Attraction of *Hylastes opacus* (Coleoptera: Scolytidae) to nonanal

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Hylastes opacus Erichson is a recently introduced bark beetle in North America (Bright and Skidmore 1997; Hoebeke 1994; Rabaglia and Cavey 1994; Wood 1992). It is widely distributed in the Palearctic region, where it usually breeds in stumps and roots of dead or dying pines (*Pinus*) and occasionally other conifers (Hoebeke 1994). Like many species of bark beetles, *H. opacus* uses host volatiles as cues to search for suitable host material for feeding and establishment of broods. Hoebeke (1994) reported the attraction of *H. opacus* to ethanol-baited logs of Scots pine (*Pinus sylvestris* L.) and red pine (*Pinus resinosa* Ait.) in New York, United States of America. In Sweden, Schroeder and Lindelöw (1989) observed *H. opacus* responding to (–)-α-pinene and to ethanol released separately, but a synergistic increase in response did not occur when these two compounds were released together. In later experiments, Lindelöw et al. (1993) found that traps baited with ethanol alone, ethanol + (–)-α-pinene, and spruce turpentine caught significantly more *H. opacus* than unbaited traps. In these experiments, (–)-α-pinene alone was not attractive, and when (–)-α-pinene was combined with spruce turpentine and ethanol, it reduced catches of *H. opacus*. In 2002, while investigating attractants for the pine shoot beetle, *Tomicus piniperda* (L.) (TM Poland, P de Groot, S Burke, D Wakarchuk, RA Haack, and RW Nott, unpublished data), we unexpectedly found significant numbers of *H. opacus* in one of our experiments. Here we report that *H. opacus* is strongly attracted to nonanal.

The experiment was conducted in a Scots pine Christmas tree plantation in southern Ontario (Essa Township, 44°14′N, 79°48′W) and replicated in an abandoned Scots pine Christmas tree plantation in Michigan (Isabella County, 43°52′N, 84°69′W). The experiment compared attraction to nonanal, myrtenol, and *trans*-verbenol added to α-pinene individually and in all possible combinations as follows: (*i*) α-pinene, (*ii*) α-pinene + nonanal, (*iii*) α-pinene + *trans*-verbenol, (*iv*) α-pinene + myrtenol, (*v*) α-pinene + nonanal + *trans*-verbenol, (*vi*) α-pinene + nonanal + myrtenol, (*vii*) α-pinene + *trans*-verbenol + myrtenol, and (*viii*) α-pinene + all compounds. α-Pinene [95% (–)-α-pinene, 99% pure] was released from two 15-mL plastic vials at a combined release rate of 300 mg/day at 24°C. Nonanal (94% pure), *trans*-verbenol (95% pure, 3.2% *cis*-verbenol), and myrtenol (94% pure) were released individually from bubble caps at 13, 1.5, and 0.75 mg/day, respectively, at 24°C (Phero Tech Inc, Delta, British Columbia). Attractants were hung outside of the 12-unit funnel trap (Phero Tech Inc) from the top of the sixth funnel. A 1.0 × 1.0 × 0.9 cm piece of dichlorvos-impregnated plastic (Vapona No-Pest® strip Green Cross, Monsanto Inc, Mississauga, Ontario; Hot Shot No Pest Strip, Spectrum Group, St. Louis, Missouri) was placed in the collection cups to

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TABLE 1. Number of *Hylastes opacus* captured in multiple funnel traps in Ontario (2 April – 16 May 2002) and Michigan (30 April – 16 May 2002).

Treatment	Ontario	Michigan
α-Pinene	9.1±1.9*b*	1.4±0.4*b*
α-Pinene + nonanal	68.1±10.7*a*	17.3±3.7*a*
α-Pinene + *trans*-verbenol	12.7±2.6*b*	2.1±0.7*b*
α-Pinene + myrtenol	15.2±1.9*b*	3.1±0.7*b*
α-Pinene + nonanal + *trans*-verbenol	65.9±12.5*a*	19.9±3.1*a*
α-Pinene + nonanal + myrtenol	71.3±8.8*a*	16.4±2.7*a*
α-Pinene + *trans*-verbenol + myrtenol	12.7±1.1*b*	2.4±0.7*b*
α-Pinene + nonanal + *trans*-verbenol + myrtenol	95.9±16.8*a*	26.4±6.2*a*

NOTE: Baits consisted of α-pinene released at 300 mg/day, nonanal released at 13 mg/day, *trans*-verbenol released at 1.5 mg/day, and myrtenol released at 0.75 mg/day. Values are given as means ± SE and means within a column (each location) followed by the same letter are not different (Tukey's test on $\log_{10}(x + 1)$ transformed data, $P > 0.05$).

kill captured insects and reduce predation. Traps were spaced approximately 20 m apart in randomized complete blocks with 10 replicates per treatment.

The experiment was conducted from 28 February to 16 May 2002 in both Michigan and Ontario. Traps were checked at approximately 2-week intervals and captured insects were removed from the traps and stored frozen in sealed plastic bags until counted. Prolonged cold weather in March delayed the flight of *T. piniperda*, which was first retrieved from the traps on 1 April in Ontario. During the first 2-week collection period (2–16 April) in Ontario, the first *H. opacus* were captured and were collected until 16 May when the experiment was terminated. Similarly, in Michigan, *T. piniperda* were first observed in traps on 1 April. Collections were made on 11 April, 29 April, and 16 May. Although the presence of *H. opacus* was noted for the first 2 collection periods, they were only saved and counted for the final collection period covering 30 April – 16 May. Trap catches over the collection periods were pooled for each trap.

Trap-catch data were transformed by $\log_{10}(x + 1)$ to satisfy the assumptions of normality and homogeneity of variance (Zar 1999) and then analyzed by ANOVA using the general linear model for complete randomized block designs by SYSTAT® version 9.0 (SPSS Inc, Chicago, Illinois). Means were compared using Tukey's test with $\alpha = 0.05$.

Adult *H. opacus* showed a clear and consistent response to nonanal in Ontario and Michigan (Table 1). Traps containing nonanal caught significantly more *H. opacus* than traps without nonanal (Table 1). Traps baited with α-pinene + *trans*-verbenol, α-pinene + myrtenol, or α-pinene + both compounds were no more attractive to *H. opacus* than traps baited with α-pinene alone.

Nonanal is a ubiquitous aliphatic aldehyde found in at least 20 essential oils, including rose and citrus oils and the oil of several species of pine. It is also used in perfumery and as a flavouring agent. For Scolytidae bettles, nonanal has been shown to be an attractant, a disruptant, or neither. Czokajlo (1998) found nonanal in volatiles from *P. sylvestris* infested with *T. piniperda* and that it was attractive to *T. piniperda* in laboratory and field bioassays. Huber and Borden (2001) found that when nonanal was combined with two other aliphatic aldehydes, hexanal and (*E*)-2-hexanal (each released separately from devices), this combination reduced the trap catch of *Dendroctonus pseudotsugae* Hopkins to about 36% of attractant-baited only traps. Similarly, Pureswaran et al. (2000) found that nonanal disrupted the response of *Ips pini* (Say) to its primary pheromone, ipsdienol. On the other hand, *I. pini* was neither disrupted nor attracted to a lure consisting of nonanal, (±)-ipsdienol, and lanierone (Huber *et al.* 2001).

Use of traps baited with attractants is becoming increasingly important and necessary to augment cargo inspections to detect exotic insects, which threaten native forests and agricultural crops. Baited traps can be used to detect the presence of exotic insects outside port areas and help determine if quarantine would be feasible. Adding nonanal to traps containing (–)-α-pinene should increase the sensitivity of traps (by about 10-fold over the standard α-pinene lure) to detect the presence of *H. opacus*.

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