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Aerial Field Tests of Five Insecticides on Western Spruce Budworm in Idaho and Montana, 1978–1980

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Each of five insecticides was applied at two or three application rates by helicopter to 20-ha plots. Effectiveness of each application rate against western spruce budworm (*Choristoneura occidentalis* Freeman) was judged by comparing larval population reduction at 15 or 20 days after treatment against populations in untreated check plots. Performance of each insecticide was then compared with the levels of control normally obtained with two registered insecticides, carbaryl and acephate (90+ pct) usually used for western spruce budworm control. Maximum population reduction from sulprofos (58 pct), phosmet (59 pct), and from the growth regulator BAY SIR-8514 (58 pct), at all application rates tested was below the acceptable minimum of 90+ percent population reduction. Methomyl reduced populations 92.3 percent at 0.28 kg a.i./ha and 94.0 percent at 0.56 kg a.i./ha. Permethrin at 0.11 kg a.i./ha reduced the population by 93.9 percent. Methomyl and permethrin at these application rates appeared to be as effective as the registered insecticides acephate and carbaryl.

Retrieval Terms: western spruce budworm, *Choristoneura occidentalis*, insecticides, aerial field tests

The Forest Service, U.S. Department of Agriculture, has underway an extensive laboratory screening program to find new chemical insecticides for control of the western spruce budworm (*Choristoneura occidentalis* Freeman).[1] The most promising insecticides found in these laboratory tests are field tested against outbreak populations of the budworm. Insecticides field tested before 1977 include carbaryl, trichlorfon, acephate, and chlorpyrifos-methyl.[2,3] Two of these materials, carbaryl and acephate, have been registered against the western spruce budworm, and have become the standard means of control in the Western United States.[4]

This note reports the results of large scale aerial field tests conducted in Montana and Idaho between 1978 and 1980. Five insecticides were selected for testing on the basis of laboratory screening: methomyl, permethrin, phosmet, sulprofos, and BAY SIR-8514. Two or three application rates were tested for each insecticide on the basis of similar tests against other Lepidoptera and on manufacturers' recommendations. Treatments were assigned to 20-ha plots at random and applied with a small helicopter. Each application rate had five replicates, and a set of five check plots was used. Larvae, pupae, and buds or new shoots on 15 sample trees in each plot were sampled before and after treatment. Larval mortality caused by each insecticide was compared against that caused by the registered insecticides acephate and carbaryl. Population reduction below 90 percent was considered unacceptable.

Methomyl and permethrin appeared to be as effective as carbaryl and acephate. All three application rates of methomyl (0.56, 0.28, and 0.14 kg a.i./ha) significantly reduced populations over those in check plots. Permethrin at the highest application rate tested (0.122 kg a.i./ha) caused 93.9 percent mortality. Phosmet and sulprofos were unsatisfactory in reducing populations. BAY SIR-8514 showed no insecticidal activity.

METHODS AND MATERIALS

The five insecticides tested were methomyl, permethrin, phosmet, sulprofos, and BAY SIR-8514. Original plans were to conduct the entire test in southwestern Idaho. However, in 1979, an operational control program was scheduled for that area and tests were moved to central Montana (*table 1*).[5] Field application rates were based on similar tests of the same insecticides against other Lepidoptera (particularly the spruce budworm, *Choristoneura fumiferana* [Clemens])[2] and on the manufacturer's recommendations. These recommendations were usually on the basis of price competitiveness of their

Table 1—*Insecticide formulations and study sites used in aerial field tests against larval populations of the western spruce budworm, 1977–1980*

Common name	Year of test	Formulation (pct a.i.)	Types of insecticide	Manufacturer	Location of study area
Methomyl	1978	Lannate L (24 pct)	Carbamate	Dupont	23 km SW Cascade, Idaho (Gem Co.)
Permethrin	1979	Pounce 3.2 ED (38.4 pct)	Synthetic pyrethroid	FMC Corp.	25 km N White Sulfur Springs, Montana (Meagher Co.)
Phosmet	1979	Imidan IE (12 pct)	Organophosphorus	Stauffer Chemicals	20 km N White Sulfur Springs, Montana (Meagher Co.)
	1980	Imidan IE (12 pct)	Organophosphorus	Stauffer Chemicals	24 km SW McCall, Idaho (Adams Co.)
Sulprofos	1980	Bolstar G (64 pct)	Organophosphorus	Mobay Corp.	18 km SW McCall, Idaho (Adams Co.)
BAY SIR-8514	1979	Wettable powder (25 pct)	Moult-inhibiting	Mobay Corp.	23 km N White Sulfur Springs, Montana (Meagher Co.)
	1980	Wettable Powder (25 pct)	Moult-inhibiting	Mobay Corp.	22 km SW McCall, Idaho (Adams Co.)

material with registered insecticides in operational use.

The total volume of spray applied was 9.3 L/ha of final spray solution. The exception was phosmet in 1980; because the formulation available (Imidan IE) contained 0.12 kg a.i./L, an applied volume of 14.07 L/ha was needed to obtain the highest application rate—1.67 kg a.i./ha. To retain the same treatment parameters for the three application rates tested that year, the applied volume of the two lower application rates was also increased to 14.0 L/ha.

Experimental design and plot layout were the same for all insecticides except the growth regulator BAY SIR-8514, for which only three plots were treated at two application rates. For each insecticide, plots were selected at approximately the same altitude, but located no closer to each other than 1 km to prevent cross-contamination by drift. Plots were 20 ha and usually rectangular. Treatments were assigned to the plots at random and consisted of five replicates for each of the three application rates tested plus a set of five check plots.

Within each plot, 15 sample trees were selected. Grand fir (*Abies grandis* [Dougl.] Lindl.) was used in the tests in Idaho, and Douglas-fir (*Pseudotsuga menziesii* variety *glauca* [Beissn.] Franco) was used in Montana. Sample trees were 10 to 20 m tall, open grown, and at least 30 percent of their foliage was within 10 m of the ground. All sample trees were more than 60 m from the plot boundary and more than 20 m apart. Larvae, pupae, and buds or new shoots were sampled before treatment on two 38.5-cm branches collected from the midcrown and on four branches at posttreatment intervals.[6] Sample branches were cut with a 9-m pole pruner with a 40-cm cloth basket underneath the cutting head. Larvae were removed at a field laboratory by beating the branches inside a separator barrel.[7] Population density was expressed as larvae (and pupae at final sampling interval) per 100 shoots. Samples were collected 24 hours before treatment and at 5-day intervals for 15 days or (when larval development was slow) for 20 days after treatment.

Defoliation was estimated using foliage sampled at the last postspray interval. Each shoot was assigned to one of four defoliation classes (25, 50, 75, and 100 percent), and classes were averaged for the four branches from each tree to give the amount of defoliation.[8]

At each sample tree, a white Kromekote card (10 by 12 cm) and two aluminum plates (21.4 by 21.4 cm) were used to determine spray deposit recovered at ground level. Rhodamine-B dye was added to all spray solutions at a rate of 0.1 percent (weight per volume) as a marker to facilitate spray deposit recovery. Cards and plates were placed in openings adjacent to each sample tree on the morning of spraying and collected within 1 hour after spraying. Cards were scanned by an IMANCO Quantimet 20 Image Analyzer to determine volume mean diameter (VMD) of the drops and the number of drops per square centimeter.[9] The aluminum plates were washed and the dye removed was analyzed by a spectrofluorometer to determine the volume of spray recovered.[10]

Analysis of variance was used to determine if differences between treatment means for each insecticide were significant ($P = 0.05$). Tukey's test was used to show where significant differences occurred between pairs of treatments.

The experimental design allowed each application rate to be compared against only the other rates of the same insecticides or the untreated check plots. Because of the need to test the materials in different years and different areas, the design did not allow direct statistical comparison between the different insecticides. Acceptability of performance for each insecticide was determined by comparing the percent mortality at the final postspray sampling period against the general performance of the two registered insecticides acephate and carbaryl. Acephate at 1.12 kg a.i./ha caused mortality ranging from 91 to 98 percent,[2, 11] and carbaryl at 1.12 kg a.i./ha caused 93 to 96 percent mortality.[12] By this criterion, any insecticide that reduced the population less than 90 percent was considered unacceptable.

SPRAY APPLICATION

All materials were applied by a small helicopter (Bell 47 or Hiller 12E) equipped with saddle tanks, hydraulic pump, a 10-m boom, and nozzles fitted with 8002 Spraying System flat fan tips, mounted forward and down. Materials were sprayed from 15 m above canopy, at 75 km/h in swatches 15 m apart. Plots were marked with fluorescent panels placed in corner trees to serve as markers for the helicopter pilot. Sprays were applied in the morning when temperatures were between 5 and 17 ° C with winds less than 9 km/h. Plots were treated when bud flash was complete and budworm larvae were actively feeding.

To minimize the variability of application between years (different plots and aircraft), extra effort was made to calibrate each aircraft and provide guidance to the pilot. Pilots were also allowed a day to spray water over practice plots and to train in the exact application procedures desired. Despite these precautions, amounts of material recovered on the ground did vary (*table 2*). Differences in VMD and the number of drops per square centimeter probably represent differences in the flowability and atomization of individual formulations rather than differences in application procedures. Differences in deposit recovered are also a result of site-specific phenomena, including canopy cover intercepting spray, and air movement patterns causing loss due to drift or evaporation.

Table 2–*Spray application as assessed from spray deposit data from field tests of five insecticides against western spruce budworm larva, Idaho and Montana, 1978–1980**

Insecticide	Application		Spray deposit assessment		
	Rate	Volume	Recovered	Drops/cm^2	VMD†
	kg a.i./ha	*L/ha*	*Percent*		*μm*
Methomyl	0.56	9.3	13	7.5	308
	0.28	9.3	26	4.0	328
	0.14	9.3	26	7.9	345
Permethrin	0.112	9.3	31	5.0	301
	0.056	9.3	25	3.2	281
	0.28	9.3	22	4.4	271
Phosmet 1979	0.56	9.3	46	16.9	344
	0.28	9.3	21	7.6	271
	0.14	9.3	36	7.5	298
Phosmet 1980	1.67	14.0	30	20.4	212
	1.122	14.0	19	7.1	237
	0.56	14.0	15	7.8	204
Sulprofos	0.56	9.3	16	3.5	259
	0.28	9.3	37	7.0	281
	0.14	9.3	21	3.6	248
BAY SIR-8514	0.14	9.3	27	11.4	281
	0.28	9.3	21	6.4	253

*Each value is the mean for the five plots treated, except values for BAY SIR-8514, which are the means of only three plots.

†VMD = Volume median diameter—the droplet size diameter that divides the spray volume into equal parts; 50 percent of the volume is in droplets below the VMD and 50 percent is above it.

RESULTS

Developmental stages of western spruce budworm larvae at time of spraying included third through sixth instars (*table 3*). Third instar larvae are often still within the buds and escape direct exposure to spray, while sixth instar larvae are large enough to have caused considerable feeding damage to the new foliage. Using these criteria, methomyl could have been applied slightly earlier and permethrin and phosmet 1979, later than the optimum timing.

Effectiveness of each treatment was determined by comparison with untreated checks and other application rates of the same insecticide (*table 4*).

Table 3—*Developmental stages of western spruce budworm larvae at times of insecticide application, Idaho and Montana**

Insecticide	Date of application	Application rate	Larval instar			
			Third	Fourth	Fifth	Sixth
		kg a.i./ha	*Percent*			
Methomyl	June 26–28, 1978	0.56	21	44	28	7
		0.28	22	38	35	5
		0.14	19	39	41	1
Permethrin	July 3–7, 1979	0.112	7	27	24	42
		0.056	16	23	30	21
		0.028	4	28	23	45
Phosmet	July 8–10, 1979	0.56	1	5	33	61
		0.28	2	5	32	61
		0.14	1	5	24	70
	July 22–24, 1980	1.67	2	57	40	1
		1.12	11	41	47	1
		0.56	7	58	33	1
Sulprofos	June 24–26, 1980	0.56	2	42	52	4
		0.28	3	50	44	3
		0.14	1	48	56	5
BAY SIR-8514	July 2, 1979	0.14	5	22	56	17
	June 22, 1980	0.28	1	29	68	2

*Each value is the mean for the five plots, except values for BAY SIR-8514, which are the means of only three plots.

Methomyl

Methomyl at all three application rates significantly reduced populations when compared with check plots. No significant differences could be detected among the application rates. The two highest dosage rates caused 92 percent (0.28 kg a.i./ha) and 94 percent (0.56 kg a.i./ha) mortality. At these two application rates, methomyl probably was as effective as the registered insecticides acephate and carbaryl.

Permethrin

Population reduction by permethrin varied considerably among the three application rates. The highest rate, 0.122 kg a.i./ha, produced 93.9 percent mortality, which was within the range generally obtained with carbaryl and acephate. The lower mortality caused by the two lower rates, 0.061 and 0.030 kg a.i./ha, indicates that the effective threshold for this

Table 4—*Reduction, uncorrected for natural mortality, of western spruce budworm larval populations after treatment with five insecticides, Idaho and Montana, 1978–1980**

Insecticide	Dosage	Mean larvae per 100 buds or new shoots: Prespray 24 hours	Postspray: 5 days	Postspray: 10 days	Postspray: 15 days	Postspray: 20 days	Population reduction final sampling interval	New foliage destroyed†
	kg a.i./ha						*Percent*	*Percent*
Methomyl	0.56	45.1a ‡	4.2a	5.4a	2.1a	—	94.0a	50.3a
	0.28	40.4a	4.3a	4.5a	2.6a	—	92.3a	52.9a
	0.14	37.2a	7.7a	6.6a	5.6b	—	83.9a	44.3a
	Check	31.2a	21.7b	22.2b	16.8b	—	43.0b (20.7)§	65.2a(33.6)§
Permethrin	0.11	9.2a	2.1a	1.6a	0.5a	—	93.9a	25.0a
	0.056	7.9a	3.9a	3.5a	2.2a	—	70.8b	29.6a
	0.028	12.5a	5.8bc	5.2b	4.0b	—	62.3bc	42.9ab
	Check	9.0a	7.5c	6.4b	4.7b	—	46.5c (18.8)	50.7b (20.4)
Phosmet 1979	0.56	9.6a	5.4a	4.1a	2.7a	—	72.9a	41.6a
	0.28	10.8a	7.6a	4.5a	3.9a	—	61.7a	48.7a
	0.14	9.9a	7.7a	5.7a	4.1a	—	55.9a	49.5a
	Check	8.0a	8.2a	5.7a	3.9a	—	54.9a (23.9)	42.7a (25.5)
Phosmet 1980	1.67	20.1a	13.2a	10.2a	11.6a	8.2a	59.6a	36.0a
	1.11	24.8a	18.6a	15.2a	11.1a	7.7a	64.3a	52.0a
	0.56	27.6a	17.7a	14.1a	14.1a	7.9a	70.5a	48.2a
	Check	28.1a	24.2a	17.8a	17.6a	18.4a	35.2a (25.6)	60.8a (34.8)
Sulprofos	0.56	24.4a	19.5a	15.0a	10.7a	9.5a	57.7a	35.3a
	0.28	18.4a	13.1a	11.2a	10.7a	10.9a	39.0a	30.4a
	0.14	16.3a	12.1a	13.2a	12.8a	9.2a	44.9a	28.9a
	Check	19.7a	22.0a	22.7a	18.6a	17.9a	13.0a (36.1)	53.9a (31.0)
BAY SIR-8514 1979	0.14	8.9a	7.2a	6.6a	4.8	—	42.2a	31.5a
	Check	9.0a	7.5a	6.5a	4.7	—	46.5a (20.4)	50.7a (39.5)
BAY SIR-8514 1980	0.28	36.2a	27.9a	30.2a	29.8a	12.3a	58.3a	65.5a
	Check	28.1a	24.2a	17.8a	17.6a	18.4a	35.2a (33.4)	60.8a (100.0)

*Each value is the mean from the five plots, except values for BAY SIR-8514 which are means from only three plots.
†Mean percent of current year's foliage destroyed at final sampling interval.
‡Means in same column for each insecticide followed by the same letter do not differ significantly at the 5 percent level.
§Tukey's least significant difference (P = 0.05).

material lies somewhere between the high rate of 0.11 kg a.i./ha and the middle rate of 0.056 kg a.i./ha.

Phosmet

Phosmet was first tested in 1979. The highest mortality was only 73 percent, and no new foliage was saved. Therefore, a higher range of application rates was tested in 1980 but was no more effective. In both years the population reduction by phosmet at all application rates tested was less than the desired 90 percent level, and also failed to protect foliage.

Sulprofos

Sulprofos performed unacceptably at all application rates tested. While some plots received rainfall after application (maximum 0.05 cm within 24 hours), many of the treated plots received no rain for up to 5 days after treatment. No differences in mortality could be detected between plots that did and did not receive rain. Therefore, the poor performance of sulprofos was not due to rainfall. Trees in plots known to have received good spray coverage—on the basis of assessment cards—were observed for 2 to 6 hours after application. No dead, morbid, or irritated larvae spinning out of the trees were noticed, although rapid knockdown within 2 hours after treatment was reported with insects on other crops such as cotton.[13]

BAY SIR-8514

The growth regulator BAY SIR-8514 was comparatively new, and preliminary laboratory screening and field tests on the spruce budworm (*C. fumiferana* [Clemens]) in eastern Canada indicated that it was promising.[14] We applied one dosage rate (selected by the manufacturer) to three plots. Results of the first test in 1979 indicated no insecticidal activity. This was confirmed in 1980, when the test was repeated at twice the application rate, and again no difference in larval mortality was detected between the treated and check plots.

CONCLUSIONS

Methomyl at 0.28 and 0.56 kg a.i./ha, and permethrin at 0.11 kg a.i./ha appeared to be as effective as the registered insecticides acephate and carbaryl in reducing populations of western spruce budworm. On the basis of the results, we recommend that pilot tests of permethrin at 0.11 kg a.i./ha and methomyl at 0.28 kg a.i./ha be undertaken to evaluate the performance of these two insecticides under operational conditions.

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This publication neither recommends the pesticide uses reported nor implies that they have been registered by appropriate governmental agencies.

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