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Residual Activity of Carbaryl Protected Lodgepole Pine Against Mountain Pine Beetle, Dillon, Colorado, 1982 and 1983.

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The mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is the most destructive insect that attacks lodgepole pine (*Pinus contorta* Dougl.), a species valued for multiple uses throughtout North America. The effective residual life of carbaryl, applied as a 2 percent suspension of Sevimol to the bark of lodgepole pine to prevent attack by mountain pine beetle, was evaluated near Dillon, Colorado. Trees (9,568) treated in 1982 under operational conditions were used to assess the efficacy of the treatment for one and two beetle flight periods after insecticide application. Estimated mortality of untreated trees was 0.91 percent compared with 0.074 percent for trees treated 16 months earlier with carbaryl. Residues of carbaryl were estimated at 359 ppm 16 months after application. When exposed to intense beetle pressure, bolts from trees treated 13 months earlier suffered fewer attacks and had shorter mean egg gallery length than did bolts from untreated trees; bolts from trees sprayed 3 months earlier suffered no attacks. Apparently a 2 percent suspension of carbaryl applied to the bole of lodgepole pine was effective in protecting lodgepole pine from mountain pine beetle for the flight period 3 months after application and even provided protection for a second flight period 16 months after treatment. The results suggest that protection cost and insecticide use could be reduced by 50 percent during a 4-year outbreak.

Retrieval Terms: mountain pine beetle, *Dendroctonus ponderosae,* carbaryl, Sevimol, insecticide, lodgepole pine, *Pinus contorta* var. *latifolia* Engelm., residue analysis

Lodgepole pine (*Pinus contorta* Dougl.) is one of the most widespread of North American pines. Although it has low value as a timber species, it is highly valued for multiple uses—watershed protection, wildlife habitat, and recreation and esthetic purposes.[1] It is a major species in National Parks, wilderness areas, and other areas of scenic and recreational value in the central and northern Rocky Mountains.[2] Owners of private and commercial properties and resource managers in Colorado have assigned high priority to maintaining lodgepole pine forests.

Lodgepole pine is susceptible to attack by a number of insects.[3] Bark beetles are the most serious, and the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is by far the most destructive.[4] Mountain pine beetle epidemics in lodgepole pine stands seriously affect sustained yield and regulation of managed stands.[5] However, mountain pine beetle is considered a natural thinning and "harvesting" agent of lodgepole pine;[6] epidemics, in effect, set harvest priorities and schedules. Where maintaining nontimber values is the primary objective, long-term management to reduce losses to beetles is necessary.[4] Trees in campgrounds, recreational areas, and homesites are of such high esthetic or economic value that their losses often cannot be tolerated.

Carbaryl (Sevimol) applied as a 2 percent spray to the bole of the tree is registered by the U.S. Environmental Protection Agency and will protect lodgepole and ponderosa pine from attack by mountain pine beetle for at least 1 year.[7] The maximum length of protection provided by a 2 percent suspension of carbaryl against this insect is not known. Two primary factors affecting efficacy of bark sprays are the toxicity of the insecticide residue and its effective life on the bark of trees. Residual toxicity, i.e., insecticide effectiveness over time, traditionally has been evaluated by cut-bolt bioassays[8] or in field experiments with living trees.[9,10] Residual life is best measured by a quantitative chemical analysis of the insecticide residues remaining on the bark over time.[11]

This note reports a study to determine whether a single application of carbaryl protects individual lodgepole pines from mountain pine beetle attack for more than 1 year.

We used about 10,000 trees that were operationally sprayed with a 2 percent suspension of carbaryl (Sevimol) in May 1982, and treated 212 additional trees in July 1983. We compared the proportions of trees treated in 1982 and untreated trees that were killed by mountain pine beetle during flight periods in 1982 and 1983. At 3 months and 16 months after treatment, we quantified carbaryl residues remaining on bark and determined their effectiveness under intense beetle pressure created by a synthetic pheromone.

Mortality of carbaryl-treated lodgepole pines due to attacks by mountain pine beetle was minimal. Only three treated trees were killed during the first flight season (3 months) after treatment. During the second beetle flight season (13 months) after treatment, the probability of treated trees being successfully attacked by mountain pine beetle still appeared to be significantly less than that for untreated trees. The results suggest that protection cost and insecticide use could be reduced by 50 percent during a 4-year outbreak.

METHODS

Study Area

On the Dillon Ranger District, Arapaho National Forest, Colorado, thousands of acres of National Forest land are managed for recreation where lodgepole pines are being severely attacked by mountain pine beetle. Consequently, the Dillon Ranger District, the Colorado State Forest Service, and private landowners have created the Summit County Integrated Forest Management Project. To minimize the adverse consequences of a widescale mountain pine beetle outbreak, susceptible, high-value lodgepole pine are being protected by application of insecticides, removal of infested trees, and direct chemical control while stands are brought into a less susceptible growing condition. In spring 1982, about 10,000 high-value lodgepole pines in recreation sites near the Dillon Reservoir were treated with a 2 percent suspension of carbaryl. Trees within campgrounds and administrative sites with high risk characteristics were identified for treatment. These trees were distributed throughout 13 locations near the reservoir.

Research Approach

We divided this study of carbaryl into three components: (1) efficacy assessment, (2) residue analysis, and (3) log bioassay. The efficacy assessment compared the proportions of trees treated in 1982 and untreated trees that were killed by mountain pine beetle during 1982 and 1983; the residue analysis quantified carbaryl residues at two times—3 months and 16 months—after treatment; and the log bioassay determined the effectiveness of carbaryl residues under intense beetle pressure created by a synthetic pheromone, 3 months and 16 months after treatment.

Table 1—*Status of untreated trees or trees treated in May 1982 with a 2 percent suspension of carbaryl on the Dillon Ranger District, Arapaho National Forest, Colorado*

	June 1-6, 1983			September 12-15, 1983[3]			
	Treated May 1982			Treated May 1982		Untreated[4]	
Site	Alive	Dead[1]	Other[2]	Alive	Dead	Alive	Dead
Administrative	724	2	50	374	0	—	([5])
Blue River	266	0	9	256	0	57	2
Dicky	236	0	4	—	([6])	51	1
Frisco Tank	158	0	14	—	([6])	—	([5])
Giberson Bay	200	0	8	203	1	45	0
Gold Pan	200	0	1	—	([6])	45	0
Heaten Bay	2,093	0	79	1241	1	446	7
Peak One	2,088	1	71	512	0	449	3
Pennisula Dump	152	0	0	—	([6])	34	0
Pine Cove	140	0	8	141	0	31	0
Prospector	2,554	0	148	1130	1	531	3
Swan Mountain	215	0	15	204	0	33	0
Windy Point	124	0	8	—	—	28	
Totals	9,150	3	415	4061	3	1750	16

[1]Killed by mountain pine beetle during the flight season of July and August 1982.

[2]Trees were in one of these categories: treated although they were already successfully attacked in 1981, not accounted for, identification tag was missing, blown down, misidentified and of the wrong species, dead or dying from causes other than mountain pine beetle attack, or labeled with more than one identification tag.

[3]Only trees that were alive in June 1983 were observed; therefore, any mortality or mass attack observed during this period was due to attack by parent adults during July and August 1983.

[4]Untreated trees were selected from "equivalent" trees adjacent to sites where trees were treated with carbaryl. Untreated trees cannot be considered true checks because they were not selected before treatment and were not randomly assigned from the population of interest.

[5]Nearly all of the trees at the site were treated so it was not possible to select check trees.

[6]Trees at these sites were not randomly selected for evaluation in September 1983.

To save time, we used nearly all of the trees operationally sprayed in spring 1982; untreated trees in the immediate vicinity of the treated trees were used as untreated checks. We treated an additional group of trees in summer 1983 to assess residual life of carbaryl and for use in the log bioassay.

Trees treated in 1982 and untreated check trees could not be randomly assigned to those treatments. Trees were treated for other than experimental reasons, and no untreated check trees were set aside before insecticide application. These restrictions, however, did not appear to compromise our interpretation of the results because the trees we later chose as checks were interspersed with the treated trees.

Efficacy Assessment

We selected a sample of untreated trees among trees sprayed in 1982 to serve as untreated check trees in the efficacy assessment in 1983. We visited 9,568 trees (i.e., nearly all of the treated trees except those on an unreachable island) in June 1983, before the mountain pine beetle flight period (July and August), to determine the level of mortality due to beetle attacks in 1982. From this information *(table 1)* and from empirical estimates of mortality of untreated trees by Ranger District personnel, we determined the number of trees we would need to visit after the 1983 beetle flight season. We wanted to estimate the proportion of trees killed ±100 percent of that proportion for carbaryl-treated trees and ±50 percent for check trees, with a probability of 0.95 that the intervals contained the true means. Therefore, we needed to visit a sample of about 4,000 trees in September 1983. Of the 13 sites *(table 1)*, 12 were used. One site, Frisco Tank, was later eliminated because of the limited number of live untreated trees in the vicinity of the treated trees. The administrative site was included but no check trees could be selected because all of the trees had been treated.

A total of 1,766 untreated trees adjacent to the treated trees in the remaining 11 sites were used as check trees. They were considered to be equivalent to the treated trees because they had about the same diameter and were adjacent to camp or picnic sites with treated trees. The number of check trees selected at each site was directly proportional to the number of treated trees at that site.

The 9,150 treated trees that survived attack in 1982 were divided into 48 groups of about 200 trees to make sampling logistically feasible. From these groups, 22 groups were randomly selected until we had a sample of 4,064 live trees that were treated in 1982. These trees and all of the newly selected check trees were revisited in September 1983, and the number dead, alive, or missing was determined. The proportions killed by mountain pine beetle during the 1983 flight season for check and treated trees were determined, and a 95 percent confidence interval about the differences in these proportions was calculated assuming independent binomial samples.[12] A confidence interval for the mortality ratio was also computed.

Residue Analysis

To establish initial carbaryl residues for measurement of insecticide persistence on bark, 212 untreated trees were randomly selected at four sites and sprayed on June 27 and 28, 1983, with a 2 percent carbaryl (Sevimol) suspension. From trees sprayed in 1982 and 1983, 100 each were randomly selected to determine carbaryl levels remaining in bark. Confidence intervals (95 percent) for the change in residue in treated trees after 1 year were calculated.

Trees were sampled for residues by removal of bark disks consisting of outer bark and cambium from two locations on opposite sides (north and south) of each tree at about 2 meters high. Disks were collected with a 3.8-cm-diameter hole punch.[10] Each pair of disks was placed in a labeled plastic bag and stored at –20°C until carbaryl residues were extracted and quantified by gas chromatography.[13]

Log Bioassay

In July 1983, 36 trees, 12 each from trees sprayed with carbaryl in 1982, trees sprayed in 1983, and untreated trees, were randomly selected and cut into 1.8-m bolts. The ends of each bolt were coated with melted paraffin to retard moisture loss. These bolts were transferred to sites with heavy mountain pine beetle activity and arranged into four 3-by-3 plots in a Latin square design. One end of each bolt was buried 0.6 m into the ground; bolts were spaced 1 m apart. The center bolt in each plot was baited with a mountain pine beetle aggregation pheromone to assure that an ample beetle population would challenge the treatments.

Treatment efficacy was evaluated in September 1983 after peak beetle flight by removing the bark from the bolts and comparing the number of beetle attacks and total egg gallery length (cm/m^2) of each treatment against those of the untreated bolts.[8] Reductions in both number of attacks and gallery length between treatments, and between treatments and the control were evaluated with 95 percent confidence intervals.

RESULTS

Efficacy of Treatment

Mortality of carbaryl-treated lodgepole pines due to attacks by mountain pine beetle was minimal during the first flight season after treatment. Of the 9,568 sample trees, 329 could not be accounted for because the identifying tag was missing or broken, 49 were blown over by high winds, 22 were tagged and sprayed although they had been infested by mountain pine beetle during summer 1981, and 15 either had two identification tags or were spruce trees killed by pathogens. Only 3 trees had been killed by mountain pine beetle during summer 1982. The remaining 9,150 trees appeared healthy. Thus, our estimate of the proportion, p, of these remaining trees killed by mountain pine beetle was $3.3 \times 10^{-4} \pm 3.8 \times 10^{-4}$ (95 percent confidence interval for p). Although we have no mortality data for equivalent untreated trees after the 1982 beetle flight, the proportion of untreated trees harvested because of mountain pine beetle infestations in the immediate vicinity of the treatment area was probably in the range of 2 to 5 percent.

Of the 4,064 trees that were treated and survived attack in 1982, only 3 ($p = 7.4 \times 10^{-4} \pm 8.5 \times 10^{-4}$) were successfully attacked in 1983. A greater proportion—16 of 1,766 ($p = 9.1 \times 10^{-3} \pm 4.5 \times 10^{-3}$)—of the check trees were successfully attacked. Thus, the probability of a tree treated 16 months earlier with a 2 percent suspension of carbaryl being successfully attacked by mountain beetle appeared to be significantly less than that of an untreated tree. The 95 percent confidence interval for the differences in mortality in 1983 between checks and trees treated in 1982 was 0.008 ± 0.004.

Residues in Bark

In 1983, the 95 percent confidence interval for mean carbaryl residues remaining on the trees sprayed in 1982 was 359 ± 71.5 ppm. The 95 percent confidence interval for initial mean residue of carbaryl for the trees sprayed in 1983 was 890 ± 164 ppm. A 95 percent confidence interval for the mean difference in carbaryl residue after 16 months was 531 ± 178 ppm.

Residual Effectiveness

One of the four plots was inadvertently destroyed before evaluation. In the three remaining plots, mean numbers of beetle attacks and total egg gallery length were as follows:

Treatment:	Attacks (S.D.)[1] *Number/m²*	Egg gallery (S.D.)[1] *cm/m²*
Carbaryl 1982	6.3 (10.6)	123.2 (241)
Carbaryl 1983	0 (0)	0 (0)
Untreated	29.5 (23)	706.9 (499)

[1]Standard deviations (S.D.) were based on nine bolts per treatment.

DISCUSSION AND CONCLUSIONS

Results of both the efficacy assessment and log bioassay indicate that the application of a 2 percent suspension of carbaryl to lodgepole pine provided protection against mountain pine beetle for two summers in the study area. The proportion of the check trees killed by mountain pine beetle was 12.3 times that of trees treated 16 months earlier. The lower confidence bound for the ratio of these proportions is 2.9. Thus, given similar conditions in the Dillon area, a person could be confident that sprayed trees would have at least 2.9 times the protection of untreated trees. Carbaryl residues remained on the bark of lodgepole pines for 16 months after application and were apparently sufficient to protect trees. The results of the log bioassay indicated that attack density and egg gallery length were reduced when the carbaryl residues remained on the bark for over 1 year.

The size of the beetle population and the condition of the trees will undoubtedly affect the efficacy of the treatment. Therefore, land managers and homeowners must consider the value they place on their trees and the risk of attack by mountain pine beetle, and the efficacy information presented here before deciding whether to apply a protective treatment yearly, every other year, or not at all.

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NOTES

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[7]This note neither recommends the pesticide uses reported nor implies that they have been registered by the appropriate governmental agencies. Trade names are mentioned only for information; no endorsement by the U.S. Department of Agriculture is implied.

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