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- 3) a) Debris greater than 50 cm in diameter—4.
b) Debris less than 50 cm in diameter—5.
- 4) a) Debris longer than 5.0 m—LEAVE.
b) Debris shorter than 5.0 m—5.
- 5) a) Debris braced on downstream side by boulders, bedrock outcrops, or stable pieces of debris—LEAVE.
b) Debris not braced on downstream side—REMOVE. ■

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MCH Pheromone for Preventing Douglas-Fir Beetle Infestation in Windthrown Trees

Mark D. McGregor, Malcolm M. Furniss, Robert D. Oaks,
Kenneth E. Gibson, and Hubert E. Meyer

ABSTRACT—A granular controlled-release formulation (98 percent inert, 2 percent 3-methyl-2-cyclohexen-1-one) was applied May 11-13, 1982, at 4.48 kg/ha to 76.9 ha of uninfested windthrown Douglas-fir by helicopter with a modified aerial spreader of 1.13 m³ capacity. Granules measured on treated plots averaged 2.04-2.69 kg/ha, sufficient to reduce Douglas-fir beetle (*Dendroctonus pseudotsugae*) infestation 96.4 percent by late June. The same MCH treatment reduced spruce beetle (*Dendroctonus rufipennis*) attacks by 55 percent in fewer, intermingled windthrown Engelmann spruce.

The Douglas-fir beetle (DFB) is an important bark beetle, infesting Douglas-fir throughout most of that tree's extensive range in western North America. Trees felled by wind or top-broken by snow are prime hosts for buildups of the insect (Furniss et al. 1981b). The extent to which enlarged populations kill standing trees depends upon availability of dense, mature Douglas-fir stands. Stand susceptibility is increased by drought and defoliation by the Douglas-fir tussock moth (*Orgyia pseudotsuga*) and sometimes the western spruce budworm (*Choristoneura occidentalis*). In mature trees, infestation by low populations of DFB is correlated with root diseases; the correlation is less strong during DFB outbreaks.

Thinning of susceptible stands and salvage of fresh windthrow will prevent tree-killing by beetles. But where windthrown trees are inaccessible, or where aesthetic or other values preclude thinning or logging, other means may be needed. One such alternative is to use the beetles' natural antiaggregative pheromone, 3-methyl-2-cyclohexen-1-one (MCH). In nature, MCH terminates attraction after enough beetles have aggregated to overcome a tree; it thus serves to forestall overcolonization and consequent lethal competition among broods.

Since 1972, we have been working to develop synthetic

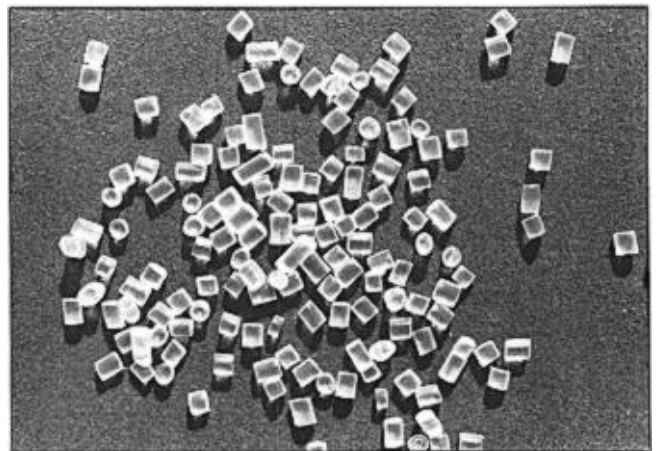


Figure 1. The antiaggregative pheromone, MCH, was time-released from inert rod-shaped granules to prevent beetles from breeding in windthrown trees.

MCH as a means of preventing outbreaks by denying beetles windthrown trees. Beetles must then cope with a more hostile environment, including increased predation and the resistance of live trees.

A granular controlled-release formulation (fig. 1) containing 2-percent MCH and 98-percent inert dimer acid polyamide beads (U.S. Patent 4,170,631) has been effective in tests on trees felled to simulate windthrow (Furniss et al. 1977). When applied by helicopter with a modified aerial spreader at ground-measured rates of 1.41-9.80 kg/ha, it reduced DFB attack density 92-97 percent (Furniss et al. 1981a).

In November 1981, strong winds blew down thousands of trees in Idaho forests, setting the stage for outbreaks of DFB as well as the spruce beetle (*Dendroctonus rufipennis*) which breeds prolifically in windfelled Engelmann spruce (*Picea engelmannii*) (Schmid and Frye 1977). This event

provided an opportunity to test MCH on a larger scale and under more natural conditions than had been possible previously.

Test Plots

Three widely separated areas were selected for the test. They were Cow Creek Saddle and Dixie Summit on the Nezperce National Forest, and Squaw Flat on the Payette National Forest. Windthrown Douglas-fir were numbered and their diameters at breast height were recorded. Trunks were rated as open, partially shaded, or heavily shaded. Shade and large diameter favor DFB attack (Furniss 1962, McMullen and Atkins 1962) and differences in those factors may be a source of variation in tests of this sort.

The Cow Creek plot was at 1,829m elevation in a stand cut by the shelterwood method in 1975. Residual stand before the windstorm was 16 trees per ha, of which 75 percent were Douglas-fir averaging 63.7 cm d.b.h. We marked 261 windfelled trees for treatment on a plot of 36.4 ha. Fifty-two untreated trees were sampled within 1.6 km of the plot.

The Squaw Flat plot was at 1,921m elevation and varied from a naturally open hilltop stand of Douglas-fir to a moderately dense stand on gentle slopes, from which some trees had been logged. Trees are mainly Douglas-fir with some lodgepole pine (*Pinus contorta*). We marked 85 windfelled Douglas-fir for treatment on an area of 16.2 ha and 37 untreated trees within 1.6 km of the plot.

The Dixie Summit plot (1,768m elevation) was mostly undisturbed prior to the windstorm. Grand fir (*Abies grandis*) and Engelmann spruce were mixed with Douglas-fir in the test area. We tallied 169 windfelled Douglas-fir and about 40 spruce on a treated area of 24.3 ha. Within 1.6 km of the plot, we sampled 9 untreated Douglas-fir and 15 spruce.

Application of MCH

A controlled-release formulation (CRF) containing 2-percent MCH was applied to plots on May 11, 12, and 13, 1982, while 0.6–1.2 m of snow was on the ground. Equipment consisted of a Bell 206B helicopter and a modified Simplex model 6400, 1.13m³ aerial spreader (fig. 2) (Furniss et al. 1982). The pilot was instructed to apply the granules in one direction on flight lines 15 m apart at an airspeed of 80 km/h with the bucket suspended 15 m above the tree tops. The pilot was oriented by ground personnel who lined up each swath by pacing to each successive flight line.

Treatment was extended 60 m beyond the windthrow on each plot but was interrupted 30 m from the only live stream (on the Dixie Summit plot), an Environmental Protection Agency requirement for testing pheromones or other chemicals.

The amount of CRF applied was controlled by loading the applicator with only enough granules to treat the known area of each plot at 4.48 kg/ha (89.6 g active ingredients/ha). Actual densities of granules reaching the ground, as measured by approximately 100 metal funnel-shaped traps, were:

Plot	Kg/ha
Cow Creek	2.69
Squaw Flat	2.44
Dixie Summit	2.04
Av., weighted	2.43

The measured application rate was thus lower than the



Figure 2. A modified aerial spreader and helicopter were used to apply granules containing pheromone.

intended 4.48 kg/ha. Causes of the discrepancy are unknown but may include retention in tree crowns and higher than specified flight (wider swath). However, measured rates as low as these have been highly effective elsewhere (Furniss et al. 1981a).

Effectiveness was determined during June 22–24, 1982, by counting DFB attacks as evidenced by piles of expelled bark fragments (boring dust) on sample trees (fig. 3). At Dixie Summit, we again tallied attacks on a subsample of 21 Douglas-fir (10 treated, 11 not treated) during August 9–11, 1982, to determine how many additional attacks occurred during the second DFB flight, which consists mainly of beetles emerged from earlier attacks. On those dates we also counted spruce beetle attacks on 0.1 m² bark samples at three locations on the underside of 29 spruce (14 treated, 15 not treated). Bark samples were used because spruce beetle boring dust was often not visible on the underside or was easily confused with that of other bark beetles.

Effectiveness of Treatment

Douglas-fir beetle.—Density of DFB infestation in plot trees is summarized in table 1. MCH greatly lessened the number of attacks, as it had done in smaller-scale field tests (Furniss et al. 1974, 1977, 1981a). Attack density is also influenced by shading and tree size (Furniss 1962, McMullen and Atkins 1962) but far less so than by MCH in this test. When average plot values were compared, only shade index and DFB density on check plots appeared correlated. Evidently, the repressive effect of MCH overwhelmed any other factor normally regulating DFB attack density. We



Figure 3. Counts of beetle attacks on 232 windthrown trees at three test locations demonstrated the effectiveness of the MCH treatment.

point out, however, that scattered (shaded) windthrown stems of large diameters have disproportionately more breeding potential than unshaded trees of smaller diameter.

The August 9–11 count at Dixie Summit found 277.3 (R = 100–600) attacks on the check plot and 41.4 (R = 0–90) on the treated plot, an 85.1-percent reduction—slightly less than the 93.3-percent reduction determined in June. In other years (with less snow) and at lower elevations, we have counted attacks weekly on downed trees and found that very few occurred after mid-June.

Spruce beetle.—Attacks in windfelled spruce at Dixie Summit averaged 0.79 (standard deviation 0.64) per 0.1 m² of bark surface for trees treated with MCH and 3.96 (std. dev. 0.84) for untreated trees.

In earlier tests, spruce beetle attraction to log sections

was nullified by MCH evaporating from open vials attached to sticky traps containing natural attractant and synthetic attractant (frontalin or seudenol) (Kline et al. 1974, Furniss et al. 1976). Similar treatment of four windthrown Sitka spruce (*Picea sitchensis*) in Oregon reduced spruce beetle attacks from 1.57 (in controls) to 0.01 per 0.1 m² (Rudinsky et al. 1974). Treatment with liquid MCH in vials or the 2-percent CRF was not effective, however, when applied to felled white spruce (*Picea glauca*) in Alaska (Furniss et al. 1979), apparently because cold temperature slowed MCH evaporation, and because spruce beetles were already in outbreak abundance and were attacking surrounding trees. In British Columbia, MCH evaporated from vials on 50 spruce stumps resulted in 50 percent fewer spruce beetle attacks than in untreated stumps (Dyer and Hall 1977).

Recommendations

Extensive windthrow has been consistently involved in Douglas-fir beetle outbreaks in the Pacific Northwest. This test, together with smaller-scale tests since 1972, demonstrated the efficacy of MCH for reducing attacks in downed trees. By keeping beetles out of these highly susceptible breeding places, the pheromone exposes them to increased predation and the greater resistance of live trees. Windthrown Douglas-firs in greatest need of treatment are those inaccessible for salvage and of medium to large diameter, shaded, and near susceptible live stands (i.e., dense Douglas-fir stands, 80+ years old). Treatment must be applied before any beetles have flown and attacked downed trees.

The few tests (all cited herein) of MCH against the spruce beetle have been in widely separated areas and have involved three species of spruce. Populations and test environments have varied greatly, as have treatment rates and sources of attraction. Nonetheless, the spruce beetle is similar in several ways to the Douglas-fir beetle, and it may be possible to develop a similar strategy for application to spruce forests extending from the southern Rocky Mountains to Alaska, where outbreaks have historically been triggered by windthrow. ■

Although MCH is not currently registered with EPA, the Forest Service is proceeding to register the 2-percent controlled-release formulation for application to inaccessible windfelled trees at the rate of 4.48 kg/ha (89.7 g AI).

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Table 1. Density of Douglas-fir beetle attacks in plot trees, June 22–24, 1982.

Plot	TREATED		CHECK		Reduction
	Trees	Attacks (and standard deviations)	Trees	Attacks (and standard deviations)	
	-----Number-----				
Cow Creek	50	8.9 (15.0)	52	186.0 (161.3)	95.2
Squaw Flat	52	1.1 (2.3)	37	104.8 (120.0)	98.8
Dixie Summit	32	6.3 (1.3)	9	93.2 (64.6)	93.3
Total	134		98		
Average		5.3 (11.2)		147.0 (145.8)	96.4

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Predicting 25th-Year Diameters of Thinned Stump Sprouts of Northern Red Oak

Paul S. Johnson and Robert Rogers

ABSTRACT—Simulated estimates of 25th-year diameters are given for northern red oak (*Quercus rubra*) stump sprouts in southwestern Wisconsin. The model shows that diameters of individual stems can be maximized by early clump thinning to one stem. Specific gains will depend on crop stem diameters, age, relative basal area (ratio of individual stem to total clump basal area) after thinning, and site quality.

Stumps of northern red oak produce dense clumps of sprouts. These clumps often retain four or more live stems for 20 years and longer (Johnson 1975). Because they grow rapidly, most of the sprouts occupy and maintain a dominant crown position in even-aged stands. An estimated 80 to 90 percent of clumps contain at least one stem of potentially high future value (Lamson 1976). Many foresters have recognized this high potential for both stem growth and quality, and this article presents a method for estimating the growth potential of stems in clumps younger than 25 years.

A Growth Simulation Model

Model construction.—A simulation model was constructed from data collected from 239 stems in 120 sprout clumps in eight stands in southwestern Wisconsin (Johnson and Rogers 1980). Initial stand ages were 4, 7, 11, 13, 14, 17, 21, and 22 years, and all stands had originated from clearcutting

predominantly red oak stands 80 to 110 years old. In each stand, 5 to 18 dominant or codominant sprout clumps containing three or more live stems were selected and thinned to one crop stem or to two crop stems, or were not thinned at all (controls). In unthinned clumps, three stems were identified as crop stems. Approximately equal numbers of clumps were contained in each of the three thinning classes.

Competition around all clumps was removed to ensure that the sprouts had all the space that they could utilize at the beginning of the growth period. The radii for removing competition were based on the maximum tree area relationship of Gingrich (1967) and ranged from 6 to 20 feet depending on clump age and number of residual stems per clump (Johnson and Rogers 1980).

Five years after initial measurements, each live stem in each clump was remeasured and two regression equations for estimating 5-year basal area increments were developed. One equation was used to estimate 5-year basal area increment of an individual stem (SBAI₅), and the other was used to estimate 5-year basal area increment of all other living stems in the clump (CBAI₅). Table 1 gives the two equations.

From these two equations, the simulation model generates 25th-year stem diameters (near the observed upper age limit of 27) from sets of initial conditions that include stem age and basal area, total clump basal area, and an index of site quality. Because age is an independent vari-