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Log Bioassay of Residual Effectiveness of Insecticides Against Bark Beetles

Richard H. Smith

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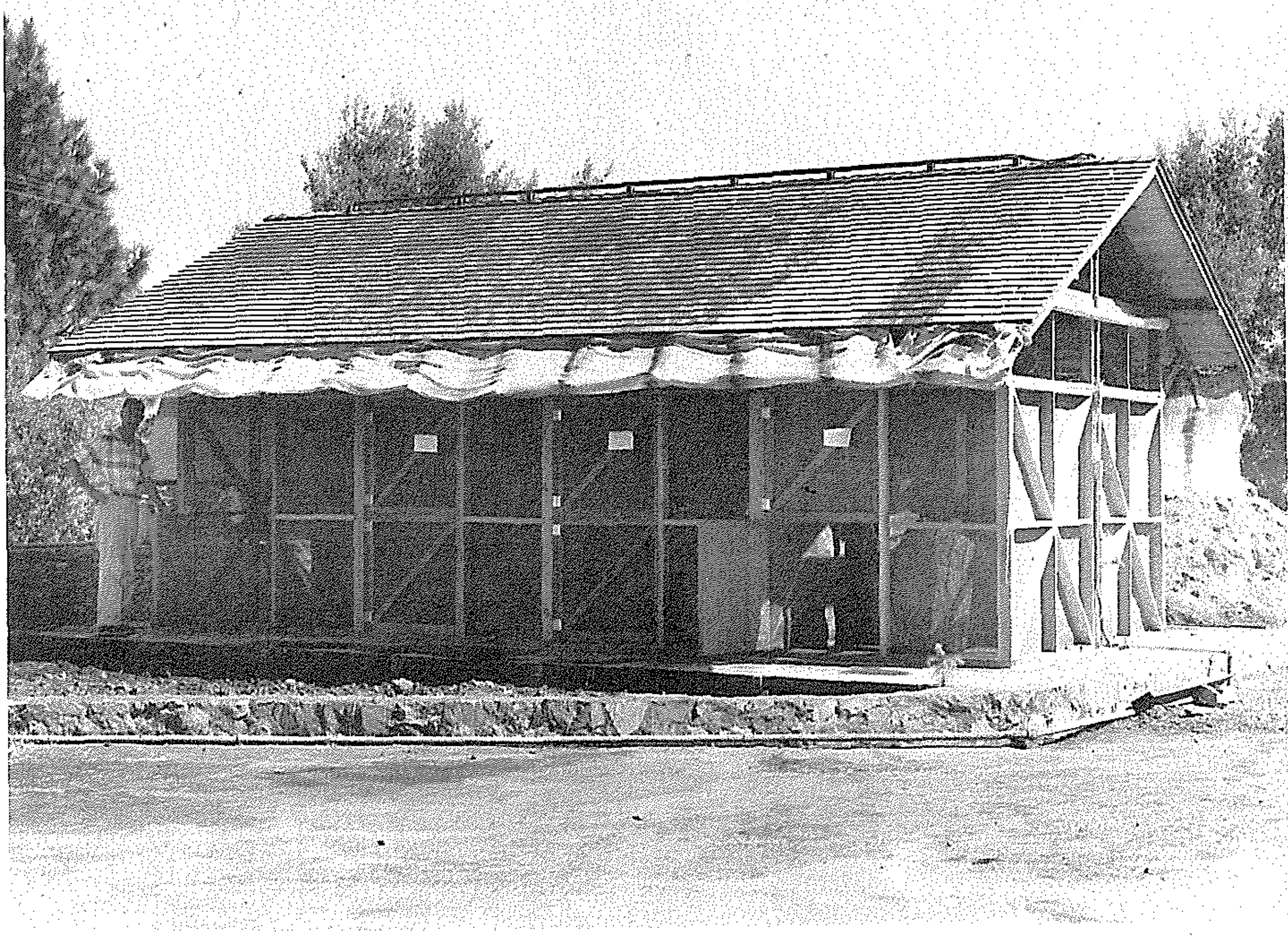

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Cover: An insectary unit at the Forest Service's Institute of Forest Genetics, near Placerville, California, served as the field laboratory for testing nine insecticides on bark beetles.

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IN BRIEF . . .

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Retrieval Terms: Western pine beetle, mountain pine beetle, Jeffrey pine beetle, lindane, Sevin, Reldan, Dursban, Sumithion, Imidan, malathion, permethrin, decamethrin

Protecting individual pines from bark beetle attack can be a viable option when beetles are active in the immediate area. Only lindane and Sevin are now permitted for this use in California. This paper reports on the results of a log bioassay procedure, with ponderosa and Jeffrey pine, in testing other insecticides for use as protective sprays for western, mountain, and Jeffrey pine beetles. Insecticides used and found to be effective in addition to lindane and Sevin were Dursban, Reldan, Sumithion, and two pyrethroids, permethrin and decamethrin. Imidan and malathion were not effective. Testing was carried out during a 5-year period.

Trees 10 to 13 inches (25 to 33 cm) in diameter growing in well-stocked stands at 2700-ft (825-m) elevation near Placerville, California, were sprayed with varying concentrations of the insecticides ranging from 0.002 percent to 0.25 percent for the pyrethroids and 0.2 percent to 2 percent for the others. A dosage of 1 gal (3.8 l) per 40 ft^2 (3.6 m^2) of bark was used in all but one test for which 1 gal (3.8 l) per 80 ft^2 (7.2 m^2) was used. Included in the testing were these variables: pH of water for Sevin only, temperature of water for Dursban only, postspray exposure to sun and water for lindane only, beetle source and attack density, and spray additives (molasses or latex).

From 2 to 13 months postspray, trees were felled and cut into 15- to 18-inch (37- to 45-cm) logs. The ends were paraffined to retain moisture and to prevent beetle attack on cut surfaces. Logs from the untreated portion of the trees served as checks. Single-log and group-log tests were used; results were comparable with both procedures. For single-log testing, the logs were individually caged and a specified number of beetles collected from naturally infested brood material was added. For group-log testing, logs for each treatment in a test were stacked in a unit of a walk-in insectary. Naturally infested brood material from which beetles would soon emerge was added to the insectary unit. This arrangement was replicated in 2 to 4 units.

About 2 weeks after beetles began to attack, the bark of all logs was shaved off down to the xylem and the length of egg galleries measured. Gallery length per square foot on the logs of each treatment was compared with that of the untreated check logs. Effectiveness of treatment was based on the reduction in length of egg gallery expressed as a percent.

To make optimal use of trees and insecticides and to examine the greatest number of treatments, there was no conventional replication. But during the 5-year period there was considerable approximate repetition of test conditions.

All chemicals were quite effective for 2 to 13 months, except for malathion and Imidan, which were relatively ineffective, depending largely on concentration and application rate. Based on equivalent amounts of lindane the ranking of effectiveness is as follows: for western pine beetle on ponderosa pine: decamethrin > permethrin > lindane > Reldan > Dursban ≅ Sumithion > Sevin; for mountain pine beetle on ponderosa pine: decamethrin > permethrin > lindane > Dursban ≅ Reldan > Sevin > Sumithion; for Jeffrey pine beetle on Jeffrey pine: decamethrin > permethrin > lindane > Sevin.

Water at pH 8 greatly reduced the effectiveness of Sevin. The addition of molasses greatly increased the effectiveness of lindane. Effectiveness was inversely related to beetle attack density. There was very little effect attributable to bark moisture and exposure, water temperature, and beetle source. The addition of latex to the water of sprays did not increase effectiveness. The most promising avenues for future work are the use of pyrethroids and the addition of molasses to potentiate lindane.

Insecticides[1] are commonly used to control infestations of bark beetles, chiefly the western pine beetle (*Dendroctonus brevicomis* LeConte) and the mountain pine beetle (*D. ponderosae* Hopkins). As a protective measure, residual insecticides can be applied to the trunks of uninfested trees. In California, only two compounds—lindane and Sevin—are registered by the U.S. Environmental Protection Agency for this purpose. And the continued use of lindane is currently being investigated by that Agency.

Other insecticides have shown promise in preventing attacks by bark beetles in field and laboratory tests. Dursban and Sevin performed well in field tests (Smith and others 1977). Sumithion and Imidan had excellent ratings in laboratory bioassays (Hastings and Jones 1976, Robertson and Gillette 1978, Robertson and Kimball 1978). Topical application studies in the laboratory (Lyon 1971) showed pyrethrins to be toxic to western pine beetle; however, the lack of persistence of pyrethrins ruled against field tests. Newly developed pyrethroids were shown to be equally or more toxic to western pine beetle than the pyrethrins (Robertson and Gillette 1978, Robertson and Kimball 1978). Earlier, a similar conclusion was reached for southern pine beetle (*D. frontalis* Zimmerman). Pyrethroids, in general, have been found to combine persistence with the toxicity of the natural pyrethrins without an appreciable shift in environmental hazards (Elliott and others 1978).

To assess their residual toxicity, I studied nine insecticides—lindane, Sevin, Dursban, Reldan, Sumithion, Imidan, malathion, and the pyrethroids, permethrin and decamethrin—for their effectiveness in preventing attack of western pine beetle and mountain pine beetle on ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). I also did preliminary studies with some of these insecticides to assess the residual toxicity to Jeffrey pine beetle (*D. jeffreyi* Hopkins) on Jeffrey pine (*P. jeffreyi* Grev. & Balf.).

The experiments were carried out during a 5-year period (1976-1980) at the Forest Service's Institute of Forest Genetics, near Placerville, in northern California. Single-log and group-log bioassays were done for western and mountain pine beetle; only group-log testing was done for Jeffrey pine beetle. Also, compared in the tests were the effects of pH, water temperature, low insecticide concentration, bark moisture and exposure, beetle source and attack density, and spray additives on the residual effectiveness of the sprays.

This paper reports the results of log bioassays that compared the residual effectiveness of nine insecticides. Effectiveness of treatment was based on the percent reduction in length of egg gallery when compared with untreated checks. The information obtained in these tests can be useful in direct application and in deciding the approach that further field tests might take.

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

METHODS

Treatment Application

All trees were 40 to 50 years old and growing at 2700-ft (825-m) elevation in well-stocked stands. Diameter-at-breast height (d.b.h.) ranged from 8 to 30 inches (20 to 76 cm); however, only those trees with d.b.h. between 10 and 13 inches (25 to 33 cm) were included in the study. None of the trees was growing under open conditions. Limbs of all trees were removed to a height of 25 ft (7.6 m) before spray application.

Insecticides were sprayed at various concentrations: Sevin, Reldan, Dursban, Sumithion, and Imidan—from 0.5 to 2 percent; lindane—from 0.2 to 2 percent; permethrin—from 0.01 to 0.25 percent; decamethrin—from 0.002 to 0.1 percent; and malathion—at 1 percent.

All insecticides were aqueous emulsions except Sevin, which was a suspension made from Sevimol concentrate. All were applied to dry bark at dosages of approximately 1 gal (3.8 l) per 40 ft^2 (3.6 m^2) or 80 ft^2 (7.2 m^2) of bark surface. All sprays were prepared within 2 h of use and were applied with a 3-gal (11.4 l) hand-pressured garden tank sprayer. Trees were sprayed to a height of 25 ft (7.6 m). Spraying was done from early spring to midsummer in early morning when there was little or no breeze and air temperatures ranged from 60° to 75°F (16° to 24°C). Water temperatures were from 55° to 60°F (13° to 16°C).

Specific conditions were established for some of the tests. The pH of the water for the preparations of Sevin was adjusted to 6 or 8 by the use of buffers. The Dursban sprays were prepared with water of different temperatures. In one test the trunks of trees sprayed with 0.5 percent and 1 percent lindane were selected so that one-half of the trees had trunks exposed to direct sunlight and the other one-half had trunks not exposed to direct sunlight. Also, the trees with exposed trunks were sprayed with water to simulate rain during the first, second, and third weeks after the insecticide was applied. Latex and molasses were added to lindane and the pyrethroids in two tests. One of the preparations of Sevin, Sevimol, was formulated by the manufacturer as a suspension, containing molasses as a major constituent. Sevimol was not altered in any way at the experimental level except for dilution. Three different source preparations of Sevin were compared. The effect of a three-fold increase in the attack density of western and mountain pine beetles was tested. Two widely separated sources of western pine beetle were compared.

Brood material for all three beetles was obtained from Eldorado County in northern California. But for the test comparing geographic sources of western pine beetle, a second brood source of beetles was Shasta County, 200 miles (322 km) to the north. The source for western pine beetle was bark from infested ponderosa pine (*Pinus ponderosa* Dougl. ex Laws); for mountain pine beetle, logs of infested sugar (*P. lambertiana* Dougl.) or lodgepole pine (*P. contorta* Dougl. ex Loud.); and for Jeffrey pine beetle, logs from infested Jeffrey pine (*P. jeffreyi* Grev. & Balf.).

All sprayed trees were exposed to the prevailing weather conditions at the Forest Service's Institute of Forest Genetics near Placerville for the varying residual periods tested. In general, the first 6 months after treatment air temperatures ranged from 60° to 90°F (16° to 32°C) with very little rainfall. During the next 6 months, the temperatures were much lower, generally ranging from 20° to 70°F (−7° to 21°C) with rainfall of about 40 inches (102 cm).

Log Bioassay

At designated periods treated trees were felled and the sprayed portion sectioned into several 15- to 18-inch (38- to 46-cm) logs. Similar sections were cut from the unsprayed portions of the trees to serve as untreated checks. Earlier work (Smith and others 1977) showed that, essentially, no difference exists in the rate of success of beetle attack on cut logs taken from various heights along the trunk of ponderosa pines of the size range included in the test. The ends of each log were given two coats of hot paraffin. The first coat was hot enough to penetrate the bark and wood tissues. The second coat was hot enough to flow easily and deposit a surface layer of paraffin. The paraffin treatment retained phloem and xylem moisture and also prevented attack through the cut surfaces.

The prepared logs, with the appropriately aged insecticide deposits, were exposed to beetles either by caging the logs singly or in groups. For single-log testing, the log was placed on short blocks to raise it off the floor of the cylindrical cage. Beetles, reared from natural brood material, were added to the cage at a rate of about 100 per ft^2 ($1100/m^2$) of bark surface for a given log for western pine beetle and about 30 per ft^2 ($330/m^2$) for mountain pine beetle. Jeffrey pine beetle was not used in single-log testing.

Group-log testing was done in units of a screened walk-in insectary at the Institute. The units were about 6-ft (1.8-m) cubes. From 8 to 12 test logs were arranged in stacks of 3 or 4 along the side of the unit with the greatest light intensity. The logs were stacked end-to-end and separated from each other by double nailed cleats to ensure beetle attack through the treated bark surface and not through the cut, paraffined surfaces. Treated and untreated logs were located randomly within the stacks of an insectary unit containing at least one log of each treatment in the particular test. Usually, three insectary units were used for each bioassay test with each beetle. In a few instances either two or four units were used, depending on the supply of brood material and the size of the test. For group-log testing, brood material from which beetles were about to emerge was placed along the dark side of the insectary unit. As beetles emerged, therefore, they flew toward the light side and the test logs. When caged, beetles readily enter freshly cut logs. The attack density, however, could only be crudely estimated with the group-log procedure. Because each treatment was represented in each insectary unit, all treatments were assumed to be exposed to an equivalent beetle attack density. In general, sufficient brood material was placed in each unit to ensure that the tests were exposed to adequate attack density. It is estimated that the numbers of beetles were as high or higher than those used in single-log testing.

Examination and Analysis

From 2 to 3 weeks after beetles began their attack, depending on temperature, all logs were examined. The bark of each log was shaved off to expose the adult galleries at the phloem-xylem interface. Total length of successful galleries, those with evidence of oviposition, was measured and converted to inches per square foot of phloem surface. Average gallery length per square foot of each treatment was compared with the untreated checks. The difference between treated and untreated logs in inches of gallery per square foot was converted to the percent reduction resulting from treatment.

Egg gallery construction was selected over other performance measures because it was the result of the full establishment phase— boring, mating, gallery construction, and oviposition.

To make optimal use of trees and insecticides and to look at the greatest number of treatment variables, there was no conventional replication. That is, all the trees with a given treatment were not cut and tested at the same time. Instead, the trees were usually cut and tested at different residual periods. At least three logs were cut from each treated tree to serve as a type of replication to test the procedure. Additionally, usually two different species of bark beetle were tested against the logs from each tree. Also, during the course of 5 years many test conditions, or approximate test conditions, were repeated. Therefore, the data seem suitable for discussion and tentative conclusions.

RESULTS

Western and Mountain Pine Beetles on Ponderosa Pine

Pyrethroids

In the 1978 tests, both permethrin and decamethrin were effective at such low concentrations that it was decided to

Table 1—*Reduction in length of egg galleries of western and mountain pine beetles in ponderosa pine logs, by months after insecticide application, 1978 and 1979*[1]

Insecticide (pct) and additive[2]	Western pine beetle			Mountain pine beetle			Western pine beetle	Mountain pine beetle
	Months after application in . . .							
	1978			1978			1979	1979
	6	9	12	6	9	12	5	6
	Percent[3]							
Lindane:								
0.5	100	97	—	85	54	—	—	—
0.5 + Mol	100	100	—	93	94	—	—	
1.0	100	100	100	100	92	100	100	100
1.0 + Mol	100	100	100	95	100	99	—	—
2.0	[4]—	—	100	—	—	100	—	—
2.0 + Mol	—	—	100	—	—	100	[5]100	[5]100
Permethrin:								
0.01	—	42	—	—	18	—	—	—
0.01 + Ltx	—	0	—	—	5	—	—	—
0.10	96	64	—	94	58	—	74	95
0.10 + Mol	—	—	—	—	—	—	98	95
0.10 + Ltx	92	27	—	53	45	—	—	—
0.25	—	—	—	—	—	—	97	100
Decamethrin:								
0.01	—	—	[7]84	—	—	[7]68	—	—
0.01 + Ltx	—	—	[7]35	—	—	[7]2	—	—
0.05	—	—	—	—	—	—	100	100
0.05 + Mol	—	—	—	—	—	—	100	100
0.10	[6]100	—	—	[6]100	—	—	100	100
0.10 + Ltx	—	—	[7]100	—	—	[7]100	—	—
Untreated	(22)	(33)	(25)	(17)	(18)	(16)	(22)	(11)

[1]Tested by group-log method: logs of different treatments stacked togther in same unit.
[2]Mol = 2 pct molasses; Ltx = 2 pct latex.
[3]Average for three logs. Values in parentheses are centimeters of gallery per 100 cm^2, representing 0 pct reduction.
[4]— = Not tested.
[5]16 months.
[6]4 months.
[7]10 months.

repeat some of the tests in 1979 (*table 1*). In 1978, 0.1 percent permethrin was nearly as effective as 0.5 percent lindane against both western and mountain pine beetle for 6 months, which can be considered a full season of beetle activity. At 9 months, however, the effectiveness of 0.1 percent permethrin was decreasing; the addition of latex decreased effectiveness against both species of beetle. Permethrin at 0.01 percent was ineffective at 9 months; unfortunately, a 6-month test was not conducted. Latex again decreased effectiveness. Decamethrin at 0.1 percent was fully effective for 4 to 6 months. With the addition of latex it was fully effective for 10 months. However, the data do not permit separation of the effect of decamethrin from latex. But, since latex had no positive effect in other tests, one might conclude that the 0.10 percent decamethrin alone would have been fully effective for the 10-month period. Decamethrin at 0.01 percent was surprisingly effective, though not fully so, at 10 months, and likely would have been fully effective at 6 months, but a 6-month test was not done. Latex again decreased effectiveness.

In one 1979 test, permethrin at 0.25 percent was nearly fully effective against both beetle species for 5 to 6 months; 0.10 percent was slightly less effective; the effect of molasses was inconclusive (*table 1*). Both 0.10 percent and 0.05 percent decamethrin were fully effective in the first 1979 test against both beetle species for 5 to 6 months; molasses did not decrease effectiveness. In the second 1979 test, very low concentrations—permethrin at 0.01 and decamethrin at 0.002 percent—were not fully effective for a 2½ month period (*table 2*).

The pyrethroids—permethrin and decamethrin—at comparatively low concentrations were effective against western and mountain pine beetle for prolonged periods of time. Results indicate that decamethrin might be at least five times as effective as permethrin which, in turn, is at least two times more effective than lindane. Both western and mountain pine beetle are somewhat equally affected by both insecticides, although western pine beetle seems to be slightly more susceptible. Neither molasses nor latex appeared to increase the effectiveness of either pyrethroid.

Table 2—*Reduction in length of egg galleries of western pine beetle in ponderosa pine logs, by months after insecticide application and by dosage, 1979*[1]

Insecticide (pct) and additive[2]	Months after application and dosage (gal/ft² bark)			
	2½		5	
	40	80	40	80
	Percent[3]			
Lindane:				
0.2	72	25	46	34
0.2 + Mol	97	99	85	87
Permethrin:				
0.01	21	0	27	0
0.01 + Mol	0	0	29	0
Decamethrin:				
0.002	60	27	40	6
0.002 + Mol	38	30	31	0
Untreated	(30)		(27)	

[1]Tested by group-log method; logs of different treatments stacked together in same unit.

[2]Mol = 2 pct molasses.

[3]Average for three logs. Values in parentheses are centimeters of gallery per 100 cm² phloem surface, representing 0 pct reduction.

Lindane

Lindane performed well over the whole testing period (*tables 1-10*). Two percent lindane was fully effective against both beetles for 12 months (*table 1*). At 0.5 percent, lindane was fully effective against western pine beetle for 6 months, but not quite fully effective against mountain pine beetle. At 1 percent it was usually nearly fully effective for more than 9 months and often for 12 months.

Molasses apparently potentiates lindane. The addition of 2 percent molasses to 0.2 percent lindane nearly doubled the effectiveness of the lindane (*table 2*). From previous results it would seem that 0.2 percent lindane with 2 percent molasses is equivalent to 0.5 percent lindane without molasses. It also appears that the addition of molasses reduces the amount of spray required. Lindane without molasses was less effective at the lower dosage of 80 ft² (7.2 m²), but lindane with molasses was equally effective at both dosages (*table 2*). Molasses, therefore, can lower both the concentration of lindane and the amount of spray needed for effective treatment.

Table 3—*Reduction in length of egg galleries of western and mountain pine beetles by residual sprays of insecticides on ponderosa pine, with postspray bark conditions for lindane, 1977*[1]

Insecticide and concentration (pct)	Postspray condition	Western pine beetle		Mountain pine beetle	
		Months after application			
		4	5	4	5
		Percent[2]			
Lindane:					
0.5	Shade and dry	97	[3]—	76	—
0.5	Sun and wet	98	—	80	—
1.0	Shade and dry	—	98	—	87
1.0	Sun and wet	—	98	—	85
Dursban:					
1.0	-	—	100	—	97
Sevin:					
2.0	-	—	91	—	87
Untreated		(29)	(16)	(32)	(22)

[1]Tested by group-log method: logs of different treatments stacked together in same unit.

[2]Average for three logs. Values in parentheses are centimeters of gallery per 100 cm² phloem surface, representing 0 pct reduction.

[3]— = Not tested.

Sevin, Dursban, Sumithion, and Reldan

All four insecticides were effective, depending on the concentration and residual period. At 0.5 percent, all were generally reasonably effective for about 2 months (*tables 3-9*). For longer periods effectiveness was uncertain, though decreasing. At 1 percent all were quite effective for 4 to 6 months and sometimes longer, even at times for nearly 10 months. At 2 percent all were usually fully effective for 10 months or longer. There was no sharp difference in effectiveness against the two beetle species, though Sevin seemed slightly more effective against mountain pine beetle and Reldan slightly more effective against western pine beetle.

Imidan and Malathion

Imidan was ineffective at 4 months at all three concentrations (0.5, 1, and 2 percent) and was not tested further (*table 5*). Malathion at 1 percent was fairly ineffective at 4 months on western pine beetle, and even more ineffective at 5 months on mountain pine beetle (*table 6*). It was not tested further.

Other Variables Tested

Water pH—pH greater than 7 markedly reduced the effectiveness of Sevin, even for as short a period as 2 h between mixing and spraying. The other insecticides were not tested for this factor (*table 6*).

Rate of application—Reducing the rate of application from 40 to 80 ft² per gal (3.6 m² to 7.2 m²/l), noticeably reduced effectiveness (*table 2*).

Beetle source and attack density—Lindane and Sevin were equally effective against beetles from Shasta or Eldorado Counties (*table 8*). In general, there was an inverse association between effectiveness and density of the beetle population (*tables 4, 8*). This association appears to be much stronger for mountain pine beetle than for western pine beetle, and appears to be independent of the insecticide (*table 4*).

Source of Sevin—There was a difference in the effectiveness of Sevin attributable to the source material. However, the testing was limited (*table 8*).

Water temperature—Low water temperature did not alter the effectiveness of Dursban (*table 7*).

Bark moisture and exposure— At both 4- and 5-month residual periods, there was essentially no difference attributable to postspray bark moisture or exposure. The results were the same against both western and mountain pine beetle by 0.5 percent and 1 percent lindane either on bark exposed to sunlight and postspray moisture or on bark in shade and without postspray moisture (*table 3*).

Table 4—*Reduction in length of egg galleries of western and mountain pine beetles by residual sprays of insecticides on ponderosa pine, with different attack densities, 1976*[1]

Insecticide and concentration (pct)	Western pine beetle				Mountain pine beetle			
	Months after application and attack density[2]							
	3		6½		3		6½	
	Light	Medium	Light	Heavy	Light	Medium	Light	Heavy
	Percent[3]							
Lindane:								
0.5	98	98	72	58	83	43	60	50
1.0	99	99	100	98	100	81	94	82
Dursban:								
1.0	86	79	100	87	100	47	64	53
2.0	93	89	100	100	100	76	88	78
Sevin:								
2.0	92	82	[4]—	91	—	—	71	31
Untreated	(8)	(17)	(8)	(39)	(2)	(19)	(26)	(39)

[1]Tested by group-log method: logs of different treatments stacked together in same unit.

[2]Light, medium, and heavy are generalized population levels of attacking beetles; medium is about twice the density of light and heavy is about three times the density of light.

[3]Average of three logs. Values in parentheses are centimeters of gallery per 100 cm^2 phloem surface, representing 0 pct reduction.

[4]— = Not tested.

Table 5—*Reduction in length of egg galleries of western and mountain pine beetles in ponderosa pine logs by months after insecticide application, 1978*[1]

Insecticide and concentration (pct)	Western pine beetle			Mountain pine beetle		
	Months after application					
	4	7	10	4	7	10
	Percent[2]					
Sevin:						
0.5	0	[3]—	—	[4]+	—	—
1.0	53	—	—	+	—	—
2.0	74	63	36	+	68	86
Dursban:						
0.5	40	—	—	+	—	—
1.0	85	—	—	+	—	—
2.0	98	99	97	+	97	85
Sumithion:						
0.5	21	—	—	+	—	—
1.0	88	—	—	+	—	—
2.0	92	99	90	+	82	68
Imidan:						
0.5	4	—	—	*	—	—
1.0	10	—	—	*	—	—
2.0	35	—	—	*	—	—
Lindane:						
1.0	—	100	100	+	98	92
Untreated checks	(17)	(22)	(33)	[3](*)	(17)	(18)

[1]Tested by group-log method: logs of different treatments stacked together in same unit.

[2]Average of three logs. Values in parentheses are centimeters of gallery per 100 cm^2 phloem surface, representing 0 pct reduction.

[3]— = not tested.

[4]Because of few beetles, only one untreated check log was attacked; * = attacked, + = unattacked.

Table 6—*Reduction in length of egg galleries of western and mountain pine beetles in ponderosa pine logs, by months after insecticide application and pH of formulations, 1976*[1]

Insecticide and concentration (pct)	pH	Western pine beetle		Mountain pine beetle	
		Months after application			
		4	13	5	13
		Percent[2]			
Sevin:					
0.5	6	80	[3]—	78	—
0.5	8	35	—	67	—
1.0	6	97	49	80	65
1.0	8	56	—	74	—
Lindane:					
0.5	[4]–	100	91	92	86
1.0	–	—	99	—	91
Reldan:					
0.5	–	96	—	61	—
1.0	–	100	97	81	63
2.0	–	—	100	—	79
Dursban:					
1.0	–	96	95	88	83
Malathion:					
1.0	–	62	—	45	—
Untreated		(22)	(24)	(15)	(30)

[1]Tested by single-log method: each log of each treatment in a separate cage.
[2]Average for three logs. Values in parentheses are centimeters of gallery per 100 cm² phloem surface, representing 0 pct reduction.
[3]— = Not tested.
[4]– = pH not altered.

Table 7—*Reduction in length of egg galleries of western and mountain pine beetles in ponderosa pine logs, by months after insecticide application and water temperature of formulation, 1976*[1]

Insecticide and concentration (pct)	Water temperature (°C)	Western pine beetle	Mountain pine beetle	
		Months after application		
		3	3	5
		Percent[2]		
Sevin:				
0.5	15	53	72	56
Lindane:				
0.5	15	99	95	70
Dursban:				
0.5	15	98	94	77
0.5	3	97	97	79
0.5	[3]3	100	100	82
Untreated		(17)	(18)	(26)

[1]Tested by single-log method: each log of each treatment in a separate cage.
[2]Average for three logs. Values in parentheses are centimeters of gallery per 100 cm² phloem surface, representing 0 pct reduction.
[3]For 4 h before application.

Table 8—*Reduction in length of egg galleries of western pine beetle in ponderosa pine logs, by months after insecticide application and source of beetles, 1977*[1]

Insecticide and concentration (pct)	Months after application			
	2	5	2	2
	Eldorado County			Shasta County
	Percent[2]			
Lindane:				
0.5	91	[3]—	87	98
1.0	100	94	100	100
2.0	—	100	—	—
Sevin:[4]				
0.5	89	19	89	86
1.0	100	—	100	100
Sevin:[5]				
1.0	98	93	100	93
Sevin:[6]				
1.0	98	0	100	95
Untreated	(31)	(18)	(42)	(20)

[1]Tested by single-log method: each log of each treatment in a separate cage.
[2]Average for three logs. Values in parentheses are centimeters of gallery per 100 cm² of phloem surface, representing 0 pct reduction.
[3]— = not tested.
[4]From Sevimol, a suspension concentrate in molasses.
[5,6]From two different water emulsion concentrates.

Table 9—*Reduction in length of egg galleries of western and mountain pine beetles in ponderosa pine logs, by months after insecticide application, 1977*[1]

Insecticide and concentration (pct)	Western pine beetle			Mountain pine beetle		
	Months after application					
	2	5	13	2	5	13
	Percent[2]					
Lindane:						
0.5	100	94	90	94	73	80
1.0	[3]—	—	98	—	—	82
Dursban:						
0.5	98	33	—	95	78	—
1.0	—	—	95	—	—	90
Sevin:						
0.5	48	12	—	69	36	—
1.0	—	—	65	—	—	47
Reldan:						
1.0	—	—	98	—	—	63
2.0	—	—	100	—	—	75
Untreated	(29)	(39)	(20)	(18)	(19)	(30)

[1]Tested by group-log method: logs from different treatments stacked together in same unit.
[2]Average for three logs. Values in parentheses are centimeters of gallery per 100 cm² phloem surface, representing 0 pct reduction.
[3]— = not tested.

Table 10—*Reduction in length of egg galleries of Jeffrey pine beetle in Jeffrey pine logs, by months after insecticide application, 1981*[1]

Insecticide and concentration (pct)	Months after application	
	3	5½
	Percent[2]	
Lindane:		
0.5	99	30
1.0	100	100
Decamethrin:		
0.01	95	89
0.05	100	83
Permethrin:		
0.05	22	0
0.1	46	20
Sevin:		
2.0	93	92
Untreated	(3)	(5)

[1]Tested by group-log method: logs of different treatments stacked together in same unit.

[2]Average of three logs. Values in parentheses are centimeters of gallery per 100 cm^2 phloem surface, representing 0 pct reduction.

Jeffrey Pine Beetle on Jeffrey Pine

Results of tests with Jeffrey pine beetle (*table 10*) show that lindane at 1 percent was fully effective at 3 and 5½ months, but at 0.5 percent was fully effective only at 3 months and ineffective at 5½ months. Sevin at 2 percent was nearly fully effective for 3 and 5½ months. Decamethrin at both 0.05 percent and 0.01 percent was about as effective as the 1 percent lindane and 2.0 percent Sevin for 3 months; at 5½ months effectiveness had dropped off a bit, but was still above 85 percent reduction. Permethrin at 0.1 percent was only partially effective at either 3 or 5½ months; but based on equivalent amounts, it appears to be more effective than lindane.

DISCUSSION

Of the insecticides tested, only malathion and Imidan were ineffective. All others— lindane, Sevin, Dursban, Reldan, Sumithion, permethrin, and decamethrin—were effective and could be considered for field application. The choice of insecticides and concentrations depends on other characteristics of the chemicals, environmental considerations, and on the length of protection desired.

Differences among the insecticides tested appear to be fairly consistent over time, concentration and, in some instances, formulation source. Four variables that appear to be of little significance are water temperature, postspray precipitation, exposure of bark, and source of beetle. Extremes of these variables could have some effect, but preliminary evidence points to other variables as being more significant.

Water pH was particularly significant in the tests with Sevin. Under most conditions in the West, pH is likely to be acidic and, therefore, favorable to insecticide stability. If Sevin is used, however, water pH should be adjusted to be lower than 7.

Application rate of 1 gal per 40 ft^2 (3.8 1/3.6 m^2) is considerably more effective than 1 gal per 80 ft^2 (3.8 1/7.2 m^2). Thus the current recommendation of 40 ft^2 should be maintained.

Beetle density could be a significant variable and, perhaps, could explain some differences between tests. Beetles do not appear to attack a log randomly because dead ones are usually found in clusters around treated logs. The behavior suggests, rather, the possibility that the spot where one beetle attempts to enter is more attractive than other spots. Successive attempts by a queue of beetles to enter the bark at a localized spot could eventually result in success in penetrating the bark, if beetle density were high enough. A large attacking population would also have a better chance of successfully penetrating the bark because of the simple increase in probability of longer queues and of finding a weak spot in the treatment.

Although no test was designed to compare single-log with group-log assay, the general results of somewhat similar tests indicate no noticeable difference. Each method has its advantages, however. Single-log testing permits regulation of attack density and compels the beetles to attack a specific log. But it requires greater handling of beetles and more time to conduct the study. Group-log testing provides more natural conditions because the beetles are not handled and there are choices for attack. Much less time is required to conduct the study. This method, however, does not permit control of attack density and does not ensure that each log is brought under the same attack pressure.

In previous work (Smith and others 1977), the effective residual periods were surprisingly long when the general ephemeral nature of some of the insecticides, such as Sevin and Dursban and, particularly, the two pyrethroids, is considered. Again, this points to an interaction between pine bark and the insecticide. Spraying pine bark might be likened to changing the place of storage of the insecticide, that is, from container to bark. Pine bark appears to trap and hold these molecules and prevent their rapid breakdown. This is a favorable environmental condition because tree bark is a relatively inert portion of the forest ecosystem. When insecticides are applied to pine bark, therefore, they remain effective for 6 to 12 months with minimum hazard to the environment. If care is taken in spraying trees, most, possibly 80 percent, of the spray will be on or beneath the surface of the bark. The small amount of drift can either be tolerated, or if necessary, caught in devices around the tree. Drift is greatly increased, however, when powered equipment is used. Where applicable, these results agree fairly well with results of extensive and intensive testing of southern pine beetle on loblolly pine (Hastings and Coster 1981).

Future studies should continue testing the pyrethroids—permethrin and decamethrin— and potentiating lindane by addition of molasses. Both offer possibilities of significant increases in tree protection through the use of lower dosage and safer insecticides.

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Residual effectiveness of nine insecticides applied to bark was tested against western, mountain, and Jeffrey pine beetles. Ponderosa and Jeffrey pine trees were treated and logs cut from them 2 to 13 months later, and bioassayed with the three beetles. The insecticides were sprayed at the rate of 1 gal (3.8 l) per 40- or 80-ft^2 (3.6 or 7.2 m^2) bark surface at varying concentrations. Effectiveness of treatment was based on reduction in length of egg galleries 2 to 3 weeks after initiating bioassay. All chemicals were quite effective for 2 to 13 months, except for malathion and Imidan which were relatively ineffective, depending largely on concentration and application rate. On the basis of equivalent amounts of lindane, the ranking of effectiveness of insecticides tested was as follows: (a) on western pine beetle: decamethrin > permethrin > lindane > Reldan > Dursban ≅ Sumithion > Sevin; (b) on mountain pine beetle: decamethrin > permethrin > lindane > Dursban ≅ Reldan > Sevin > Sumithion; (c) on Jeffrey pine beetle: decamethrin > permethrin > lindane > Sevin. The residual effectiveness of lindane was about doubled by adding 2 percent molasses, and high pH of water reduced effectiveness of Sevin. Other application parameters had little effect.

Retrieval Terms: Western pine beetle, mountain pine beetle, Jeffrey pine beetle, lindane, Sevin, Reldan, Dursban, Sumithion, Imidan, malathion, permethrin, decamethrin