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SHORT COMMUNICATION

Effects of bark beetle pheromones on the attraction of *Monochamus alternatus* to pine volatiles

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Abstract We evaluated the attraction of *Monochamus alternatus* Hope (Coleoptera: Cerambycidae), *Dryocoetes luteus* Blandford and *Orthotomicus erosus* Wollaston (Coleoptera: Curculionidae: Scolytinae) to multiple-funnel traps baited with the pine volatiles, ethanol and (+)-α-pinene and the bark beetle pheromones, ipsenol and ipsdienol. *M. alternatus* were attracted to traps baited with ethanol and (+)-α-pinene but not those baited with ipsdienol and ipsenol. Ipsdienol and ipsenol decreased catches of *M. alternatus* in traps baited with ethanol and (+)-α-pinene. Traps baited with either binary combinations of ethanol and (+)-α-pinene or ipsdienol and ipsenol were attractive to *D. luteus* and *O. erosus*. The addition of ipsenol and ipsdienol to traps baited with ethanol and (+)-α-pinene synergized attraction of *O. erosus* but not *D. luteus*.

Key words bark beetle pheromones, *Dryocoetes luteus*, *Monochamus alternatus*, *Orthotomicus erosus*, pine volatiles

Introduction

In China and Japan, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae) is a serious pest management concern in stands of pines. Beetles transmit the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle (Nematoda: Aphelenchoididae), which causes a devastating pine wilt disease. Monoterpenes and ethanol produced from stressed hosts play an important role in host location by *M. alternatus* in Japan and China (Ikeda *et al.*, 1980; Song *et al.*, 1996; Jiang *et al.*, 1997; Zhao *et al.*, 2000). Traps baited with ethanol and α-pinene are effective in monitoring populations of *M. alternatus* in China. Field trials have demonstrated that (+)-α-pinene is the most attractive compound for *M. alternatus* and the addition of ethanol to host terpene greatly enhances attraction (Fan *et al.*, 2007).

In a comprehensive review of the chemical ecology of longhorn beetles, Allison *et al.* (2004) note that various species of *Monochamus* (Coleoptera: Cerambycidae) respond to conifer volatiles and bark beetle pheromones. In Texas, Billings and Cameron (1984) and Billings (1985) found a kairomonal response by *Monochamus titillator* (F.) to a blend of *Ips* spp. pheromones (ipsenol, ipsdienol and *cis*-verbenol). In southeastern United States, *M. titillator* is attracted to traps baited with ipsenol or ipsenol and ipsdienol (Miller & Asaro, 2005). Raffa (1991) reported that *M. carolinensis* (Olivier) were captured in ipsdienol-baited traps in Wisconsin. In British Columbia, Miller and Borden (1990) found that trap catches of *M. clamator* (LeConte) increased as the combined release rates of ipsdienol and (−)-β-phellandrene increased. Allison *et al.* (2001) found that four *Monochamus* spp. in northwestern North America respond to the pheromones of sympatric bark beetles, likely a mechanism for optimal foraging by adults for oviposition sites. In Spain, traps for

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M. galloprovincialis (Olivier) are baited with a combination of host volatiles and *Ips* pheromones (Pajares *et al.*, 2004; Ibeas *et al*., 2007).

Our objective was to assess the effects of *Ips* pheromones on enhancing the attraction of *M. alternatus* to traps baited with ethanol and (+)-α-pinene as they do for North American and European species of *Monochamus*. In addition, we monitored the responses of the bark beetles, *Dryocoetes luteus* Blandford and *Orthotomicus erosus* Wollaston (Coleoptera: Curculionidae: Scolytinae). The bark beetle *D. luteus* is an invasive species from New Zealand that has become established in China (Hu *et al.*, 2007) whereas *O. erosus* is a native pest species in China, which has also been introduced in Africa, North and South America (Haack, 2004; Seybold *et al.*, 2006).

Similar to Cerambycidae, bark beetles locate hosts or mates either by pheromones or by host volatiles, which at times can enhance responses of beetles to their respective pheromones (Byers, 1989; Seybold *et al.*, 2006). Host volatiles may provide bark beetles with information about the physiological states of the host (Lorio *et al.*, 1995; Klepzig *et al.*, 1995; Wallin & Raffa, 1999; Erbilgin & Raffa, 2000). There is no information on the chemical ecology of *D. luteus* and *O. erosus* in China.

Materials and methods

In 2007, we conducted one experiment at the Jingtingshan Forestry Centre of Xuancheng, Anhui Province, China, to assess the attraction of *M. alternatus* and associated species of beetles to a lure composed of four compounds: ethanol, (+)-α-pinene, ipsenol and ipsdienol. A 2 × 2 factoral design was employed with the following treatments: EA, ethanol and (+)-α-pinene; SD, ipsenol and ipsdienol; ALL, ethanol and (+)-α-pinene and ipsenol and ipsdienol; and CK, blank control. All lures were purchased from PheroTech Inc. (now Contech Inc., Delta, BC, Canada; Table 1). Unbaited traps were used as blank controls.

Forty eight-unit funnel traps were set in 10 replicate blocks of four traps per block. Funnel traps were suspended on wire rope attached horizontally between two adjacent trees with the collection cups approximately 50 cm above ground level. All traps were > 2 m from any tree to minimize the risk of spill-over attacks by beetles and reduce potential interference of tree volatiles with the traps and lures. Using a randomised block design, the four treatments were allocated to each trap within a block such that all treatments appear only once within a block. Blocks were set 20–25 m apart, whereas traps within each block were placed 10–12 m apart in a square layout. Each collection cup contained 150–200 mL of pink propylene glycol solution (Kebang, Tianjin Kebang Chemical Products Ltd, Tianjin, China). The experiment ran from May 28 to August 13, 2007. Data analyses on trap catches were carried out using statistical software SPSS 11.0 (2001) for Windows (SPSS Inc., Chicago, IL, US). For each species, differences in the numbers of beetles attracted by different treatments were analyzed by one-way analysis of variance (ANOVA). Means were compared with Bonferroni multiple-comparison test.

Results and discussion

Our results for *M. alternatus* are consistent with previous studies demonstrating the attractiveness of ethanol and (+)-α-pinene with other species of *Monochamus* in North America (Allison *et al.*, 2004; Miller, 2006). Traps baited with ethanol and (+)-α-pinene caught more *M. alternatus* than control traps (Fig. 1). Catches in traps baited with ipsdienol and ipsenol were not different from those in control traps. Traps baited with the full blend captured significantly more beetles than the control, but less than traps baited with ethanol and (+)-α-pinene. None of the control traps caught any *M. alternatus*.

Unlike many other species of *Monochamus*, *M. alternatus* was not attracted to traps baited with the bark beetle pheromones, ipsdienol and ipsenol. Perhaps bark beetles that produce the two pheromones tested here do not inhabit the same hosts as *M. alternatus*. However, other

Table 1 Chemical lures and enantiomeric purity of chemicals tested in the field assay.

Compound	Formula	Chemical purity (%)	Enantiomeric ratio (+:−)	Release rates at 23–25°C
(+)-α-pinene pouch	$C_{10}H_{16}$	>99	95: 5	2–5 g/day
Ethanol pouch	C_2H_5OH	>99	–	0.6 g/day
Ipsenol bubblecap	$C_{10}H_{18}O$	>98	50: 50	0.1–0.2 μg/day
Ipsdienol bubblecap	$C_{10}H_{16}O$	>98	50: 50	0.1–0.2 μg/day

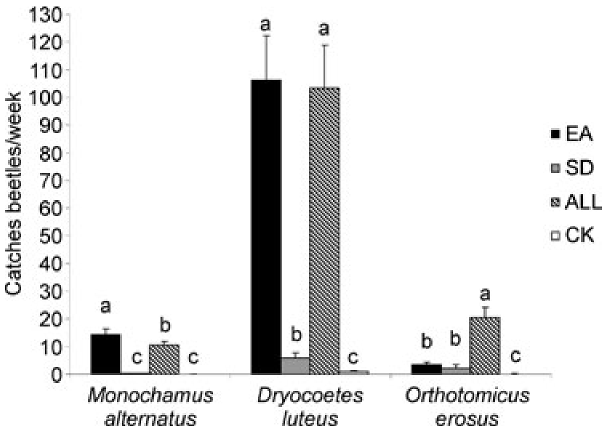

Fig. 1 Catches of *M. alternatus*, *D. luteus* and *O. erosus* in unbaited traps (CK) and traps baited with ethanol and (+)-α-pinene (EA), ipsenol and ipsdienol (SD), ethanol, (+)-α-pinene, ipsenol and ipsdienol (ALL) ($n = 10$). For each species, means followed by a different letter are significantly different at $\alpha = 0.05$ using the Bonferroni approach.

bark beetle pheromones, such as methylcyclohexanone (MCH), frontalin, *cis*-verbenol, may be important for *M. alternatus* as noted with other species of *Monochamus* (Allison *et al.*, 2001; Ibeas *et al.*, 2007). Further work is needed to determine possible bark beetle pheromones that might be associated with host material for *M. alternatus*.

We obtained some significant results with *D. luteus* and *O. erosus* (Fig. 1). Traps baited with the experimental treatments captured significantly more individuals of both *O. erosus* and *D. luteus* than did controls. The addition of ipsenol and ipsdienol to traps baited with ethanol and (+)-α-pinene had no effect on *D. luteus*. In contrast, catches of *O. erosus* were higher in traps baited with the full blend lures than in traps baited with the other treatments.

Our results with *D. luteus* provide further support for the use of traps baited with ethanol and α-pinene. Miller and Rabaglia (2009) recommended the continued use of separate traps baited with ethanol alone and ethanol with (−)-α-pinene to detect and monitor native and exotic bark and ambrosia beetles (Coleoptera: Scolytidae and Platypodidae).

Our results with *O. erosus* suggest that some, if not all, of the compounds in the full blend lures are important as attractants. Further work is required to determine the optimal blend, particularly with respect to the role of host volatiles. Traps baited with ipsdienol and methylbutenol have been found to be attractive to *O. erosus* in Europe and South Africa (Giesen *et al.*, 1984; Mendel, 1988). In the United States, Seybold *et al.* (2006) found that *O. erosus* was attracted to traps baited with methylbutenol and (−)-ipsdienol while the addition of (+)-ipsdienol decreased trap catch. They did not find any clear effect of host volatiles.

Finally, such knowledge supports the use of traps baited with the pine volatiles, ethanol and α-pinene, to detect and monitor Cerambycidae and bark beetles while providing information about the physiological states of the host.

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