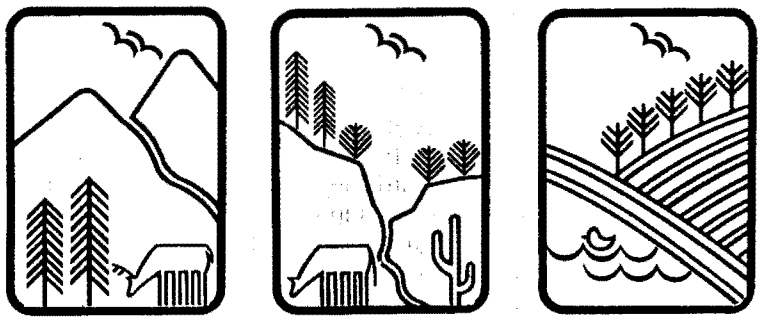

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Does Verbenone Reduce Mountain Pine Beetle Attacks in Susceptible Stands of Ponderosa Pine?

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Verbenone capsules were stapled to trees in mountain pine beetle infested stands of ponderosa pine at densities of 10, 20, 40, and 68 capsules per acre. None of the treatments were effective in reducing the number of attacked trees. The effectiveness of the treatments may have been compromised when above-average temperatures followed early placement of the capsules, which may have degraded the verbenone before peak beetle emergence.

Keywords: Mountain pine beetle, *Dendroctonus ponderosae*, ponderosa pine pheromones

Forest pest managers are continually searching for new ways to prevent or reduce tree mortality caused by the mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins. Sprays are currently available to prevent attacks on high value trees. Carbaryl[4] sprayed on the bole from ground level to the lower crown just before beetle emergence will prevent attacks for up to 2 years (McCambridge 1981). However, because preventive sprays also affect nontarget insects, their use is less desirable in forest ecosystems. Recent developments in the commercial production of MPB pheromones have led pest managers to consider antiaggregating pheromones as a substitute for preventive sprays for high-value trees.

The MPB communication system utilizes both aggregating and antiaggregating pheromones (Pitman et al. 1969). Verbenone, an antiaggregating semiochemical of the MPB that apparently influences population density, has shown promise in repelling MPB attacks. In British Columbia, field tests of commercially produced verbenone in the presence of a MPB bait inhibited both the attraction of male and female MPB to funnel traps as well as the responses of numerous associated species of bark beetles (Borden et al. 1987). In field tests in Idaho, verbenone treatments with and without MPB tree baits reduced the average percentage of infested trees (Amman et al. 1989).

Sensing the practical value of verbenone in reducing tree mortality, forest managers are interested in knowing the amount of verbenone needed to prevent infestation of susceptible trees. This study was conducted to evaluate the effectiveness of different densities of verbenone capsules in reducing the number of MPB-infested trees in two different outbreaks.

Methods

The verbenone capsules were field tested in stands of ponderosa pine, *Pinus ponderosa* Lawson: one on the Black Hills National Forest in South Dakota, the other on the Uncompahgre National Forest in Colorado. The Black Hills study area was located about 9 miles northwest of Custer, in the White House Gulch area. The Uncompahgre area was located about 14 miles east of Nucla, on Pine Ridge in the Cottonwood Creek drainage.

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[4]*This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and/or federal agencies before they can be recommended.*

MPB infestations in both areas were in outbreak status, but the intensity of the infestations, as evidenced by the number of infested trees per acre, was higher in the Uncompahgre area. In the outbreak cycle, the Uncompahgre area was considered at its peak with stand depletion exceeding 35 trees per acre. In contrast, the Black Hills area was in the early stages of an outbreak, with tree mortality averaging about nine trees per acre.

In each area, four replications with five plots per replication, or twenty, 2.5 acre plots, were selected in June 1988. The five plots per replicate accommodated the five treatments: control—no verbenone capsules—and 10, 20, 40, and 68 verbenone capsules per acre. Plots within each replicate were selected to minimize differences in stand conditions and topographic features so that variability due to these conditions would not influence the results. Each plot contained at least 10 infested trees.

Each plot was completely inventoried before the verbenone capsules were set out. All trees greater than 5 inches diameter at breast height (d.b.h.) were recorded in 1-inch diameter categories and classified as: green, uninfested; 1987 mass attacked; 1987 pitchout; 1987 strip attacked; or nonhost species. Trees killed by the MPB before 1987 were classified as old MPB mortality, but not used in the analyses.

Verbenone capsules were set out on the Black Hills plots June 15–19, 1988, and on the Uncompahgre plots June 28–29, 1988. While we would have preferred to set out the capsules just before beetle emergence, other commitments forced placement well before the anticipated emergence period of late July through early August. Capsules were set out on a grid pattern with approximate equidistant spacing between adjacent capsules. Spacing varied from 25.4 to 66 feet between adjacent capsules depending on the treatment. Capsules were stapled 5 to 6 feet aboveground on the north side of the tree or shrub closest to the grid point.

To determine the longevity of the verbenone capsules, five capsules were stapled to each of three trees in the northern Black Hills on June 20, 1988. One capsule from each tree was removed at irregular time intervals during the summer. The three capsules were then mailed to Corvallis, Ore., where personnel in the Behavior and Microbial Agents for Managing Western Forest Insects project of the Pacific Northwest Forest and Range Experiment Station made quantitative and qualitative analyses.

Plots in both areas were resurveyed for 1988 MPB-attacked trees during late September and early October 1988. All green trees in the plots were classified in 1-inch d.b.h. classes as: uninfested, mass attacked, pitchout, or strip attacked.

To determine if beetles move to the area immediately outside of each treatment area (the 2.5-acre plot), a 2-chain-wide strip around each plot was surveyed for 1988-attacked trees after the plot survey was completed.

The null hypothesis of no treatment effect was tested using randomized block analysis of variance in each area ($\alpha = 0.05$). For the most accurate measure of beetle pressure, the sum of all 1988 mass-attacked, strip-attacked, and pitchout trees for each treatment was used. Because past mortality had variously depleted the number of live trees available for attack among the replications in the Uncompahgre data, the number of live trees in 1988 was used as a covariate in analyses for both areas. The first analysis of the Uncompahgre data indicated the number of trees attacked in 1988 was correlated to the number of live trees, so treatment effect was further analyzed using the number of attacked trees and live trees in 1987 as repeated measures in the analysis of variance. For further analysis of the influence of stand conditions, d.b.h. was tested as an additional source of variation. To avoid zero values in some 1-inch diameter classes, diameters were grouped into three classes: 5-9 inches, 10-13 inches, and 14 inches and above.

Results

Numbers of attacked trees were not significantly different among treatments in either the Uncompahgre or Black Hills areas (table 1). Numbers did vary significantly among replications in the Uncompahgre area, however, but not in the Black Hills area. Numbers of attacked trees generally increased from 1987 to 1988 in the Uncompahgre area (table 2) but generally decreased in the Black Hills area (table 3).

In the Uncompahgre area, numbers of trees attacked in 1988 were positively correlated with the number of live trees available for attack. When the effect of live trees was removed from the analysis, treatment effects were still not significantly different. Although the number of attacked trees per diameter class changed significantly between 1987 and 1988, neither diameter class nor the interaction of diameter class and time significantly influenced treatment effect.

In the Black Hills area, the number of live trees in 1988 in each treatment did not influence subsequent attacks. The number of attacks varied significantly among d.b.h. classes, but d.b.h. did not cause a significant effect among the treatments.

In both areas, trees with verbenone capsules were attacked. In the Black Hills, about one tree per plot was attacked in the 20, 40, and 68 capsules per acre treatments.

Table 1.—Number and percentage of the combined mass-attacked, strip-attacked, and pitchout trees by treatment.

Area	Treatment[1]	Trees attacked in 1988	
		Number	Percentage
		X±S.D.	
Black Hills	0	35 ± 46	5 ± 7
	10	10 ± 9	2 ± 1
	20	14 ± 10	2 ± 1
	40	8 ± 15	2 ± 3
	68	4 ± 4	1 ± 1
Uncompahgre	0	233 ± 121	78 ± 27
	10	182 ± 133	59 ± 15
	20	238 ± 223	60 ± 41
	40	174 ± 148	55 ± 37
	68	324 ± 285	64 ± 37

[1]*Number of verbenone capsules per acre.*

Table 2.—Numbers of green, mass-attacked, pitchout, and strip-attacked trees by treatment, Uncompahgre study area, 1988.

Reps	Treatment[1]	Green trees[2]		Type of MPB attack: Mass		Pitchout		Strip	
		1987	1988	1987	1988	1987	1988	1987	1988
Rep 1									
	0	341	312	29	105	4	23	0	0
	10	248	231	16	98	0	4	1	1
	20	330	311	19	0	0	1	0	0
	40	775	737	38	10	14	14	0	0
	68	622	577	45	35	10	18	0	0
Rep 2									
	0	681	514	167	373	38	34	0	1
	10	762	480	282	330	97	42	0	3
	20	568	404	164	327	50	38	0	3
	40	692	456	236	197	74	46	0	1
	68	627	571	56	460	21	42	0	9
Rep 3									
	0	248	214	34	180	8	11	0	4
	10	528	321	202	113	48	39	5	12
	20	869	679	109	431	57	37	0	12
	40	476	406	69	324	18	16	1	7
	68	819	760	59	543	32	62	0	18
Rep 4									
	0	218	197	21	195	10	4	0	2
	10	165	137	28	80	9	6	0	0
	20	165	133	32	101	4	4	0	0
	40	191	108	83	80	14	3	0	0
	68	182	147	33	95	5	11	2	3

[1]*Number of verbenone capsules per acre.*
[2]*Green trees available for attack prior to beetle flight of the respective year.*

Table 3.—Numbers of green, mass-attacked, pitchout, and strip-attacked trees by treatment, Black Hills study area, 1988.

Reps	Treatment[1]	Green trees[2]		Type of MPB attack: Mass		Pitchout		Strip	
		1987	1988	1987	1988	1987	1988	1987	1988
Rep 1									
	0	554	546	8	14	5	1	0	0
	10	853	835	18	18	15	5	0	0
	20	800	783	16	8	12	4	1	0
	40	710	688	21	1	12	1	1	0
	68	488	482	5	0	2	0	1	0
Rep 2									
	0	521	509	7	0	7	0	5	0
	10	372	346	20	2	7	3	6	0
	20	410	386	19	2	5	1	5	0
	40	726	705	21	0	18	0	0	0
	68	473	461	10	0	8	1	2	0
Rep 3									
	0	618	589	29	20	6	3	0	0
	10	417	399	18	10	10	0	0	0
	20	541	517	23	14	10	3	1	0
	40	563	538	18	27	12	3	7	1
	68	501	549	38	6	20	3	4	1
Rep 4									
	0	711	682	28	90	7	12	1	0
	10	815	782	33	0	5	2	0	0
	20	1,113	1,045	68	19	16	7	0	0
	40	1,010	987	23	0	13	0	0	0
	68	787	726	60	4	14	0	1	0

[1]*Number of verbenone capsules per acres.*
[2]*Green trees available for attack prior to beetle flight of the respective year.*

In the Uncompahgre treatments, 15% to 25% of the trees in all treatments were attacked.

The number of mass-attacked trees in the 2-chain-wide strip surrounding each plot was not significantly different from the numbers inside the plot. In general, the numbers in the perimeter strip reflected the numbers in the plot.

When set out, verbenone capsules were essentially 100% verbenone. One month later, the quantity of liquid was essentially unchanged, but it was 92% verbenone. Six weeks after placement, and during peak emergence, 40% of the liquid had evaporated and the remaining liquid was 94% verbenone. In August, after MPB emergence was essentially complete, 48% of the verbenone remained. Approximately 15% of the capsules were essentially dry by mid-September because of leakage.

Discussion

The verbenone treatments did not produce any significant differences in the number of attacked trees in either area. There were apparent treatment effects in one replication in each area (tables 2 and 3), but the effects were not consistent throughout all replications. Variation in the distribution of diameter classes suggested that stand structure influenced beetle behavior and, thus, the number of infested trees. However, treatment effects were not influenced by the numbers of trees in each diameter class.

A more plausible explanation is that the number of green and 1987-infested trees differed within the replications, particularly in the Uncompahgre area, as a result of natural differences in the stands and in previous MPB-caused mortality. At the same time, beetle population levels—both the number of infested trees and brood production within the trees—differed within the replications. The combination of these differences produced considerable variation in the number of trees infested in 1988 in the various treatments. The natural tendency is to conclude that this variation masks the treatment effects in most of the replicates, and the effect is truly evident in the one replication showing treatment effect. This conclusion is erroneous because trees with verbenone capsules were attacked and the verbenone capsules changed both quantitatively and qualitatively. If the verbenone capsules were effective, trees with capsules would not have been attacked. Also, the decrease in quantity and quality of the verbenone throughout the 90-day test exposure suggests that it was changing chemically and perhaps evaporating faster than the manufacturer's estimated rate.

In retrospect, the above-average temperatures throughout the West during June and July may have reduced the effectiveness of the verbenone capsules. For whatever reason, the capsules did not effectively repel the MPB, and the occurrence of one set of treatments indicating treatment effect seems more chance than true effectiveness.

Conclusions

The verbenone capsules did not measurably inhibit MPB populations from attacking green trees in either a high-level or a low- to moderate-level MPB infestation. The effectiveness of the verbenone may have been compromised by unseasonably high temperatures between placement and beetle flight. Thus, inadequate amounts of verbenone may have been disseminated during beetle flight.

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