Effective Residual Life of Carbaryl for Protecting Ponderosa Pine from Attack by the Western Pine Beetle (Coleoptera: Scolytidae)[1]

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ABSTRACT The effectiveness of carbaryl in protecting high-value ponderosa pine trees from attack by *Dendroctonus brevicomis* LeConte was tested at reduced concentrations or for longer than one beetle flight season. A 2.0% suspension of carbaryl provided substantial protection of ponderosa pine from attack by *D. brevicomis* for the 5 months adults are actively attacking trees. Lesser concentrations, notably 1.0 and 0.5%, provided some protection but with greater tree mortality. Neither 2.0% Sevimol® nor 2.0% Sevin XLR® provided adequate protection for 9 or 12 months, respectively, after application.

THE WESTERN pine beetle, *Dendroctonus brevicomis* LeConte, 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 in California from 1975 to 1977, are often accompanied by excessive mortality of ponderosa pines in managed and unmanaged stands as a result of attacks by several bark beetle species, including *D. brevicomis*. In addition, mortality of high-value trees located in residential and recreational 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 their protection may be justified until they can recover from stress. This situation emphasizes the need for assuring that effective insecticides are available for individual tree protection.

Carbaryl and lindane are the only insecticides now registered and considered to be effective for protection of individual ponderosa pine trees from attack of western pine beetle. These registrations are primarily the result of small-scale tests conducted by Smith (1967 and 1970) and Smith et al. (1977). In an extensive, large-scale field experiment, Hall et al. (1982) demonstrated that 1% suspensions of carbaryl, in the Sevimol® formulation, may be as effective as a 2% suspension—the concentration currently registered for protecting trees. Lindane appears to be effective for up to 22 months as a 2% water emulsion (Smith 1970). We know of no research on the effective residual life of carbaryl at the registered dosage for protecting individual ponderosa pines from attack by western pine beetle.

Protection of high-value pines with insecticide sprays is usually accomplished by applying the insecticide to the bole of the tree in spring. In mountain parks and campgrounds the application usually needs to precede the beginning of the summer vacation season, a time when application may be difficult because of visitors to these high-use areas. Unfortunately, these insecticide applications also have associated with them substantial amounts of drift and fallout (Haverty et al. 1983). Because of this, people frequenting these high-use areas may be exposed to these insecticide residues on the soil surface and on vegetation. If applications of insecticides in fall could provide sufficient residue to protect pines from western pine beetle attack through the following summer, exposure of people to carbaryl residues would be greatly reduced. This is probable because the carbaryl residues tend to be fairly long-lived on bark while not long-lived on leafy vegetation and surface soil. And if insecticide applications could last for two flight seasons (i.e., two summers) human exposure would be much reduced and so would application costs.

In this study we had four objectives: to validate earlier results (Hall et al. 1982) indicating that a 1% suspension of carbaryl (Sevimol) applied in spring will protect ponderosa pines through one flight season; to determine whether a 0.5% suspension of carbaryl (Sevimol) applied in spring could protect ponderosa pines through one flight season; to determine whether a 1 or 2% suspension of carbaryl (Sevimol) applied to the bark of ponderosa pines in the fall could provide adequate protection through the following summer flight season; and to determine whether a 2% suspension of carbaryl in the Sevin XLR formulation applied in spring could protect ponderosa pines through one or two flight seasons, especially since this formulation has never been tested against *D. brevicomis* in the field.

[1] This paper reports the results of research only. Mention of a pesticide or a proprietary product does not constitute a recommendation or an endorsement for its use by USDA, nor does it imply registration under FIFRA as amended.

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Materials and Methods

Tree Selection. All sample trees were living ponderosa pines, 28 to 50 cm diameter at breast height (dbh), growing on the western slope of the Sierra Nevada between 750 and 1,700 m elevation in the Georgetown, Placerville, and Amador Ranger Districts of the Eldorado National Forest in northern California. The spacing of trees was no less than 0.4 km to assure that enough beetles were in the vicinity of each tree to test rigorously the effectiveness of the treatments. The sites selected were the same as those we used to evaluate the effectiveness of permethrin and fenitrothion (Shea et al. 1984).

A total of 205 trees was initially selected for this experiment. All trees appeared healthy and uninfested at the beginning of the experiment. Each of the five insecticide treatments was randomly assigned to 35 trees: 1.0% Sevimol applied in fall, 2.0% Sevimol applied in fall, 0.5% Sevimol applied in spring, 1.0% Sevimol applied in spring, and 2.0% Sevin XLR applied in spring. Thirty trees were randomly assigned to the check. During the experiment (June 1981 to October 1983), several trees were lost because of road building, wood cutting, logging, or top-killing by *Ips*, and were deleted from the experiment.

For the second-year evaluation of Sevin XLR, we decided to eliminate test trees in the Georgetown Ranger District from our study because of excessive mortality of adjacent trees associated with pheromones used in this experiment, and the inaccessibility of these trees because of washed-out roads. The check trees used for the second-year evaluation of 2% Sevin XLR consisted of check trees that survived baiting the previous summer; newly selected, uninfested trees 10 to 50 m from previously baited and dead check trees; and trees 10 to 50 m from those treated with 2% Sevimol in fall 1981. Thus, the sample sizes of the treatment and the check are different from the original 35 and 30, respectively.

Insecticide Application. Carbaryl (Sevimol and Sevin XLR) was formulated in water (pH $\leq$ 5) and applied to trees at doses of 1 and 2% (Sevimol) in September 1981, and 0.5 and 1.0% (Sevimol) and 2.0% (Sevin XLR) in June 1982. Insecticides were applied from the ground to the bark surface with a Maruyama 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 until spray ran off over the entire bole of the tree to a height of ca. 10 m. This treatment required about 8.0 liters of formulated spray per tree or ca. 0.8 liter/m^2 of bark surface. All treatments were applied between 0600 and 1100 hours when winds were minimal.

Pheromone Baiting. To test the effectiveness of the insecticides against *D. brevicomis*, all test trees were baited with *D. brevicomis* aggregation pheromone (*exo*-brevicomin, frontalin, and myrcene) in September 1982, and the surviving 2.0% Sevin XLR-treated trees and 27 check trees were baited in July 1983. Each time trees were baited, this pheromone was dispensed as described in Hall et al. (1982) and Shea et al. (1984), and remained on the trees for 5 weeks, sufficient time to assure that significant flight activity occurred (Stark and Dahlsten 1970). All baited trees were checked periodically during the baiting period for evidence of beetle visitation or attack. A 10-by-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 Effectiveness. The only criterion used to determine the effectiveness of the insecticide treatment was whether or not the individual trees succumbed to *D. brevicomis* attack (Hall et al. 1982). Tree mortality was assessed on 20 and 21 June 1983, for trees baited in September 1982, and on 6 October 1983 for trees baited in July 1983. The period between pheromone removal and mortality assessment was sufficient for trees to "fade," an irreversible symptom of pending mortality. Presence of *D. brevicomis* galleries was verified in each tree counted as dead or dying. Treated trees were assumed to have had sufficient attack pressure by *D. brevicomis* if at least 60% of the untreated check trees died after 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 effectiveness of insecticide treatments had to account for less than maximum beetle attack pressure for that baiting period. We considered insecticide treatments to be ineffective if less than 90% of the trees survived (Shea et al. 1984). Treatments were compared to their respective checks with a 2-by-2 contingency table (dead or alive versus treatment or check) (χ^2 test of independence, $\alpha = 0.05$).

Results and Discussion

A rigorous test of the treatments occurred in both baiting periods because 62.1% of the untreated trees were killed by *D. brevicomis* in 1982 and 74.1% in 1983 (Table 1). Of the 18 untreated trees that did not die, all withstood substantial attack by *D. brevicomis* and managed to pitch out all attacking beetles.

All treatments, except 2.0% Sevimol (fall), incurred significantly less mortality than their respective checks. Only one treatment—2.0% Sevin XLR—met the criterion of effectiveness (less than 10% mortality) set forth in our experimental design. All of the other treatments were considered ineffective.

Table 1. Number of carbaryl-treated, pheromone-baited ponderosa pine trees killed by western pine beetles

	1982			1983		
	No. trees		Mortality[a]	No. trees		Mortality[a]
	Dead	Total %		Dead	Total %	
1.0% Sevimol (fall)	11	34	32.4 (16.0)[b]	—	—	—
2.0% Sevimol (fall)	14	33	42.4 (17.2)	—	—	—
0.5% Sevimol (spring)	13	35	37.1 (16.3)[b]	—	—	—
1.0% Sevimol (spring)	8	34	23.5 (14.6)[b]	—	—	—
2.0% Sevin XLR (spring)	1	33	3.0 (12.4)[b]	8	24	33.3 (19.2)[b]
Untreated check	18	29	62.1 (18.0)	20	27	74.1 (16.9)

[a] Values in parentheses are the 95% confidence interval.
[b] Difference between the percentage of mortality of the treatment and its appropriate check are statistically significant at $\alpha = 0.05$.

All of the objectives of this study were met. The 1.0% Sevimol (spring) treatment, in this study, was judged not effective even though the level of mortality we observed was significantly less than the untreated check. The 0.5% Sevimol also did not meet our criterion, but this treatment also resulted in significantly less mortality than did the untreated check. From these results, and those reported earlier (Hall et al. 1982), we suggest that the registered dose of carbaryl—a 2.0% suspension in water, in either the Sevimol or Sevin XLR formulation—will provide substantial protection of ponderosa pines from attack by western pine beetles for one flight season. Lesser concentrations, notably 1.0 and 0.5%, do provide some protection, but at the risk of tree mortality.

The effective residual life of applications of the registered concentration of carbaryl appears to be only one flight season. Neither the 2.0% Sevimol nor the 2.0% Sevin XLR provided adequate protection 9 or 12 months, respectively, after application. If the financial or an esthetic consequence of losing a ponderosa pine to attack by western pine beetle is great, an annual application is advisable. However, some users may be willing to accept the higher risk and use a lower concentration or not make annual applications.

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