EFFECTIVENESS OF FENITROTHION AND PERMETHRIN FOR PROTECTING PONDEROSA PINE TREES FROM ATTACK BY THE WESTERN PINE BEETLE[1,2]

Patrick J. Shea[3], Michael I. Haverty[3],
and Richard C. Hall[4]
Pacific Southwest Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture
P.O. Box 245
Berkeley, California 94701
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ABSTRACT

A large-scale field experiment was conducted to evaluate the efficacy of 1, 2, and 4% fenitrothion and 0.1, 0.2, and 0.4% permethrin for protecting high-value ponderosa pine trees, *Pinus ponderosa* Dougl. ex Laws, from attack by *Dendroctonus brevicomis* Le Conte. The 270 trees used in the experiment were separated from one another by a distance of at least 0.4 km. At one month and 13 months after insecticide application, *D. brevicomis* aggregation pheromone was attached to the boles of treated and untreated check trees. Only the 0.1% permethrin treatment was regarded as ineffective one month after application. At 13 months after application, only 2 and 4% fenitrothion were still considered to be providing effective protection.

Key Words: *Dendroctonus brevicomis*, permethrin, fenitrothion, tree protection, power statistics

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The western pine beetle, *Dendroctonus brevicomis* Le Conte, is the most serious insect pest of mature ponderosa pine, *Pinus ponderosa* Dougl. ex Laws, in California (Stark and Dahlsten 1970). Severe droughts, such as the one experienced in California during 1976 to 1978, are often accompanied by excessive mortality of ponderosa pine in managed and unmanaged stands. In addition, mortality of high-value trees located in residential and recreation areas or administrative sites can occur as a result of stress associated with drought, overcrowding, soil compaction or injury due to construction, logging activity, fire or vandalism. The value of these individual trees or the cost of their removal is so great that protection of each individual tree may be justified until the trees can recover from the stressed condition. This situation emphasizes the need for assuring that effective insecticides are available for

[1] *Dendroctonus brevicomis* Le Conte (Coleoptera: Scolytidae).
[2] This paper does not recommend the chemicals used, nor does it imply that the use described here has been registered by any agency.
[3] Supervisory Research Entomologist.
[4] Assistant Professor, Department of Entomology, The Ohio State University, Columbus, Ohio 43210.

individual tree protection.

Presently, carbaryl and lindane are the only insecticides considered to be effective and registered for protection of individual ponderosa pine trees from attack of western pine beetle. These registrations are primarily the result of limited testing conducted by Smith (1967, 1970) and Smith *et al.* (1977). In an extensive experiment, Hall *et al.* (1982) demonstrated that a 1% suspension of carbaryl in the Sevimol 4® formulation may be as efficacious as a 2% suspension, the concentration currently registered. Lindane underwent the Rebuttable Presumption Against Registration and has been registered as a restricted use pesticide which may severely limit its use. Furthermore, some pest management specialists are hesitant to recommend use of lindane because of the controversy surrounding its use in forestry (Koerber 1976).

Given the uncertain future availability of any commercial insecticide, it is important to have alternative chemicals. This study was done to evaluate two additional insecticides, fenitrothion and permethrin, for protecting individual ponderosa pines from the western pine beetle. In laboratory and remedial experiments, fenitrothion has been shown to be more toxic to the southern pine beetle, *Dendroctonus frontalis* Zimmerman, than lindane (Hastings and Jones 1976, Hastings *et al.* 1981), and is currently registered for protection of southern pines from *D. frontalis.* Fenitrothion also has been shown to be effective in reducing attacks of ponderosa pine bolts by *D. brevicomis* (Smith 1982). In laboratory and cut-bolt bioassays, permethrin also has been shown to be more toxic to *D. brevicomis* and *D. frontalis* than lindane (Smith 1982, Hastings and Jones 1976, Hastings *et al.* 1981).

METHODS AND MATERIALS

Tree Selection

All sample trees were living ponderosa pine, 28 to 52 cm diameter at breast height (dbh), located on the western slope of the Sierra Nevada between 750 and 1,700 m elevation in the Tahoe and Eldorado National Forests. The spacing of the trees was the same as reported by Hall *et al.* (1982) to assure that a sufficient number of beetles were in the vicinity of each tree to rigorously test the efficacy of the treatments.

A total of 270 trees was used in this experiment. Each insecticide treatment was randomly assigned to 35 trees; 30 trees were randomly assigned to each check. One set of check trees was used for each of two baiting periods. During the course of the experiment (June 1981 to October 1982), several trees were lost because of road building, wood cutting or logging, and were removed from the analysis. Thus, sample sizes were not equal between all treatments and years. All trees appeared healthy and uninfested at the beginning of the experiment.

Insecticide Application

Fenitrothion (Sumithion 8E) and permethrin (Pounce®) were formulated in water and applied to trees at rates of 1, 2, and 4% and 0.1, 0.2, and 0.4%, respectively. Insecticides were applied from the ground to the bark surface with a Muryama® portable hydraulic sprayer mounted in the back of a pickup truck. The insecticides were formulated before application and hydraulic lines were purged after each treatment unless the same concentration of the same insecticide was applied sequentially to two trees. Insecticides were applied to the point of runoff over the entire bole of the trees to a height of ca. 10 m. This treatment required about 8.0 liters of formulated spray material per tree or ca. 0.8 liter/m^2 of bark surface. All treatments were applied between 6:00 a.m. and ca. 11:00 a.m. when winds were minimal.

Pheromone Baiting

To test the effectiveness of the insecticides on *D. brevicomis*, all treated trees and 30 untreated trees were baited with *D. brevicomis* pheromone. Trees were baited in July 1981 and July 1982. Thirty different untreated check trees were used each time the treated trees were baited. Each time trees were baited, pheromone remained on the trees for 4 to 5 weeks. To bait a tree, each component of the pheromone (*exo*-brevicomin, frontalin, and myrcene) was placed in a glass tube that had one end sealed. Three tubes, each containing one of the compounds, were placed upright in foil-covered inverted salt shakers and suspended on the bole of the sample tree ca. 3 m above the ground. Weight losses for these compounds under field conditions averaged ca. 2 mg/day (Browne 1978). *Exo*-brevicomin and frontalin were obtained from Chemical Samples Co., Columbus, OH; myrcene from Aldrich Chemical Co., Milwaukee, WI. All baited trees were checked periodically during the baiting period for evidence of beetle visitation and/or attack. A 10 x 25 cm piece of hardware cloth coated with Stikem Special® was suspended from the bole of each baited tree ca. 0.15 m below the pheromone bait. Presence of entrapped *D. brevicomis* on the sticky trap, new pitch tubes or boring dust in the bark crevices indicated that beetles were visiting the tree.

Determination of Insecticide Efficacy

The only criterion used to determine the efficacy of the insecticide treatment was whether or not the individual tree succumbed to *D. brevicomis* attack after one or two pheromone baiting periods (Hall *et al.* 1982). Residual effectiveness was assessed by observing cumulative tree mortality resulting from the second baiting. Presence of *D. brevicomis* galleries was verified in each tree counted as dead or dying. Mortality was assessed both for each baiting period alone and by combining mortality from both baiting periods for a cumulative total mortality. Treated trees were assumed to have had sufficient attack pressure by *D. brevicomis* if at least 18 of 30 (60%) of the untreated check trees died following pheromone baiting. If less than 18 untreated trees were killed after a certain baiting period, our criterion of sufficient beetle attack was not met, and any inferences concerning efficacy of insecticide treatments must acount for less than maximum beetle attack pressure for that baiting period.

Insecticide treatments were considered efficacious if less than 7 of the treated trees died as a result of *D. brevicomis* attack. The above criteria were established based on a sample size of 30 to 35 trees/treatment and the test of the null hypothesis, H_0: S(survival $\geqslant$ 90%). These parameters provide a conservative binomial test ($\alpha = 0.05$) to reject H_0 when more than six trees die. The power of this test, that is the probability of having made the correct decision in rejecting H_0, is .84 when the true protection rate is 70%. Based on the above error rate consideration, we will fail to reject the null hypothesis

(90% survival) for any treatment where no more than six out of 30 trees die as a result of western pine beetle attack.

RESULTS AND DISCUSSION

A rigorous test of the treatments occurred in the first baiting period since 23 of 31 (74.2%) untreated trees were killed by *D. brevicomis*, thus exceeding the untreated mortality criterion of at least 60% (Table 1). Of the eight untreated trees that did not die, seven withstood substantial attack by *D. brevicomis* without being killed. Overall, only 15 of the 239 trees (ca. 6%) had less than 30 beetles on the arrival traps during this baiting period, suggesting that sufficient populations of *D. brevicomis* were available. Only the 0.1% permethrin treatment failed to meet the criterion of efficacy (six or less trees killed) set forth in the experimental design. All other treatment groups are considered effective in protecting ponderosa pine from lethal attack by *D. brevicomis* when trees were challenged within one month of treatment.

Only eight of the 217 trees (3%) challenged in 1982 had fewer than 30 beetles on the arrival traps, and none of these eight trees were untreated checks. Therefore, we can assume that a sufficient beetle population was present in 1982. During the 1982 baiting period, only 16 of 29 (55%) untreated trees were killed by *D. brevicomis* (Table 1). This reduced mortality in the checks may have resulted from increased tree vigor resulting from above average precipitation during the preceding winter. Even though we failed to achieve the predetermined and arbitrary level of mortality in the untreated check trees during the second baiting period, this does not seriously alter our conclusions. Without considering the 0.1% permethrin treatment, which was judged to be ineffective during the first baiting period, only the 2.0 and 4.0% fenitrothion treatments can be considered effective in protecting ponderosa pine from *D. brevicomis* for two beetle flight seasons. The permethrin treatments and the 1.0% fenitrothion treatments did not provide adequate protection for two summer seasons (Table 1). We wish to caution readers on the interpretation of the confidence intervals presented in Table 1. Because the experimental design was based on testing the null hypothesis of $H_0: S \geqslant 90$ against the $H_1: S = 70\%$, the estimate of survival that is less than 90% (fenitrothion 2%) and that has a confidence interval that extends below 90% yet is judged to be efficacious is subject to higher type II error rate.

The results of this and similar experiments (Hall *et al.* 1982, Haverty *et al.* unpublished), combined with other information on application and handling, safety, environmental considerations, and cost information can be used by the land manager to make informed decisions regarding individual tree protection. Management scenarios that may require protection of individual ponderosa pine from lethal attack from *D. brevicomis* could include such situations as those involving developed recreation sites or where individual trees possess some unique characteristic (specimen tree or seed production). Trees recovering from injury due to construction, logging activity or fire may also require protection for some given amount of time. If the duration of protection needed is short, *e.g.*, one summer season, our data suggest that either 0.2% permethrin or 1.0% fenitrothion would sufficiently protect ponderosa

Table 1. – Mortality of ponderosa pine trees baited with *Dendroctonus brevicomis* pheromone during July of 1981 and 1982.

Treatments	1981				1982				Cumulative			
	Dead	Total	% survival	95% C.I.	Dead	Total	% survival	95% C.I.	Dead	Total[a]	% survival	95% C.I.
0.1% Permethrin	10	35	71.4	±15	12	25	52.0	±19.4	22	35	37.1	±15.9
0.2% Permethrin	1	35	97.1	±5.5	22	33	33.3	±16.1	23	33	30.3	±15.4
0.4% Permethrin	0	34	100	±0	14	33	57.6	±16.9	14	33	57.6	±16.8
1.0% Fenitrothion	4	35	88.6	±10.5	7	31	77.4	±14.7	11	33	66.7	±15.7
2.0% Fenitrothion	2	35	94.3	±7.7	4	33	87.9	±11.0	6	35	82.9	±12.3
4.0% Fenitrothion	0	34	100	±0	1	33	97.0	±5.9	1	34	97.1	±5.7
Check 1981	23	31	25.8	±15.4	–	–	–	–	–	–	–	–
Check 1982	–	–	–	–	16	29	44.8	±18.0	39	60	65.0	–

[a]During the course of the experiment several trees were lost due to unforeseen reasons and were removed from the analysis, hence the uneven sample sizes between treatments from year to year.

pine. However, if maximum time of protection were an important consideration, then only the 2.0 or 4.0% fenitrothion treatments tested in this experiment would be considered effective.

Lastly, we wish to discuss use of the power statistic described in the methods section of this paper and in Hall *et al.* (1982). Power statistics reflect the sensitivity of the analysis (Cohen 1977). In reporting results of experiments utilizing null hypotheses tests there are two types of errors to consider: type I error rate (α) which refers to the probability of mistakenly rejecting a true null nypothesis; and a type II error rate (β), the probability of failing to reject a false null hypothesis given a level of α set by the investigator. Alpha levels are always published when reporting results of these analyses. In contrast, type II error probabilities (or their estimates) are virtually never published. The power of a test, $1-\beta$, is simply the probability of not committing a type II error. In our study the power = .84, thus, we had only a 16% chance of committing a type II error given a 5% chance of committing a type I error. In testing the efficacy of insecticides against insect pests, the commission of a type II can have serious economic consequences, perhaps even greater than a type I error. For example, when testing insecticides against a particular pest, an important objective is to identify the minimum effective dosage required to achieve a given level of relief from pest damage. If we state that there is no statistical difference between the efficacy of two (or more) dosage rates tested (do not reject H_0), we will likely select the lowest rate to reduce cost of treatment and minimize nontarget effects. If, however, the lack of statistical difference is due to sample size, magnitude of differences between dosages, or α, a difference between dosages would go undetected due to lack of power. This could be of great *practical* importance in terms of crop loss. Computing confidence intervals for estimated differences between doses will indicate the precision of these estimates. We strongly recommend, however, that power statistics be reported from tests involving economic poisons so that the audience can have information regarding the sensitivity of the analyses. For a thorough discussion of power analysis see Cohen (1977).

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