SHORT COMMUNICATION

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

Jian-Ting Fan¹,², Daniel R. Miller³, Long-Wa Zhang⁴ and Jiang-Hua Sun²

¹ School of Forestry and Bio-technology, Zhejiang Forestry University, Lin’an, Zhejiang Province, China, ² State Key Laboratory of Integrated Management of Pest Insects and Rodents, Institute of Zoology, Chinese Academy of Sciences, Beijing, China, ³ Southern Research Station, USDA Forest Service, Athens, Georgia, USA, and ⁴ School of Forestry and landscape Architecture, Anhui Agriculture University, Hefei, China

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
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 factorial 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.

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.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
<th>Chemical purity (%)</th>
<th>Enantiomeric ratio (+:−)</th>
<th>Release rates at 23–25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>(+)-α-pinene pouch</td>
<td>C_{10}H_{16}</td>
<td>&gt;99</td>
<td>95:5</td>
<td>2–5 g/day</td>
</tr>
<tr>
<td>Ethanol pouch</td>
<td>C_{2}H_{5}OH</td>
<td>&gt;99</td>
<td>−</td>
<td>0.6 g/day</td>
</tr>
<tr>
<td>Ipsenol bubblecap</td>
<td>C_{10}H_{18}O</td>
<td>&gt;98</td>
<td>50:50</td>
<td>0.1–0.2 μg/day</td>
</tr>
<tr>
<td>Ipsdienol bubblecap</td>
<td>C_{10}H_{16}O</td>
<td>&gt;98</td>
<td>50:50</td>
<td>0.1–0.2 μg/day</td>
</tr>
</tbody>
</table>
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.

### Acknowledgments

This work was funded by the State Key Laboratory of Integrated Management of Pest Insects and Rodents (Grant No. ChineseIPM0904) and the National Nature Science Foundation of China (30800107, 30621003, 30525009). All experiments were done in China according to the rules of the ethical board for animal experiments, complying with the current laws of this country.

### References


