Integrating Pheromone and Silvicultural Methods for Managing the Douglas-fir Beetle

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ABSTRACT Historically, approaches to reducing losses caused by the Douglas-fir beetle have focused on protecting the timber resource. Past recommendations included harvesting mature stands, treatment or removal of large diameter slash, prompt salvage of dead and dying trees, preventing tree stress and injury, thinning of young stands, and treatment or processing of infested material to destroy developing brood. Although some of these recommendations are still appropriate, there are limitations to implementing them in the context of ecosystem management. Recently, several new methods of using aggregation and antiaggregation pheromones of the Douglas-fir beetle have been shown to be effective for manipulating the distribution and possibly amount of tree mortality during outbreaks. These new methods along with existing silvicultural and pheromone-based treatments provide new opportunities to develop integrated programs for managing this important forest pest. The potency of these pheromone technologies suggest the potential for regulating beetle activity over wide areas, thus raising the need for field-testing at landscape scales.

KEYWORDS Scolytidae, *Dendroctonus pseudotsugae*, pheromones, 3-methylcyclohex-2-en-1-one, MCH, mass trapping

THE DOUGLAS-FIR beetle, *Dendroctonus pseudotsugae* Hopkins, is found throughout the range of Douglas-fir, *Pseudotsugae menziesii* (Mirb.) Franco, in western North America (Furniss and Carolin 1977). This beetle usually breeds in portions of tree boles that are greater than about 20 cm in diameter. At low population densities, most infestations occur in trees that have recently died or live trees with limited defenses resulting from stress or injury (McMullen and Atkins 1962, Furniss 1965, Rudinsky 1966, Furniss et al. 1981, Wright et al. 1984). When populations reach high densities, large numbers of healthy trees may be successfully attacked and killed (Johnson and Belluschi 1969, Furniss et al. 1979). Epidemics often develop following natural or human-caused disturbances that create abundant breeding sites. Tree mortality during epidemics can alter the structure, composition, and ecological processes of forests in ways that may conflict with resource management objectives (Cornelius 1955, Furniss and Orr 1978, Hadley and Veblen 1993).

The Douglas-fir beetle is similar to other aggressive bark beetle species in the genus *Dendroctonus*. This species has only one generation per year, although sister broods may be produced when the weather is favorable. Adults fly from early spring through mid-summer (Ross and Daterman 1996). Broods overwinter within the phloem in the adult, pupal, or late larval stages. The pheromone system of the Douglas-fir beetle has been well studied. Among the many compounds that have been found to be attractive to the Douglas-fir beetle, combinations of frontalin with seudenol, ethanol, and/or MCOL elicit the strongest responses (Pitman and Vité 1970, Vité et al. 1972, Rudinsky et al. 1974, Pitman et al. 1975, Libbey et al. 1983, Lindgren et al. 1992, Ross and Datermen 1995a). The antiaggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH), significantly reduces beetle response to attractant

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odors (Kinzer et al. 1971, Furniss et al. 1972, Rudinsky et al. 1972, Furniss et al. 1974, McGregor et al. 1984, Lindgren et al. 1988).

History of Management Practices

Until recently, management of Douglas-fir in the U.S. was primarily directed toward timber production. Consequently, the earliest recommendations to prevent losses caused by the Douglas-fir beetle were developed to protect the timber resource. These recommendations emphasized silvicultural activities that either reduced the availability of breeding sites or directly reduced the beetle population (Bedard 1950, Furniss 1959, Lejeune et al. 1961, Williamson and Price 1971, Furniss and Orr 1978, Furniss et al. 1979). Recommendations for limiting potential breeding sites included harvesting mature stands, treatment or disposal of slash greater than 20 cm in diameter, prompt salvage of windthrown, fire-damaged, and otherwise dead and dying trees, fire prevention, and thinning of young stands. Harvesting or treatment of infested material to destroy developing broods was also encouraged to reduce beetle populations. During outbreaks, the use of felled trap-trees was recommended to concentrate beetle activity in accessible areas where the brood could be destroyed (Lejeune et al. 1961). The effectiveness of these practices was often limited because of an inability to treat the entire infested area in a timely manner.

New possibilities for managing the Douglas-fir beetle arose following the identification of its aggregation and antiaggregation pheromones. Because outbreaks often occur following disturbances, particularly windstorms, a considerable effort was devoted to developing ways to use MCH to prevent the infestation of windthrown trees. Although an effective treatment was developed and shown to be operationally feasible (McGregor et al. 1984), it has never been implemented because of continuing delays in the registration process. Aggregation pheromones have been used to bait trap-trees making them more competitive with natural sources of attraction (Knopf and Pitman 1972, Pitman 1973, Ringold et al. 1975, Thier and Weatherby 1991). Since this application of pheromones does not require registration in the U.S., baited trap-trees have been used in operational programs (Patterson 1992). However, the efficacy of baited trap-trees has never been fully evaluated.

Emerging Pheromone-Based Methods

Since 1992 we have been studying new pheromone-based management stategies for the Douglas-fir beetle. We have focused primarily on two treatments. First, using pheromones to protect live trees in relatively small, high-risk, high-value stands during outbreaks. And second, using pheromone-baited traps to affect the amount and distribution of beetle-caused tree mortality at the landscape scale during outbreaks.

Antiaggregation Peromone, MCH

A study conducted in northeastern Oregon in 1992 demonstrated the feasibility of using pheromones to protect live trees in small, high-value stands (Ross and Daterman 1994). A combination of pheromone-baited traps and MCH application significantly reduced the percentage of host trees that were infested compared with an untreated control (Fig. 1). Although this treatment was successful in reducing the infestation within the area designated for protection, there were some problems associated with using traps for this purpose including "spill-over" attacks on nearby trees. Consequently, a follow-up study was conducted in the same general area in 1993 to test the efficacy of MCH alone (Ross and Daterman 1995b). The results indicated that MCH alone was at least equal to and perhaps more effective than the combination of baited traps and MCH that was tested the previous year (Fig. 1). In both of these studies, MCH was applied as bubble capsules at a rate of 150 capsules per hectare (60 g/ha).

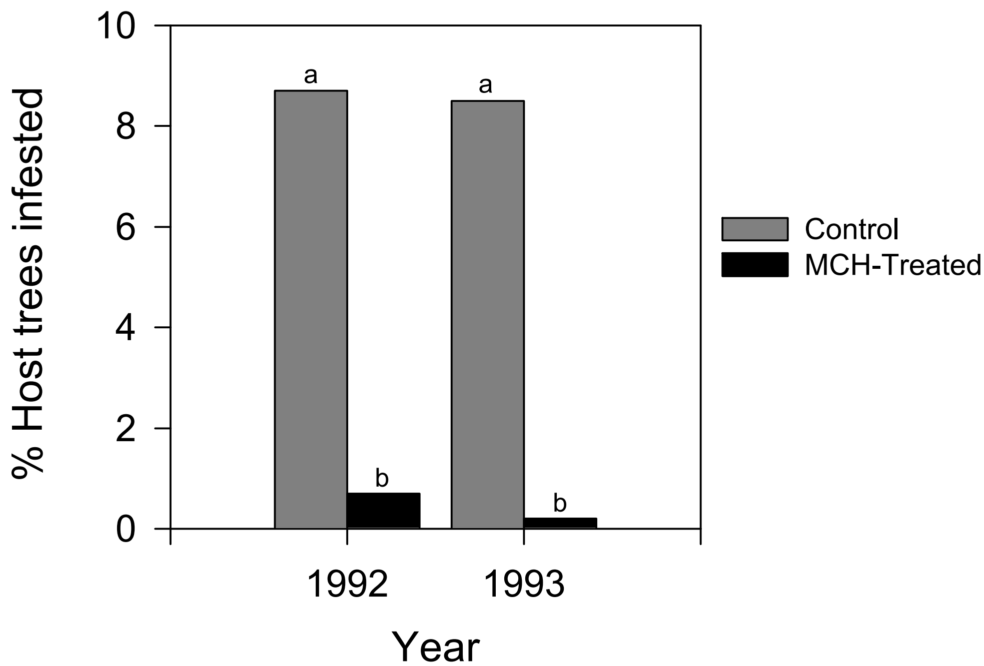

Fig. 1. Percentage of host trees infested on MCH-treated (60 g/ha) and control plots during studies conducted in northeastern Oregon in 1992 and 1993. In 1992, the treatment was a combination of MCH and pheromone-baited traps. In 1993, the treatment was MCH alone. Both years, differences between treated and control plots were significant ($\underline{P} < 0.05$).

Further studies were conducted in 1994 and 1995 to determine the lowest effective dose of MCH for protecting live trees (Ross et al. 1996). Each year, the tests were replicated in high-risk stands in Oregon, Idaho, Montana, and Utah. In 1994 and 1995, MCH was applied at rates of 0, 20, 40, and 60 g/ha and 0, 6, 12, and 20 g/ha, respectively. In 1994, all three doses of MCH were equally effective in reducing infestations compared to the untreated control (Fig. 2). In 1995, there were no significant differences in the percentage of host trees that were infested among the treatments, although the infestation rate at the highest dose was less than half that following any other treatment (Fig. 3). These results demonstrated that MCH applied at rates as low as 20 g/ha can reduce the probability that high-risk trees will become infested. However, for practical purposes slightly higher doses should be used to ensure treatment efficacy.

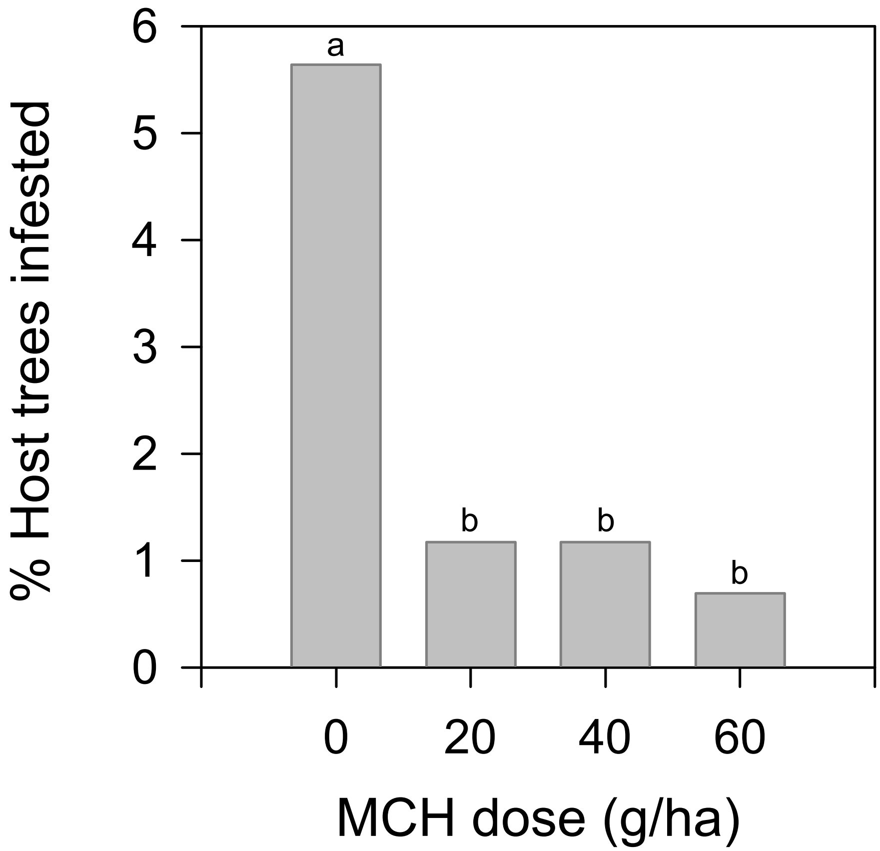

Fig. 2. Percentage of host trees infested following application of MCH at various doses on plots throughout the western U.S. in 1994. Letters indicate significant differences ($\underline{P}$ < 0.05).

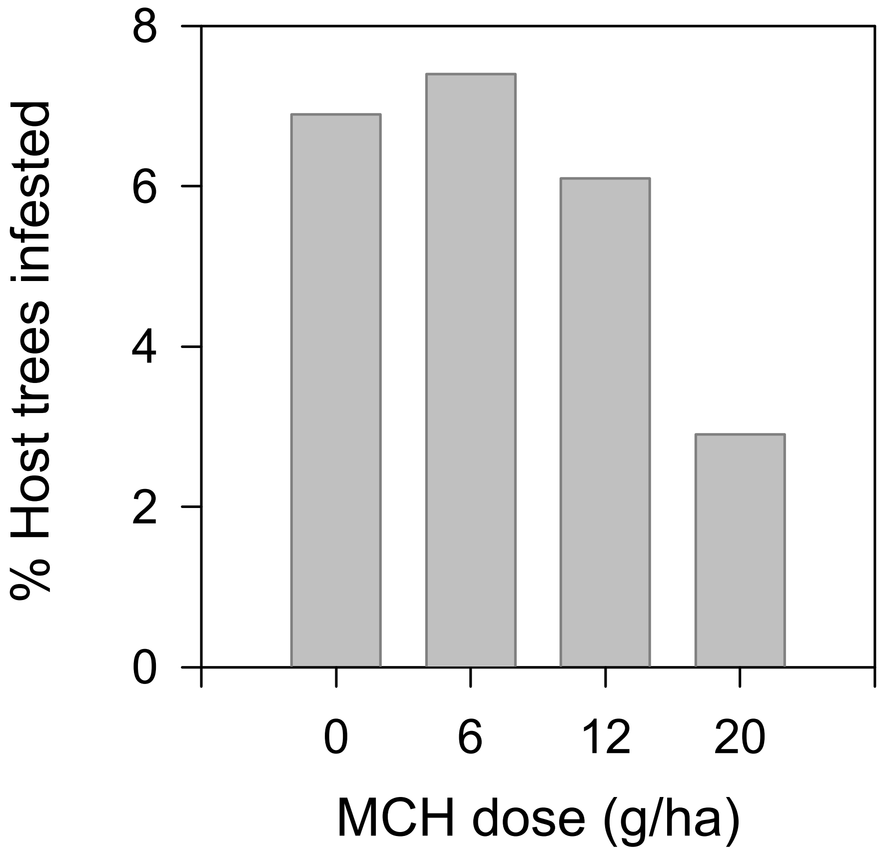

Fig. 3. Percentage of host trees infested following application of MCH at various doses on plots throughout the western U.S. in 1995. There were no significant differences among treatments ($\underline{P}$ > 0.05).

In all four studies conducted between 1992 and 1995, pheromone-baited traps were placed at the center of MCH-treated and control plots to evaluate treatment effects. In every case, traps on MCH-treated plots caught significantly fewer Douglas-fir beetles compared with traps on untreated controls. In contrast, there were much smaller or, in most cases, no differences in catches of predators among MCH-treated and control plots (Fig. 4). Furthermore, there were no significant differences in abundance of natural enemies or brood production from the lower 7 m of mass-attacked trees on MCH-treated and control plots in 1995 (Table 1, unpublished data). This limited evidence suggests that MCH treatments have no negative impacts on natural enemies.

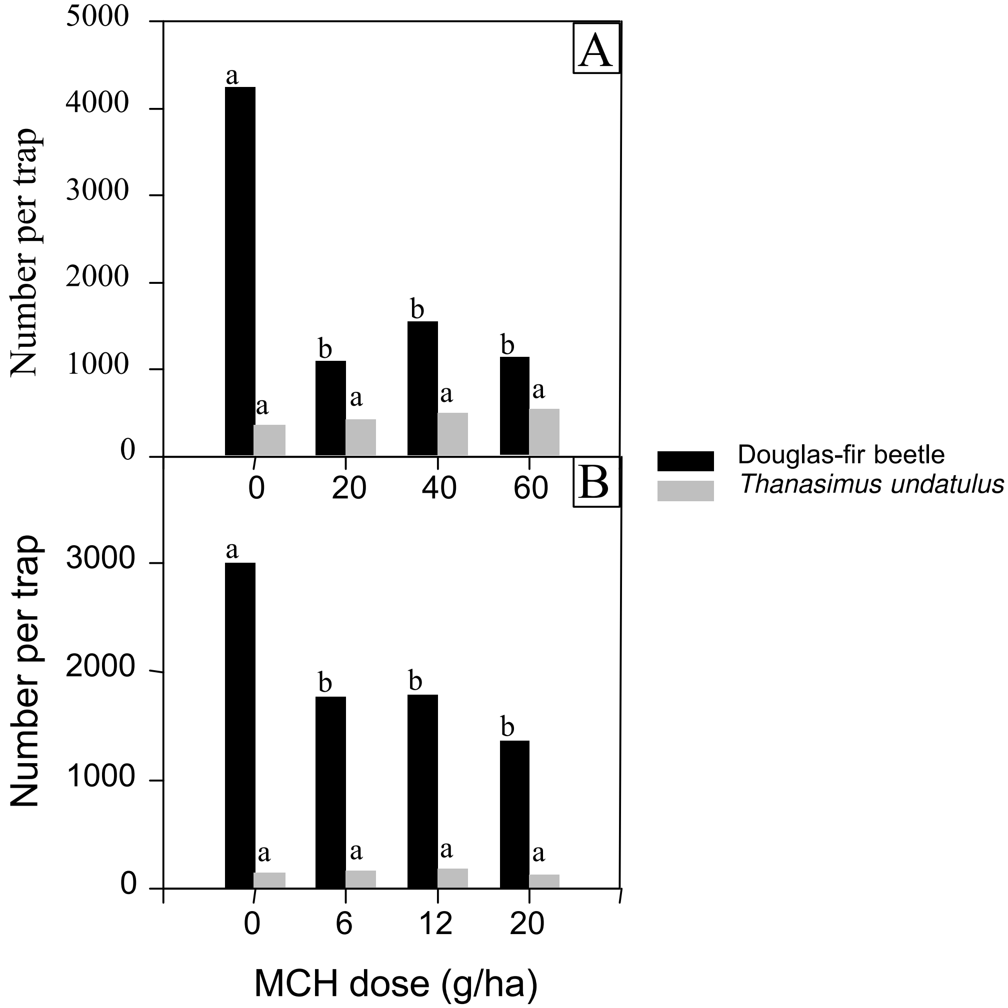

Fig. 4. Mean numbers of Douglas-fir beetles and *Thanasimus undatulus* collected in pheromone-baited traps at plot centers following application of MCH at various doses in (A) 1994 and (B) 1995. For each year and insect species, letters indicate significant differences ($\underline{P} < 0.05$).

Table 1. Brood production and brood adult and natural enemy densities (#/m²) in bark samples collected at 7 m height from Douglas-fir beetle infested trees on MCH-treated and control plots in northeastern Oregon, 1995.

	Control	MCH-treated
Brood production (brood adults/2(attacks))	0.58	0.59
Brood adults	138.2	162.3
Hymenopteran cocoons	129.2	144.9
Thanasimus undatulus	0	3.3
Enoclerus sphegeus	5.8	3.3

Data from four 120 cm² samples collected from 7 trees in each treatment. There were no significant differences between treatments ($\underline{P} > 0.05$).

At the present time, the use of MCH to protect live trees in high-value stands is an operational treatment. The only obstacle to full implementation of this technology in the U.S. is registration of MCH by the Environmental Protection Agency.

Aggregation Pheromones

Aggregation pheromones have been used in the trap-tree harvest method to concentrate Douglas-fir beetles. In this approach, pheromone-baited trees are harvested after they become infested to destroy the developing brood. Replacing the baited tree with an artificial trap could potentially increase the efficiency of a trapping program in a number of ways. Possible advantages of traps over trees include more flexibility in placement, unlimited trapping capacity, no reemergence, and less impact on some natural enemies.

A study conducted in northeastern Oregon in 1992 and 1993 demonstrated the potential for using pheromone-baited traps to manage the Douglas-fir beetle (Ross and Daterman 1997). Large numbers of beetles were collected in the traps and infested trees were concentrated near the trap sites. Although this study did not demonstrate conclusively that trapping reduced tree mortality in the outbreak area, it did show that mass-attacked trees were concentrated in the vicinity of traps even though traps were placed in openings 50-150 m from host trees. In British Columbia, pheromone-baited traps had a similar effect (Paulson 1995). Another potential problem with traps is the large numbers of predators that are collected. In the Oregon study, *Thanasimus undatulus* represented over 97% of the predators that were trapped and the ratio of Douglas-fir beetles to *T. undatulus* was about seven to one (Ross and Daterman 1996). The significance of catching such large numbers of *T. undatulus* is unknown. Under laboratory conditions, *T. undatulus* prefers smaller scolytids that are sometimes associated with the Douglas-fir beetle (Schmitz 1978). Additionally, over the last two years we have found approximately equal numbers of *T. undatulus* and *Enoclerus sphegeus* in bark samples from the lower 8 m of Douglas-fir beetle infested trees (unpublished data). The number of predators collected in multiple-funnel traps can be reduced by physical modifications that selectively exclude them or provide for their escape (unpublished data). Lure composition and pheromone release rates can affect trap selectivity also. There are still many questions that remain to be answered regarding the most efficient design of an operational trapping program. Other possible uses of Douglas-fir beetle pheromones include creating snags and canopy gaps to increase structural diversity in managed stands, monitoring population trends, and enhancing effectiveness of natural enemies.

Meeting Ecosystem Management Objectives Through IPM

Forest management in the U.S. has been undergoing dramatic changes in recent years, particularly on public lands. The emphasis on timber production that prevailed through the mid 1980's has been replaced by the concept of ecosystem management. Maintaining the ecological integrity and sustainability of forests while producing desired resources is the cornerstone of ecosystem management. Forestry has become much more complex as a result of this shift in policy. Forest managers are currently struggling to find the appropriate balance in producing a diverse array of resources and values.

Pest management has also become more complicated in the context of ecosystem management. There are now more constraints to implementing silvicultural controls for the Douglas-fir beetle than there were just a few years ago. However, silvicultural treatments remain the first line of defense for preventing undesirable tree mortality. Silvicultural strategies should be used wherever they are compatible with resource management objectives, especially on private lands managed primarily for timber. On most public lands, there are limited opportunities to prevent Douglas-fir beetle outbreaks through silviculture. For example, virtually all existing mature or old-growth stands on public lands are now reserved as habitat for species that depend upon late successional stage forests. The goal of management is to protect existing old-growth stands and facilitate successional processes in younger stands to increase the area of forests with similar characteristics. The short supply of old-growth forests makes them highly valued, but also places them at high risk to infestation by the Douglas-fir beetle which prefers to breed in large, old trees (Furniss et al. 1979).

A number of recent changes in silvicultural practices on public lands could potentially create favorable habitat for the Douglas-fir beetle. Rather than removing or treating large diameter slash following harvest operations as was common in the past, the current trend is to leave more of this material on the site. In some cases, trees are purposely topped or felled and left on the site to create standing and down woody debris for added structural diversity, wildlife habitat, and forage. There is also increasing opposition to removal of dead and dying trees such as those damaged by windstorms and wildfires. Much of this material is now being left in the forest for its ecological value rather than being removed for economic, pest management, or wildfire prevention considerations. There has been increasing interest in allowing wildfires to burn if they do not threaten life or property. If this trend continues, it may result in more fire-damaged trees some of which will not be salvaged. Although there is interest in thinning the abundance of overstocked stands on public lands, many areas will remain untreated to provide thermal and hiding cover for wildlife, to protect soil and water resources, and for other reasons. The combined effect of these changes in management practices will be to create more breeding sites for the Douglas-fir beetle.

Pheromone applications could help to prevent or alleviate some of the potential Douglas-fir beetle problems associated with changing silvicultural practices. MCH could be applied to high-value stands such as recreational, cultural, and administrative sites, highway corridors, old-growth reserves, and riparian areas to reduce the probability of tree mortality occurring in these locations during beetle outbreaks. At the same time, pheromone-baited traps could be located in general forest areas where tree mortality is less disruptive to management objectives. Sanitation or salvage logging might be prescribed in the vicinity of trap sites if it is consistent with management objectives. Where large volumes of fresh woody debris from natural or human-caused disturbances must be left in the forest, MCH could be applied to prevent the buildup of beetle populations that could threaten resource values. Other pheromone-based strategies that are yet to be developed could further compliment existing pheromone and silvicultural treatments. We plan to begin testing the application of pheromones at the landscape scale beginning in 1997.

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