Frontalin interrupts attraction of *Ips pini* (Coleoptera: Scolytidae) to ipsdienol

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The pine engraver, *Ips pini* (Say), breeds in the phloem tissue of dead, dying, or downed pines, occasionally attacking standing live trees when populations build up to significant levels following logging activities or infestations by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Furniss and Carolin 1980). In British Columbia, *I. pini* uses ipsdienol as an aggregation pheromone to facilitate large aggregations of mated beetles and breeding galleries (Miller *et al.* 1996). The aggregation pheromones, *exo*-brevicomin and *cis*- and *trans*-verbenol, used by *D. ponderosae* (Borden *et al.* 1987; Miller and Lafontaine 1991) interrupt attraction of *I. pini* to ipsdienol (Miller 1991). Another semiochemical, frontalin, is used by *D. ponderosae* as a multifunctional pheromone (Borden *et al.* 1987), enhancing attraction of beetles at low release rates and interrupting attraction at high release rates. I tested the effect of frontalin, over a broad range of release rates, on the attraction of *I. pini* to ipsdienol-baited traps.

(±)-Ipsdienol (98% chemical purity) was obtained from Bedoukian Research Inc (Danbury, Connecticut). Each ipsdienol lure consisted of a 10-cm length of C-flex® tubing (i.d. 1.6 mm, o.d. 3.2 mm) (Concept Inc, Clearwater, Florida), filled with an ethanol solution of (±)-ipsdienol, and heat-pressure sealed at both ends. The release rate of ipsdienol was about 0.6 mg/d at 24°C (determined by collection of volatiles on Porapak-Q). Ethanol, used to prevent polymerization of ipsdienol, has no effect on the attraction of *I. pini* (Miller 1991). (±)-Frontalin (>99% chemical purity) was obtained from BASF (Ludwigschafen, Germany). The following three types of lures were used to obtain five release rates with frontalin: (*i*) one Microcap® disposable pipette (2 µL) (Drummond Scientific Co, Broomall, Pennsylvania), sealed at one end, filled with frontalin, and placed in an open polypropylene, microcentrifuge tube (1.5 mL) (Evergreen Scientific, Los Angeles, California); (*ii*) five 2.5-cm glass capillary tubes (i.d. 1 mm), each sealed at one end and filled with frontalin, and all placed in one open, polypropylene, microcentrifuge tube; and (*iii*) one closed polyethylene microcentrifuge tube (250 µL) containing 150 µL of frontalin. The release rates of frontalin from these devices were about 0.11, 1.28, and 2.10 mg/d at 23–25°C (determined by weight loss). Higher rates were obtained with multiple devices. The experiment was conducted from 18 to 28 August 1988 in mature stands of lodgepole pine near Princeton, British Columbia (49°27′N, 120°31′W). Five replicates of six eight-unit multiple-funnel traps (Phero Tech Inc) per replicate were set in grids of 2 × 3. Treatments, randomly assigned within each replicate, were as follows: (*i*) a control treatment of ipsdienol alone, and (*ii–vi*) five treatments consisting of ipsdienol and frontalin released at different rates. Replicates were spaced at least 100 m apart, and traps were spaced 10–15 m apart within each replicate. Each trap was suspended by rope such that the top of each trap was about 1.4 m above ground level. No trap was within 2 m of any tree. Trap catch data were transformed by $\ln(x)$ to remove heteroscedasticity and analysed using

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TABLE 1. Catches of *Ips pini* in ipsdienol-baited multiple-funnel traps in response to frontalin near Princeton, British Columbia, from 18 to 28 August 1988 (n = 5).

Release rate of frontalin (mg/d)	Mean (± SE) number of beetles
0.00 (control)	1117±201
0.11	1149±170
1.28	534±141*
2.10	781±231
3.84	571±34*
6.30	526±63*

NOTE: Means followed by an asterisk are significantly different from the control baited without frontalin (LSD multiple comparison test, $P < 0.05$).

ANOVA, followed by Fisher's least significant difference (LSD) multiple comparison test when $P < 0.05$ (SYSTAT version 9.01; SPSS Inc, Chicago, Illinois).

Attraction of *I. pini* to ipsdienol-baited traps was interrupted by frontalin ($F_{5,24}$ = 3.464, P = 0.017). Catches in traps baited with frontalin released at three of the four highest rates were lower than those in control traps (Table 1). These rates may be similar to those arising from large aggregations of *D. ponderosae*, which can infest trees at densities ranging from 10 to 261 attacks/m^2 (Safranyik and Linton 1998). Frontalin, released at high rates, may have the potential to mitigate impacts of *I. pini* on forest resources in a fashion similar to that of the pheromone interruptants, ipsenol and verbenone, which can protect downed lodgepole pine from attacks by *I. pini* (Borden *et al.* 1992).

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