences among spray treatments was minimal.

Table 2 —*Defoliation of Douglas-fir trees sampled on Dimilin treatment plots, British Columbia*

Treatment (oz a.i./gal)	Number of trees showing complete defoliation of vertical length of crown shown:						
	None	Top 1/6	Top 1/3	Top 1/2	Top 2/3	Entire crown	All categories
2.0	72	3	0	0	0	0	75
1.0	75	0	0	0	0	0	75
0.5	63	5	4	3	0	0	75
Untreated	54	6	5	3	7	0	75

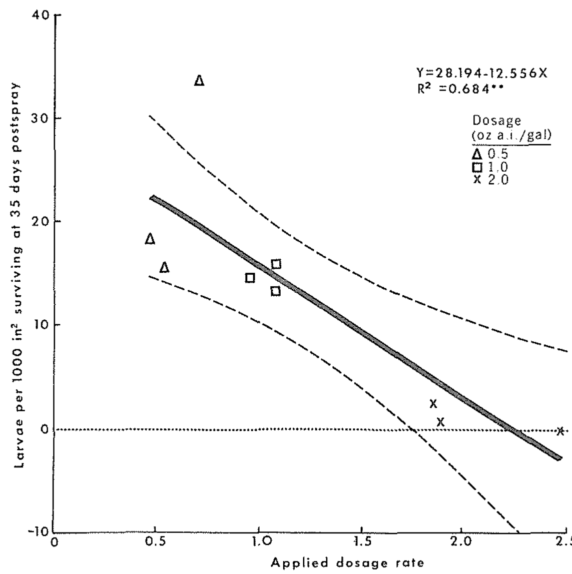

Figure 3—Mean number of surviving Douglas-fir tussock moth larvae/1000 in^2 per plot at 35 days postspray is lowest in plots treated with 2 ounces of Dimilin per gallon of spray. Applied dosage rate is calculated as in figure 2. Dotted lines show 95 percent confidence limits; ** = significant at 1 percent level.

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APPENDIX

Table 3—*Summary of meteorological conditions in plots during spray application of Dimilin to Douglas-fir plots, British Columbia, 1976*

Block	Date	Time	Sky	Temperature range		Maximum relative humidity	Wind speed	Airflow
				°F	*°C*	*Pct.*	*Miles/hr*	
1.N. Palmer-Forsyth	June 13	0500-0800	Overcast	45.0-50.0	7.2-10.0	60	3.0-6.0	Downslope
2. Dairy Creek	June 17	0530-0800	Clear	47.0-53.0	8.3-11.7	72	2.0-4.0	Downslope, then upslope
3. S. Palmer-Forsyth	June 18	0500-0730	Clear	52.5-56.5	11.4-13.6	77	2.0-4.0[1]	Downslope

[1]Air unstable early in morning, one 9-mi/h gust at 0515 on 1.0-oz treatment plot.

Table 4 — *Aerial spray parameters and plot areas*

Formulation (oz a.i./gal)	Date (June)	Swaths	Total spray time	Ground speed range	Fluid temperature	Pressure range	Flow range	Mean flow rate	Total flow	Plot area
			Min	*Miles/hr*	°C	*Psi*	*Gal/min*	*Gal/min*	*Gal*	*Acres*
2.0	13	12	3.72	90-123	36-42	40-57	20-23	20.3	75.6	80.0
2.0	17	13	3.33	90-120	38-42	38-52	19-22	21.7	72.4	78.0
2.0	18	13	3.55	105-132	42-45	36-52	20-24	20.6	73.0	59.0
1.0	13	13	2.95	90-120	34-40	45-61	21-25	22.4	66.2	60.8
1.0	17	13	3.27	99-126	36-46	40-51	20-23	21.3	69.6	73.0
1.0	18	13	3.43	90-138	38-46	40-54	21-24	21.7	74.3	68.1
0.5	13	13	2.93	81-134	34-38	49-65	21-24	22.2	65.1	61.1
0.5	17	12	3.05	102-129	36-42	54-62	24-26	24.6	75.0	80.7
0.5	18	13+	3.38	96-129	38-46	35-52	20-24	20.7	70.1	50.4

Table 5 — *Sample spray deposit parameters, by Dimilin treatment*

Treatment (oz a.i./gal)	Mean deposit and standard error[1]		
	Drops/cm^2	Volume median diameter (microns)	Gallons/acre
2.0	20.56 ± 0.54	269.6 ± 35.0	0.30 ± 0.10
1.0	22.51 ± 2.75	244.6 ± 39.3	0.22 ± 0.06
0.5	25.65 ± 7.34	174.7 ± 23.3	0.20 ± 0.11

[1]Computed from three replicate averages per treatment.

Table 6—*Probability of detecting a significant difference in mortality among Dimilin-treated plots, with treatments replicated three times*[1]

Percent difference in mortality to be detected		Probability at number of days postspray shown:				
Range	*Deviation from mean*	7	14	21	28	35
10.0	5.0, 0, -5.0	<20	<20	33	50	89
15.0	7.5, 0, -7.5	21	22	66	83	>99
20.0	10.0, 0, -10.0	37	40	89	97	>99
35.0	17.5, 0, -17.5	83	84	>99	>99	>99

[1]Outlined area shows that experimental power is high if the threshold for adequate power is arbitrarily set at 80 percent probability of detecting a significant difference.

Table 7 — *Summer weather summary for Kamloops, B.C., 1976*[1]

Month	Temperature		Precipitation		
	Average	Deviation from normal	Total	Deviation from normal	Days with trace or more
	°C	°C	*Mm*	*Mm*	
June	16.2	-1.8	33.1	−3.2	13
July	19.6	-1.3	32.4	+6.5	12
August	17.5	-2.2	122.4	+95.5	21

[1]Taken from Monthly Meteorological Summaries, Kamloops Airport, Environment Canada.

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1978. **Control of Douglas-fir tussock moth by aerially applied Dimilin (TH 6040).** Res. Paper PSW-130, 6 p., illus. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

Epidemic Douglas-fir tussock moth larval populations treated with 2.0 oz, 1.0 oz, and 0.5 oz per acre of aerially applied Dimilin were reduced 99.7 percent, 92.2 percent, and 89.7 percent, respectively, at 35 days postspray. Numbers of surviving larvae per 1000 in² were significantly different (a) at 35 days postspray, between the 2.0-oz treatment and the 1.0-oz and 0.5-oz treatments; and (b) at 28 and 35 days postspray, between the three Dimilin treatments and untreated checks. Analysis of percent unadjusted mortalities showed significant differences between the 2.0-oz treatment and the 1.0-oz and 0.5-oz treatments at 14, 21, 28, and 35 days postspray. Sample trees were heavily defoliated only in untreated and 0.5-oz treated plots.

Oxford: 145.7x18.77 *Orgyia pseudotsugata:* 453 — 414.12 Dimilin: (711)
Retrieval Terms: tussock moth, Douglas-fir, insecticides, performance tests, Pacific Northwest, British Columbia.