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Carbaryl Applied at Reduced Dosage Rates for Control of Western Spruce Budworm

George P. Markin David R. Johnson

Authors:

GEORGE P. MARKIN is a research entomologist working with the Station's unit that is studying the biology of insects adversely affecting regeneration and establishment of western forests. He holds three degrees in entomology—a B.S. from Montana State College (1962), an M.S. from the University of Idaho (1964), and a Ph.D. from the University of California at Riverside (1967). He joined the Forest Service in 1973 and the Station's staff in 1976. **DAVID R. JOHNSON**, at the time of this study, was a biological technician with the Station's field evaluation of chemical insecticides research unit at Davis, Calif. He earned a B.A. degree (1972) in biology at California State University, Fresno, and an M.S. in entomology (1976) at the University of California, Davis. He is now a biological technician with the Station's Institute of Forest Genetics, Placerville, Calif. He joined the Forest Service in 1978.

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IN BRIEF . . .

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Retrieval terms: western spruce budworm, *Choristoneura occidentalis*, spray test, carbaryl, Sevin-4-oil, Montana

Of three chemical insecticides presently registered for control of the western spruce budworm (*Choristoneura occidentalis* Freeman), carbaryl in the formulation Sevin-4-oil is the most extensively used. Since carbaryl was first tested in 1975, all subsequent field tests and eventual operational programs have been at the same dosage rate of 1.12 kg a.i. per hectare (1 lb/acre), the rate at which this insecticide is now registered. To determine the effectiveness of lower dosage rates, an aerial field test was conducted in July 1979, north of the community of White Sulphur Springs in western Montana. Rates of 0.28 and 0.56 kg a.i. per hectare (0.25 and 0.5 lb a.i./acre) were compared with the registered rate of 1.12 kg a.i. per hectare. Each dosage was applied to five randomly selected 20-hectare plots by helicopter with Beecomist nozzles while the larvae were in the fifth and early sixth instars. Branch samples were collected from 15 randomly selected Douglas-fir trees before spraying and at intervals of 5, 10, and 15 days after spraying to determine larval populations. An additional sample was collected when 95 percent pupation had occurred to determine percent loss of current year's foliage due to larval feeding. All three treatments significantly reduced larval populations and the amounts of foliage destroyed when compared with the untreated controls. It appears, however, that the rates of 1.12 and 0.56 kg per hectare provided a comparable degree of population control while the rate of 0.28 kg per hectare was possibly 10 percent less effective.

Control of all treatments would have been slightly higher except 17 percent of the trees had unopened buds at the time of spraying, which would have protected any budworm larvae still in the bud mining stage. Results of the test were recalculated after dropping those trees on which 50 percent or more of the buds were still closed at treatment. The final percent population reductions of budworm larvae were 93.9, 95.5, 85.5, and 43.1 percent, respectively, for the dosages of 1.12, 0.56, and 0.28 kg per hectare and the untreated controls. Under the conditions of our test, the rate of 0.56 kg a.i. per hectare compared favorably with the rate of 1.12 kg per hectare in reducing larval populations of the western spruce budworm and preventing destruction of new foliage in Douglas-fir.

Three chemical insecticides are registered for aerial control of western spruce budworm (*Choristoneura occidentalis* Freeman). Among them, carbaryl in the formulation Sevin-4-oil at the dose of 1.12 kg a.i. per hectare (1 lb a.i./acre) is the most extensively used. The registered dosage is the result of field tests in 1975 in Montana (Flavell and others 1978) and in 1976 in Washington (Mounts and Gregg 1978). In both tests, carbaryl was applied at the single dosage of 1.12 kg a.i. per hectare. Data were not available at the time of its registration or have become available since then to indicate if this is the minimum effective dosage rate. The insecticide was tested at two dosage rates in 1975 on eastern spruce budworm (*C. fumiferana* [Clemens]). The rate of 0.56 kg per hectare (0.5 lb/acre) was almost as effective (92 pct control) as the 1.12 kg per hectare rate (96 pct control) (Millers 1976). Those test results suggest that a lower dosage rate might be as effective as the registered dosage in controlling western spruce budworm. A lower rate not only would be cheaper, but also might reduce some of the undesirable effects, such as on aquatic insects, caused by the registered rate (Shea 1978).

To determine the effectiveness of lower dosage rates of carbaryl, an aerial field test was conducted in July 1979 in Montana. Rates of 0.28 and 0.56 kg a.i. per hectare (0.25 and 0.50 lb a.i./acre) were compared with the registered rate of 1.12 kg a.i. per hectare (1.0 lb a.i./acre).

This paper describes the results obtained at lower dosage rates and compares them with results of previous tests and operational programs in which the registered dosage was used.[1]

METHODS AND MATERIALS

Twenty experimental plots were located north of White Sulphur Springs, Montana, most of them on the Lewis and Clark National Forest, with a few on private land within or adjacent to it. Elevation ranged from 1700 to 2000 m. Stand composition was primarily second-growth Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), with a scattering of lodgepole pine (*Pinus contorta* Dougl.).

Each plot was a 20-ha square or rectangle located within a topographically similar area. All sampling was done in the center area of the plot, 60 m or more from the plot perimeter, where 15 open-grown Douglas-fir trees were randomly selected. Each sample tree was at least 40 m from any other sample tree and small enough so that a 10-m pole pruner could reach at least 30 percent of the foliage. To eliminate the possibility of cross contamination by spray drift, all plots were located at least 1 km apart. Treatments (three dosage rates and a control) were randomly assigned to the 20 plots.

Carbaryl was received from the manufacturer in 18.94-*l* (5-gal) metal containers in the formulation Sevin-4-oil. Each can was rolled for 5 min before opening to assure resuspension of any settled material, and checked afterwards to see that no residue remained in the can. Carbaryl was applied at three dosages: 1.12, 0.56, and 0.28 kg a.i. per hectare, diluted with no. 2 diesel fuel and sprayed at the rate of 4.67 *l* per hectare. Rhodamine B dye, 0.1 percent by volume, was added to facilitate spray deposit assessment.

Western spruce budworm larval population was determined for each sample tree 24 h before spraying and 5, 10, and 15 days later. Two 40-cm branches were removed from midcrown of each sample tree at prespray and four branches postspray (Carolin and Coulter 1972). Sample branches were collected with a 10-m extendable pole pruner with a 50-cm cloth basket fastened just blow the cutting head. They were kept separately in a marked paper bag and stored in an ice chest until brought to the field laboratory.

In the field laboratory, larvae were removed from the branch samples with a beating barrel and collected in shallow pans (Martineau and Benoit 1973). The laboratory crew then counted buds, identified and counted the larvae, expressing budworm population as larvae per 100 buds on new shoots.

Spray deposit was sampled by placing a 10- by 12.7-cm white Kromekote card and two 15- by 15-cm aluminum plates at ground level in an opening adjacent to each sample tree. Cards and plates were left in place for at least 30 min after spraying before being collected, to assure complete settling and drying of the spray. Cards were analyzed on an Imanco Quantimat 720 image analyzer at the Department of Advanced Instrumentation, University of California, Davis,[2] for drop size (volume median diameter [VMD]), and number of drops per square centimeter. Plates were analyzed by washing the deposit off the plate and analyzing for the fluorescent dye tracer (Yates and Akesson 1963) to determine the volume of spray recovered in liters per hectare.

When 95 percent pupation had occurred, we collected four branch samples from the midcrown of each sample tree to determine current year's defoliation from budworm feeding. Defoliation was assessed by examining 25 shoots per branch and estimating the amount of new foliage consumed or destroyed by budworm feeding. The percentages were averaged to estimate the amount of defoliation of the branches sampled for each tree. Analysis of variance was used to determine if the four treatments (three dosage levels and a control) differed significantly in larval population reduction. Pairwise comparisons (treatment as against control) were conducted with Tukey's test.

[1]This publication does not contain recommendations for the pesticide uses reported, nor does it imply that they have been registered by appropriate governmental agencies.

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

SPRAY APPLICATION

Carbaryl was applied by a Bell 47G-3B-2 helicopter, equipped with a hydraulic spray system, 10-m boom, and three Beecomist nozzles equipped with Wettable Powder sleeves. Two of the nozzles were mounted on the extreme ends of the boom and the third mounted on the rear skid support of the helicopter. The materials were mixed in a 750-*l* mixing tank equipped with both mechanical and recirculating agitation. The compound was mixed immediately before spraying (10 to 30 min) and agitated until all materials had been pumped into the helicopter. It was applied at the rate of 4.67 *l* per hectare (1/2 gal/acre). The helicopter flew 75 km/h, 15 m above treetops, and made a 20-m swathe. Each plot was marked with a treetop banner in each corner to help the pilot locate the plot perimeter.

The plots were sprayed early in the morning of July 6 through July 8, when temperatures ranged from 9° to 18°C, and winds were less than 7 km/h. Rain of less than 0.5 cm fell briefly 4 days before spraying; and at 6 days after spraying, less than 0.1 cm of rain fell. Bud development that spring was slow and quite variable. At the time of spray application, only 83 percent of the trees had buds fully opened. Fifteen percent of the trees had buds that were bursting and 2 percent had buds that were still closed. Carbaryl is best applied against the western spruce budworm when buds are opened because that exposes the larvae to the spray. In waiting for buds to open we found that larval development progressed farther than desirable. At time of spraying 51 percent of larvae were in early sixth instar; normally less than 10 percent of larvae would be in sixth instar.

RESULTS

During the treatments, we observed that none of the plots were missed or double treated. An examination of the spray cards and plates indicated that within the plots no major skips occurred since all trees showed some deposit. The carbaryl provided by the manufacturer was highly viscous, but differed considerably in the tree dosage rates applied—depending on the amount of diesel fuel added. With increased diluent the resulting droplet size decreased and the number of droplets increased (*table 1*).

Table 1—*Spray deposits assessed from Kromekote cards and aluminum plates in plots treated with carbaryl, Montana, 1979*

Dosage (kg a.i./ha)	Volume spray applied	Deposit recovered from plates		Deposit recorded on cards	
	l/ha	*l/ha*	*Percent*	*Drops/cm²*	*VMD (μm)*
1.12	4.67	0.90	19.3	10.1	178
.56	4.67	.73	15.7	15.5	173
.28	4.67	.71	15.3	28.5	161

The recovery at ground level of only 15 to 19 percent of the volume of spray applied was slightly lower than we have encountered in previous tests of this type (20 to 30 percent). This result was not unexpected, however, since the droplet size was smaller (less than 200 μm VMD), allowing the droplets to remain suspended in the air longer. The other 81 to 85 percent of the spray probably could be accounted for by interception by the foliage within the plot or lost from the plot by drift.

All three treatments significantly reduced larval population and the amounts of foliage destroyed when compared with the untreated controls (*table 2*). But the design used could not detect differences among individual treatments. It appeared, however, that the rates of 1.12 and 0.56 kg per hectare provided a comparable degree of population control, and that the rate of 0.28 kg per hectare was possibly 10 percent less effective.

A question remains, however, about the effect that partial bud burst at the time of spraying may have had on budworm mortality. An early study suggested that bud development can be critical on the effectiveness of an insecticide with a short field life (Markin and others 1978). In the present test, approximately 17 percent of the trees being sampled had buds bursting or partially open. Larvae and new foliage on these trees, therefore, were not exposed to the spray. To find evidence of an effect on the resulting population reduction, we examined the larval population on individual trees. We found that trees with the highest survival often were those with the slowest bud development at time of spraying.

Percent population reduction was, therefore, recalculated for each plot by using only larval number from those trees in which more than 50 percent of the buds were open. The total

Table 2—*Population reduction, uncorrected for natural mortality, of western spruce budworm larvae populations after application of three rates of carbaryl, Montana, 1979*[1]

Dosage (kg a.i./ha)	Prespray larvae/ 100 buds	5 days postspray		10 days postspray		15 days postspray		Destruction of new foliage[2]
		Larvae/ 100 buds	Percent reduction	Larvae/ 100 buds	Percent reduction	Larvae/ 100 buds	Percent reduction	
1.12	8.24	2.68	67.5a	1.45	84.0a	0.58	92.8a	29.8a
.56	8.65	1.27	85.2a	.69	92.2a	.58	93.5a	27.5a
.28	9.81	4.26	54.4	1.89	78.8a	1.70	83.1a	32.2a
Control	10.16	9.51	7.3b	7.28	26.3b	5.64	42.3	56.4b

[1]Means are for five plots, each with 15 sample trees. Values followed by the same letters do not differ significantly at 5 percent level of probability.
[2]Current year's foliage at beginning of pupation.

number of trees dropped from each of the five replicates in each dosage rate and the corresponding increase in population reduction was computed (*table 3*). Although none of the increases was large—1 to 3 percent—they do indicate that early spraying, when some of the buds were closed, probably affected overall budworm mortality.

Results of this field test with dosage rates of 1.12 and 0.56 kg per hectare were in the same range as those of previous tests and operational programs (*table 4*), particularly after correction for the effect of bud development. The 0.28 kg per hectare rate, even after correcting for bud development, was almost 10 percent less than that obtained with the higher dosages. Under the conditions of our test, 0.56 kg a.i. per hectare compared favorably with 1.12 kg a.i. per hectare in reducing larval populations of western spruce budworm and preventing destruction of new foliage.

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Table 3—*Effect of bud development at time of carbaryl spraying on reduction of western spruce budworm larvae population 15 days after spraying*

Dosage (kg a.i./ha)	Reduction uncorrected for bud development	Buds open at spraying	Trees dropped from 75 observed	Reduction corrected for bud development	Change in larval population reduction due to correction
	Percent	*Percent*		*Percent*	*Percent*
1.12	92.4	91.7	7	93.9	1.1
.56	93.4	85.6	12	95.5	2.1
.28	83.1	75.2	16	85.3	2.2
Control	42.3	79.4	15	45.1	2.8

Table 4—*Reduction in western spruce budworm population achieved by application of carbaryl, western United States, 1976-1979*

Year, type of test	Location	Hectares sprayed	Average reduction[1] Treated plots	Average reduction[1] Control	Source
			Percent	*Percent*	
Preregistration test:[2]					
1975	Montana	1,412	84.4	14.7	Flavell and others (1978)
1976	Washington	3,103	96.2	—	Mounts and Gregg (1978)
Registered use:[2]					
1977	Washington	144,455	91.7	59.0	Mounts and Gregg (1978)
1977	New Mexico	15,168	93.1	44.5	Parker and others (1978)
1979	Idaho	40,000	97.0	55.5	Livingston and others (1982)
Reduced dosage test:					
1979[2]	Montana	100	92.8	45.0	
1979[3]	'Montana	100	93.5	45.0	

[1]Uncorrected for natural mortality. [2]Dosage 1.12 kg/ha. [3]Dosage 0.56 kg/ha.

Markin, George P.; Johnson, David R. **Carbaryl applied at reduced dosage rates for control of western spruce budworm.** Res. Paper PSW-170. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1983. 3 p.

Carbaryl is registered for control of the western spruce budworm (*Choristoneura occidentalis* Freeman), at the dosage rate of 1.12 kg per hectare. That rate and two lower ones were field tested in western Montana in July 1979 to determine if a lower rate would be as effective as the registered dosage. Each dosage was applied to five randomly selected 20-ha plots by helicopter with Beecomist nozzles while larvae were in the fifth and early sixth instars. Reduced dosages of 0.28 and 0.56 kg a.i. per hectare resulted in 83 and 93 percent population reduction, respectively, compared with 93 percent population reduction for the registered dosage of 1.12 kg a.i. per hectare.
Retrieval terms: western spruce budworm, *Choristoneura occidentalis*, spray test, carbaryl, Sevin-4-oil, Montana