Elution Rate and Spacing of Antiaggregation Pheromone Dispensers for Protecting Live Trees from *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae)

Author(s): Darrell W. Ross, Gary E. Daterman, and Kenneth E. Gibson

Source: Journal of Economic Entomology, 95(4):778-781. 2002.
Published By: Entomological Society of America
DOI: http://dx.doi.org/10.1603/0022-0493-95.4.778
URL: http://www.bioone.org/doi/full/10.1603/0022-0493-95.4.778

Elution Rate and Spacing of Antiaggregation Pheromone Dispensers for Protecting Live Trees from *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae)

DARRELL W. ROSS,[1] GARY E. DATERMAN,[2] AND KENNETH E. GIBSON[3]

Department of Forest Science, Oregon State University, Corvallis, OR 97331–5752

J. Econ. Entomol. 95(4): 778–781 (2002)

ABSTRACT The antiaggregation pheromone 3-methylcyclohex-2-en-1-one (MCH) is highly effective in preventing the infestation of high-risk trees by Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins. A large portion of the cost of an MCH treatment is related to the time applicators spend walking through an area dispersing the formulated pheromone. Application of fewer MCH dispensers eluting at a higher rate than those currently registered for operational use could potentially reduce treatment costs. Two higher elution rates, 6 and 18 mg/d per dispenser, were compared with the current standard of 2 mg/d per dispenser and an untreated control on 1-ha circular plots. Dispensers were spaced 5, 15, and 44 m apart around the plot perimeters eluting 2, 6, and 18 mg/d, respectively. The nominal dose of MCH was 144 mg/ha/d on all plots. Percentages of Douglas-fir trees ≥20 cm diameter at breast height mass attacked by Douglas-fir beetle were significantly lower on plots treated with dispensers eluting 2 and 6 mg/d and spaced 5 and 15 m apart, respectively, compared with the untreated control. Infestation rate on plots treated with dispensers eluting 18 mg/d and spaced 44 m apart was not significantly different from the control. Douglas-fir beetle abundance and host tree availability were similar on all plots. These results indicate that MCH dispensers eluting 6 mg/d (three times the current standard rate) and spaced 15 m apart (three times existing standard distance) can effectively prevent Douglas-fir beetle infestations.

KEY WORDS *Dendroctonus pseudotsugae,* Douglas-fir beetle, 3-methylcyclohex-2-en-1-one.

THE DOUGLAS-FIR BEETLE, *Dendroctonus pseudotsugae* Hopkins, antiaggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH), is consistently effective in preventing the infestation of high-risk trees and stands during outbreaks (Ross and Daterman 1994, 1995). Reliable formulations and application techniques have been developed, and the optimal dose of MCH has been identified (Ross et al. 1996). In 1999, MCH became available for operational applications following registration by the U.S. Environmental Protection Agency. The cost of MCH applications may be justified for many management areas including recreational sites, residential properties, old growth reserves, riparian zones, and other special use areas. A significant portion of the cost of MCH applications is the time required for applicators to walk through a treatment area and staple dispensers to trees, snags, and other objects. This is particularly true for areas >1 ha where applicators must walk back and forth along parallel lines across the unit. Dispensers eluting at a higher rate than those currently available could potentially reduce the cost of ground applications. With fewer dispensers to be applied at a wider spacing, applicators would walk a shorter distance (i.e., walk fewer lines spaced farther apart), carry and handle fewer dispensers, and stop less often to attach dispensers, thus covering a given area in less time and thereby reducing labor costs. Another potential benefit of using a smaller number of dispensers eluting at a higher rate would be less plastic debris left in treated areas. The objective of this study was to compare different combinations of elution rate and spacing of MCH dispensers to the current standard while maintaining a constant dose over the treated area.

Materials and Methods

This study included five replications of four treatments in a randomized complete block design. The methods were similar to those used in previous studies on the efficacy of MCH (Ross and Daterman 1995, Ross et al. 1996). The study site was located at 48° 18′ N latitude and 114° 48′ W longitude ≈32 km WSW of Whitefish, MT, This area supported higher than av-

This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or recommendation by the USDA for its use.

[1] E-mail: darrell.ross@orst.edu.

[2] USDA Forest Service, Pacific Northwest Research Station, 3200 Jefferson Way, Corvallis, OR 97331.

[3] Northern Region, Cooperative Forestry and Pest Management, USDA Forest Service, P.O. Box 7669, Missoula, MT 59807.

erage Douglas-fir beetle populations during the study (USDA Forest Service 2000). Elevations across the plots ranged from 1340 to 1400 m. Circular, 1-ha plots were located in stands with a large component of mature Douglas-fir, *Pseudotsugae menziesii* (Mirbel) Franco, near trees containing brood adults. Plots were located ≈200 m apart. No brood containing trees were located on the plots, but they were present in the areas between plots. Plots were established between 27 and 29 April 1999. Treatments included three MCH elution rates and an untreated control. Rather than using separate formulations with different elution rates, a single bubble capsule formulation was applied as individual dispensers or as groups of dispensers together to achieve the desired elution rates. The bubble capsule formulation contains 400 mg of MCH (Phero Tech, Delta, BC, Canada) and releases ≈2 mg/d under field conditions (Ross and Daterman 1995). The current recommended dose for operational MCH applications is 74 bubble capsules/ha, although lower doses are known to be effective (Ross et al. 1996). A 72 bubble capsule/ha dose was chosen for this study because it was close to the recommended dose and evenly divisible by 3 and 9 to create higher elution rates. Elution rates of 6 and 18 mg/d from a point source were achieved by attaching three and nine bubble capsules together. Groups of one, three, and nine bubble capsules were located at 72, 24, and eight spots, spaced 5, 15, and 44 m apart, around the plot perimeter, respectively, to achieve a nominal dose of 144 mg/ha/d for each treatment. Bubble capsules were attached to north sides of trees, snags, or shrubs at a height of ≈2 m.

A pheromone-baited, 16-unit multiple-funnel trap (Lindgren 1983) (Phero Tech, Delta, BC, Canada) was placed at the center of each plot to provide a standard source of attraction and to monitor beetle activity. Each trap was baited with a lure containing ≈10 mg of frontalin and 5 mg of seudenol in polyvinyl chloride formulations (Daterman 1974). Release rates at 24°C and chemical purity for frontalin and seudenol were 0.5 and 0.25 mg/d and 95.0 and 99.3%, respectively. This low strength, monitoring lure was used to measure and compare beetle populations among plots. A small piece of dichlorvos-impregnated plastic (3 by 3 cm) was placed in each collection cup to kill trapped insects. Trap catches were collected on 28 May and 3 June 1999. Traps were removed after the second sample date when beetle attacks on trees within plots were first observed. Numbers of Douglas-fir beetles and associated predators in each sample were counted in the laboratory. One hundred Douglas-fir beetles were sexed from each sample for the first collection date only (Jantz and Johnsey 1964) because sex ratio changes very little during the first several weeks of the Douglas-fir beetle flight season (D.W.R., and G.E.D., unpublished data).

Basal area of all trees with diameter at breast height (dbh) ≥20 cm was measured at the plot center and recorded by species on each plot. The Douglas-fir component was expressed as a percentage of total basal area of all species.

Table 1. Mean number (±SE) of Douglas-fir beetles and clerid predators, *Thanasimus undatulus*, caught in traps baited with aggregation pheromones on MCH-treated and control plots in northwestern Montana, 1999 ($n = 5$)

MCH elution rate and no. dispensers/ha	Douglas-fir beetles (mean no./trap)	*Thanasimus undatulus* (mean no./trap)
Control	549.3 ± 157.1	132.4 ± 44.1
2 mg/day, 72	275.9 ± 85.1	275.7 ± 100.2
6 mg/day, 24	551.4 ± 189.2	254.3 ± 105.6
18 mg/day, 8	431.6 ± 131.9	185.0 ± 68.4

There were no significant differences at $\alpha = 0.05$ in numbers of insects caught among the treatments.

The central 0.3-ha portion of each plot was surveyed on 5 October 1999 after beetle flight had ended to determine the infestation status of all large Douglas-fir trees (≥20 cm dbh). Only the central portion of each plot was surveyed to avoid any edge effect around the perimeter. Previous studies with the same experimental design have consistently shown that almost all infested trees are located in the plot centers near the pheromone-baited traps (Ross and Daterman 1994, Ross et al. 1996). Again, the purpose of traps at each plot center is to confirm presence and compare relative density of beetles among sites, and to provide at least a modicum of beetle pressure at all sites to add rigor for evaluating MCH effectiveness. The dbh and infestation status of each tree was recorded. Trees were classified as mass-attacked or unattacked based on presence or absence of large amounts of boring dust on the lower several meters of the bole (Knopf and Pitman 1972, Ringold et al. 1975). The percentage of large Douglas-fir trees that were mass-attacked was calculated for each plot.

Data Analyses. Total numbers of Douglas-fir beetles and predators caught in multiple-funnel traps during both collection periods were subjected to analysis of variance (ANOVA) for a randomized complete block design (Steel and Torrie 1980). Tree and stand data were also subjected to ANOVA. Before analysis, each variable was tested for homogeneity of treatment variances by Levene's method (Milliken and Johnson 1984). If variances were nonhomogeneous, integer data were transformed to $\ln(Y + 1)$ and percent data were transformed to arcsine of the square root (Y) before ANOVA. Means were compared and separated by Fisher protected least significant difference (LSD) when $P < 0.05$ (Steel and Torrie 1980). Only nontransformed means are reported. All statistical analyses were performed with SAS computer programs (SAS Institute 1985).

Results and Discussion

There were no significant differences in mean number of Douglas-fir beetles captured among treatments ($F = 1.59$; df = 3,12; $P = 0.2430$) (Table 1). This is contrary to results of earlier studies where trap catches were consistently lower on MCH-treated plots compared with untreated controls (Ross and

Table 2. Mean ± SE stand and tree characteristics for Douglas-fir ≥20 cm dbh on MCH-treated and control plots in northwestern Montana, 1999 (n = 5)

MCH elution rate and no. dispensers/ha	Basal area (m^2/ha)	% basal area (% of total)	Tree density (stems/ha)	Dbh, cm	% mass attacked
Control	21.2 ± 8.3	48.0 ± 15.1	114.3 ± 7.4	38.9 ± 1.2	17.8 ± 5.2 a
2 mg/day, 72	24.8 ± 3.4	73.5 ± 14.2	131.6 ± 16.4	42.1 ± 1.0	3.7 ± 1.7 b
6 mg/day, 24	24.8 ± 5.4	71.3 ± 9.6	143.5 ± 29.4	37.8 ± 0.9	1.8 ± 1.1 b
18 mg/day, 8	25.8 ± 6.1	89.3 ± 6.6	128.1 ± 11.2	39.3 ± 1.1	10.9 ± 4.8 ab

Means in each column followed by the same letter or no letter are not significantly different at α = 0.05.

Daterman 1995, Ross et al. 1996). This may be due to the fact that traps were only left in place for the first 5 wk of the beetle flight season in the current study. Local resource managers wished to minimize the number of new infestations occurring in the study area and wanted the traps with aggregation pheromones removed as soon as possible. Therefore, traps were removed at the first sign of new beetle attacks on trees within the plots. In earlier studies, traps and aggregation pheromones were left in place throughout the beetle flight period. As beetles attack trees near traps on some plots, they release pheromones. Although these infested trees may compete with the traps for flying beetles, the increase in pheromone concentration may attract more beetles to plots with infested trees and potentially increase beetles captured in traps compared with plots without infested trees. By removing the traps at the first sign of beetle infestations, we likely reduced the chances of detecting differences among the treatments. However, the lack of differences in numbers of beetles captured among treatments at the start of the experiment suggests that beetle pressure was similar on all plots.

The mean percentage of male Douglas-fir beetles in trap catches ranged from 77–85% with no significant differences among treatments (F = 1.86; df = 3, 12; P = 0.1901). A strong male bias in trap catches early in the flight season is consistent with results from a previous study (Ross and Daterman 1997). *Thanasimus undatulus* (Say) was the only predator caught. In previous studies with MCH and similarly baited traps, *Enoclerus sphegeus* F. and *Temnochila chlorodia* (Mannerheim) were also collected although in much smaller numbers than *T. undatulus* (Ross and Daterman 1995, Ross et al. 1996). As in the earlier studies, there were no significant differences in number of *T. undatulus* captured among treatments (F = 1.54; df = 3, 12; P = 0.2551) (Table 1). MCH apparently has no repellent effect on associated predators because trap catches on MCH-treated plots are consistently equal to or greater than those on untreated, control plots (Ross and Daterman 1995, Ross et al. 1996).

There were no significant differences among treatments for basal area (F = 0.10; df = 3, 12; P = 0.9581), percent of total basal area (F = 2.37; df = 3, 12; P = 0.1217), tree density (F = 0.38; df = 3,12; P = 0.7708), or dbh (F = 2.96; df = 3, 12; P = 0.0751) for large Douglas-firs (Table 2). This was expected because plots were chosen to be as similar as possible with respect to stand structure and composition. However, mean percentages of large Douglas-firs that were mass attacked by Douglas-fir beetle were significantly lower on plots with the dispensers having the two lowest MCH elution rates and closest spacings, 2 mg/d at 5 m spacing and 6 mg/d at 15 m spacing, compared with the control (F = 4.89; df = 3, 12; P = 0.0191) (Table 2). Percentage of trees mass attacked on the plots with the highest MCH dispenser elution rate and widest spacing, 18 mg/d and 44 m spacing, was not significantly different from the control or the other two MCH treatments (Table 2). Because host availability and beetle pressure were similar among all treatments, the differences in infestation rates were apparently due to the MCH treatment effects.

These results indicate that MCH formulations eluting at a higher rate with wider spacing between dispensers than formulations and spacing currently in use can effectively prevent Douglas-fir beetle infestations. The main advantage of a formulation with a higher elution rate and wider spacing of dispensers would be to reduce time and cost of application. During operational MCH treatments on units larger than the 1-ha plots used in this study, applicators must traverse the unit along parallel transects placing bubble capsules at the desired spacing. With fewer dispensers to place in a treatment area, applicators would walk a shorter distance (i.e., fewer transects at wider spacing) and would stop less often to attach dispensers thereby covering a given area in less time. An additional advantage of using a smaller number of dispensers would be less debris left in the forest following an MCH treatment. Formulations eluting at three times the rate and spaced at three times the distance of those currently in use would be effective.

Acknowledgments

This research was supported by the USDA/IR-4 Biopesticide Research Program. We thank Ed Lieser and Barb Ping from the Tally Lake Ranger District, Flathead National Forest, USDA Forest Service for providing access to study sites and technical assistance.

References Cited

Daterman, G. E. 1974. Synthetic sex pheromone for detection survey of European pine shoot moth. USDA For. Ser. Res. Pap. PNW-180.

Jantz, O. K., and R.L. Johnsey. 1964. Determination of sex of the Douglas-fir beetle *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Scolytidae). Can. Entomol. 96: 1327–1329.

Knopf, J.A.E., and G. B. Pitman. 1972. Aggregation pheromone for manipulation of the Douglas-fir beetle. J. Econ. Entomol. 65: 723–726.

Lindgren, B. S. 1983. A multiple-funnel trap for scolytid beetles. Can. Entomol. 115: 299–302.

Milliken, G. A., and D. E. Johnson. 1984. Analysis of messy data, vol. I. Designed experiments. Van Nostrand Reinhold, New York.

Ringold, G. B., P. J. Gravelle, D. Miller, M. M. Furniss, and M. D. McGregor. 1975. Characteristics of Douglas-fir beetle infestation in northern Idaho resulting from treatment with douglure. U.S. For. Serv. Res. Note INT-189.

Ross, D. W., and G. E. Daterman. 1994. Reduction of Douglas-fir beetle infestation of high-risk stands by antiaggregation and aggregation pheromones. Can. J. For. Res. 24: 2184–2190.

Ross, D. W., and G. E. Daterman. 1995. Efficacy of an antiaggregation pheromone for reducing Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Scolytidae), infestation of high risk stands. Can. Entomol. 127: 805–811.

Ross, D. W., and G. E. Daterman. 1997. Using pheromone-baited traps to control the amount and distribution of tree mortality during outbreaks of the Douglas-fir beetle. For. Sci. 43: 65–70.

Ross, D. W., K. E. Gibson, R. W. Their, and A. S. Munson. 1996. Optimal dose of an antiaggregation pheromone (3-methylcyclohex-2-en-1-one) for protecting live Douglas-fir from attack by *Dendroctonus pseudotsugae* (Coleoptera:Scolytidae). J. Econ. Entomol. 89: 1204–1207.

SAS Institute. 1985. SAS/STAT guide for personal computers, version 6 edition. SAS Institute, Cary, NC.

Steel, R.G.D., and J. H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach. McGraw-Hill, New York.

USDA Forest Service. 2000. Forest insect and disease conditions in the United States 1999. USDA For. Serv. For. Health Protection (http://www.fs.fed.us/foresthealth/annual_i_d_conditions/cy98a.pdf)

Received for publication 25 September 2001; accepted 18 March 2002.