

# Attractive responses by *Monochamus galloprovincialis* (Col., Cerambycidae) to host and bark beetle semiochemicals

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**Abstract:** The pine sawyer *Monochamus galloprovincialis* is the European vector of the recently introduced pine wood nematode. This nematode is the causal organism of pine wilt disease, a serious tree killer in East Asia. Efficacious baits and traps to monitor and control this beetle are now required. The effect of bark beetle (*Ips* spp.) pheromone components, released individually (ipsenol) or in blends (ipsenol, ipsdienol, *cis*-verbenol and methyl-butenol), together with host volatiles (turpentine or  $\alpha$ -pinene and ethanol) on *M. galloprovincialis* trap catches has been studied in Spain. A kairomonal response by male and female of *M. galloprovincialis* to *Ips* semiochemicals was found. Beetles were more attracted to host blends supplemented with bark beetle pheromones than to host volatiles alone. Ipsenol alone was attractive to pine sawyers, and was synergistic with  $\alpha$ -pinene and ethanol. The full blend of the four *Ips* semiochemicals and the host compounds was highly attractive. Multiple-funnel traps were as effective as black cross-vane traps in capturing this insect when the escape of trapped beetles was prevented. Trapping of non-target bark beetle predators was also evaluated. The trogossitid *Temnochila coerulea* and clerid *Thanasimus formicarius* were kairomonally attracted to and killed in traps baited with bark beetle pheromones. These results suggest that effective monitoring of *M. galloprovincialis* would be possible by baiting any of these traps with host volatiles and *Ips* semiochemicals, but reduction of the lure components and trap modification to minimize impact on predators should be considered.

**Key words:** *cis*-verbenol,  $\alpha$ -pinene, ipsdienol, ipsenol, methyl-butenol, traps

## 1 Introduction

Bark and wood boring longhorn beetles form a large group of species usually colonizing woody plants that are severely stressed, often near to death, by fire, drought or by the action of other organisms. Many adults feed on nectar or pollen of flowers while others feed on bark in the crown of trees. Eggs are usually deposited in bark crevices or in niches chewed within the bark. Larvae bore under the bark, feeding in the phloem tissues, later mining into the sapwood, and in some cases into the heartwood, to complete their development and to finally pupate in characteristic pupal cells (BENSE, 1995). Most forest cerambycids are considered secondary pests of trees that could be included in the stressed or dead host species categories (*sensu* HANKS, 1999), representing good biological indicators of forest biodiversity. However, a few species are capable attacking and killing living, healthy trees or those with defences that have been weakened (HANKS et al., 1995; HANKS, 1999; SMITH and HUMBLE, 2000; MACLEOD et al., 2002).

The most economically important damage produced by longhorned beetles is timber degradation caused by larva boring in the sapwood and heartwood. For example, estimated degrade losses caused by cerambycid larvae in Canada have been set at \$43 million annually in British Columbia (Phero Tech Inc. unpub-

lished report, 1997, in McINTOSH et al., 2001) or as high as 30% in log yards in Alberta (SAFRANYIK and RASKE, 1970). In Europe, timber degradation by *Monochamus sutor* (Linnaeus), *Monochamus sartor* (Fabricius) and *Tetropium castaneum* (Linnaeus) affected 120 000 m<sup>3</sup> of pine and 225 000 m<sup>3</sup> of spruce in Romania during the 1990s (EVANS et al., 2004). Apart from this damage, the roles of the species in the genus *Monochamus* Dejean as vectors of the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner et Buhner) Nickle, the causal agent of pine wilt disease, are of enormous relevance. Healthy trees are inoculated with nematodes during adult maturation feeding on the shoots (MAMIYA and ENDA, 1972) and transmission to susceptible dying or dead trees occurs during female oviposition. Disease expression and extensive tree mortality has been associated with the presence of highly susceptible tree species, suitable vector species and mean daily summer temperatures above 20°C (RUTHERFORD et al., 1990). Pest risk assessments concluded that the nematode would survive in Europe, although tree mortality would likely be restricted to the warmer southern countries (EVANS et al., 1996). Recent discovery of the pine wood nematode causing death of *Pinus pinaster* trees in Portugal (MOTA et al., 1999) has created great concern in Europe. *Monochamus galloprovincialis* (Olivier) has

been confirmed as the vector of *B. xylophilus* in Portugal (SOUSA et al., 2001), thus increasing the demand for effective methods to monitor and control this beetle.

Many woodborers infesting dying conifers are known to be attracted by host odours (PHILLIPS et al., 1988) and commercial baits are currently based on host monoterpenes ( $\alpha$ -pinene) and ethanol. BILLINGS and CAMERON (1984) and BILLINGS (1985) demonstrated in North America a kairomonal response by *Monochamus titillator* (Fabricius) to blends of bark beetle pheromones, synergized by host turpentine. ALLISON et al. (2001, 2003) suggest that this behaviour may benefit host-seeking woodborers by mitigating the cost of host location and placing larval cerambycids in the proximity of bark beetle larvae which may serve as prey items. Recent studies have found kairomonal responses by four other *Monochamus* species in Canada [*M. clamator* (LeConte), *M. scutellatus* (Say), *M. notatus* Casey and *M. obtusus* Drury] to bark beetle pheromone blends consisting of ipsenol, ipsdienol, 3-methyl-2-cyclohexen-1-one and frontalin (ALLISON et al., 2001). Further research on the individual bioactivity of bark beetle semiochemicals showed that ipsenol and ipsdienol, aggregation pheromones of *Ips* DeGeer spp., were highly synergistic to  $\alpha$ -pinene and ethanol in the attraction of *M. clamator* and *M. scutellatus*, whereas pheromone compounds emitted by *Dendroctonus* Erichson spp. were not (ALLISON et al., 2003).

Several trap designs have been tested for capturing large woodborers. It has been shown that traps with black silhouettes are significantly more effective in capturing woodborer cerambycids, including *M. scutellatus*, than traps with clear vanes (DE GROOT and NOTT, 2001). In another experiment, black-panel cross-vane traps were more effective than dry multiple-funnel traps for capturing several North American *Monochamus* species (MCINTOSH et al., 2001). Of the three suggested potential limitations of multiple-funnel traps for trapping *Monochamus* beetles [(i) escape by captured insects from the collecting cup, (ii) insects falling outside the funnel column and (iii) poor visual orientation to a narrow silhouette], the former proved to be important. Thus, when multiple-funnel traps were provided with water-filled collecting cups they

were as effective as cross-vane traps in trapping *M. scutellatus* and *M. obtusus* (MOREWOOD et al., 2002).

In this paper we report results of field experiments aimed to: (i) determine if *M. galloprovincialis* would also present a kairomonal response to *Ips* spp. pheromone components that could be used for control purposes, (ii) compare the efficacy of black-panel cross-vane traps vs. multiple-funnel traps in capturing *M. galloprovincialis* and (iii) determine if non-target bark beetle predators would be also attracted and captured.

## 2 Materials and Methods

Four experiments were carried out at two different sites in north-west and south-east Spain. Experiments 1 and 2 were set up at a planted *P. pinaster* forest with trees approximately 60 years old in Sierra de la Culebra, Zamora, and were conducted from 26 June to 8 August and 8 August to 6 October 2003 respectively. They compared 12-unit multiple-funnel traps (LINDGREN, 1983; Phero Tech Inc. Delta, BC, Canada) to cross-vane traps made by the authors with two interlocked black PVC panels, 80 cm high, 30 cm wide, held at right angles by an iron frame and connected to a 33-cm diameter white plastic funnel ending in a 500 ml collecting bottle. Both traps were tested baited with host volatile stimuli either alone or supplemented by a blend of *Ips* spp. semiochemicals (table 1). Traps were hung by a rope to branches of trees and suspended 3–4 m above ground. The four treatments for experiments 1 and 2 were: host volatiles in (i) cross-vane traps or (ii) multiple funnel traps, host volatiles plus *Ips* spp. pheromone blend in (iii) cross-vane or (iv) multiple-funnel traps. Host volatiles consisted of *Pinus* spp. turpentine plus ethanol in experiment 1 and of  $\alpha$ -pinene and ethanol in experiment 2. The pheromone blend was composed of ipsdienol, *cis*-verbenol and 2-methyl-3-butenol in experiment 1 and of ipsdienol, ipsenol and 2-methyl-3-butenol in experiment 2.

Experiments 3 and 4 were conducted from 20 June to 10 August and 10 August to 26 September 2003, in a *Pinus halepensis* natural forest at Sierra Espuña, Murcia. They tested the response of *M. galloprovincialis* to different combinations of host volatiles and *Ips* pheromone compounds deployed in 12-unit multiple-funnel traps suspended between trees with the top funnel 1.8 m above ground.

**Table 1.** Compounds tested as attractants for *Monochamus galloprovincialis* in field experiments

| Compound                | Chemical purity (%)   | Enantiomeric ratio (+:–) | Source <sup>a</sup> | Release device <sup>b</sup> | Release rate (mg/24 h) <sup>c</sup> |
|-------------------------|-----------------------|--------------------------|---------------------|-----------------------------|-------------------------------------|
| Ipsenol                 | 99                    | 50:50                    | Phero Tech          | Bubble cap                  | 0.40                                |
| Ipsdienol               | 95                    | 50:50                    | Phero Tech          | Bubble cap                  | 0.20                                |
| <i>cis</i> -verbenol    | 90 (5% <i>trans</i> ) | 20:80                    | Phero Tech          | Bubble cap                  | 0.25                                |
| 2-methyl-3-butenol      | 99                    | Not Chiral               | Phero Tech          | Bubble cap                  | 11                                  |
| $\alpha$ -pinene        | 95                    | 5–10:90–95               | Esencias Catalá     | Plastic vial                | 2106                                |
| Ethanol                 | 96                    | Not Chiral               | Panreac             | Plastic vial                | 1179                                |
| Turpentine <sup>d</sup> | –                     | –                        | Unión Resinera      | Plastic vial                | 2620                                |

<sup>a</sup> Phero Tech Inc. Delta, BC, Canada; Esencias Catalá S.L., Gandía, Valencia, Spain; Panreac Química S.A., Montcada i Reixac, Barcelona, Spain; Unión Resinera Española S. A., Madrid, Spain.  
<sup>b</sup> Release devices for ipsdienol, ipsenol, *cis*-verbenol and 2-methyl-3-butenol were from Phero Tech Inc. Release devices for  $\alpha$ -pinene, ethanol and turpentine were 50 ml plastic vials with perforated caps. All compounds were released separately.  
<sup>c</sup> Release rates for ipsdienol, ipsenol, *cis*-verbenol and 2-methyl-3-butenol were determined at 25°C by Phero Tech Inc.; release rates for  $\alpha$ -pinene, ethanol and turpentine were gravimetrically calculated at Universidad de Valladolid at 27–30°C.  
<sup>d</sup> Turpentine distilled from *Pinus* spp. resin. Major compounds were determined at INIA, Madrid, Spain, as:  $\alpha$ -pinene (65.1%),  $\beta$ -pinene (20.8%), limonene (1.9%), longifolene (1.6%), camphene (1.1%).

Experiment 3 tested the effect of supplementing host volatiles with ipsenol and ipsdienol. Treatments were: turpentine plus ethanol (i) alone; (ii) plus ipsenol; (iii) plus ipsenol and ipsdienol and (iv) plus ipsdienol, *cis*-verbenol and 2-methyl-3-butenol. Experiment 4 tried to determine if there was synergism between ipsenol and host volatiles and compare it with a full blend of host and *Ips* compounds. Traps were baited with (i)  $\alpha$ -pinene plus ethanol; (ii) ipsenol; (iii)  $\alpha$ -pinene plus ethanol and ipsenol and (iv)  $\alpha$ -pinene plus ethanol, ipsenol, ipsdienol, *cis*-verbenol and 2-methyl-3-butenol.

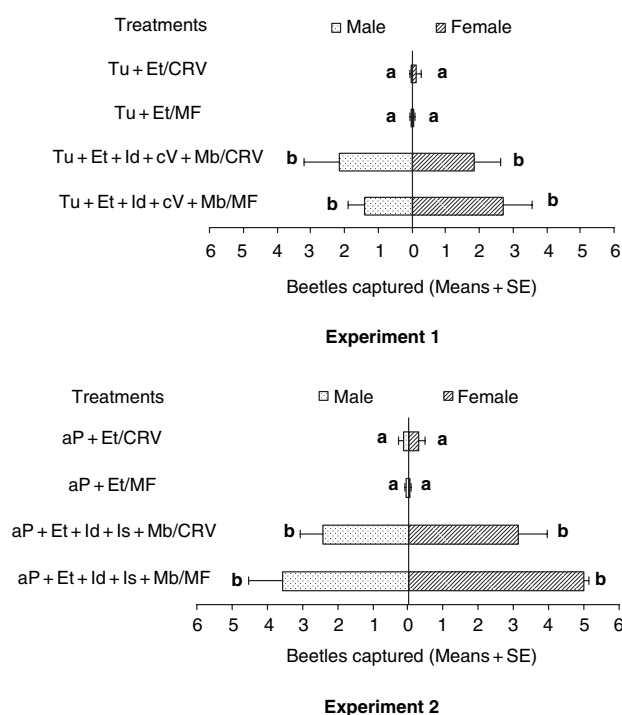
All experiments were deployed in seven randomized complete blocks. Distance between traps was at least 100 m and nearest blocks were 700 m apart. Collecting cups were provided with a small piece of DDVP insecticide (Econex S. L., Murcia, Spain) to avoid escape of the trapped beetles. Captured *M. galloprovincialis* were collected every 10–14 days and stored frozen until identified and sexed (VIVES, 2000). Adults of bark beetle predators *Thanasimus formicarius* (Linnaeus) and *Temnochila coerulea* (Olivier) were also collected to assess trapping of these natural enemies.

Data for each sex or species (predators) were transformed by  $\log_{10}(x + 1)$  to meet assumptions of normality and homocedasticity, and subjected to ANOVA (GLM) for randomized complete blocks with the SAS System software (SAS INSTITUTE INC., 1999–2000). Mean values were compared by Tukey's multiple comparisons test at  $\alpha = 0.05$ .

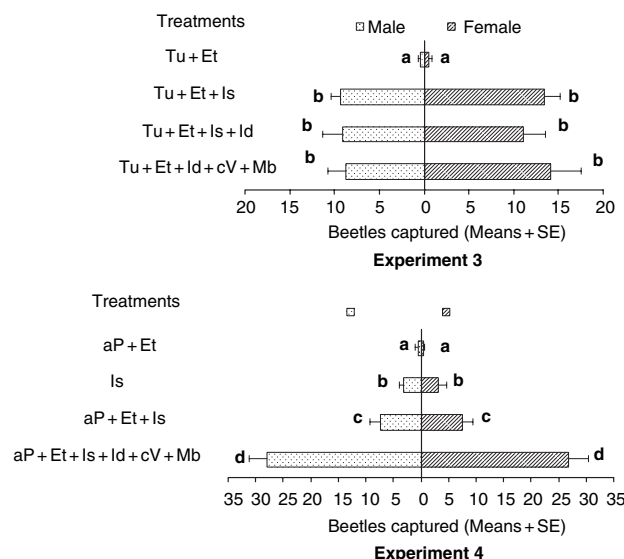
### 3 Results

In experiments 1 and 2, catches of both sexes of *M. galloprovincialis* were significantly greater in traps baited with host volatiles plus the three-component blend of *Ips* spp. pheromones than in traps baited with host volatiles alone (fig. 1). Host volatiles alone (either turpentine plus ethanol in experiment 1 or  $\alpha$ -pinene plus ethanol in experiment 2) resulted in low trap catches at the release rates tested. No differences were observed in the trap catches of cross-vane traps and multiple-funnel traps baited with either host volatiles alone or host volatiles plus bark beetle semiochemicals in either experiment 1 or 2. This suggests that both types of traps are equally effective in capturing *M. galloprovincialis*, providing the insects cannot escape from the collecting receptacle.

In experiment 3, multiple funnel traps baited with *Pinus* spp. turpentine plus ethanol trapped very few individuals of *M. galloprovincialis* (fig. 2). Addition of ipsenol to the host blend greatly increased catches of males and females of this beetle. Traps baited with host volatiles, ipsenol and ipsdienol did not catch any more beetles than traps baited with host volatiles plus ipsenol alone. Similarly, the addition of the three-component pheromone blend tested in experiment 1, ipsdienol, *cis*-verbenol and methyl-butenol, to traps baited with host volatiles alone, had the same effect on *M. galloprovincialis* trap catches as the addition of ipsenol alone. Experiment 4 tested the synergistic effect between host volatiles and ipsenol. As before, traps baited with host



**Fig. 1.** Catches of *Monochamus galloprovincialis* in Sierra de la Culebra, Zamora, Spain to cross-vane (CRV) or to multiple-funnel (MF) traps baited with host volatile blend alone or supplemented with *Ips* spp. pheromone blend. Components are Tu, turpentine; aP,  $\alpha$ -pinene; Et, ethanol; Id, ipsdienol; Is, ipsenol; cV, *cis*-verbenol; Mb, 2-methyl-3-butenol. For each sex, bars followed by the same letter are not significantly different. Tukey's test,  $P > 0.05$ . ANOVA statistics are: experiment 1: males  $F = 3.02$ ,  $d.f. = 9$ ,  $P = 0.0221$ ,  $n = 7$ ; females  $F = 4.18$ ,  $d.f. = 9$ ,  $P = 0.0048$ ,  $n = 7$ ; experiment 2: males  $F = 7.58$ ,  $d.f. = 9$ ,  $P = 0.0001$ ,  $n = 7$ ; females  $F = 9.99$ ,  $d.f. = 9$ ,  $P < 0.0001$ ,  $n = 7$



**Fig. 2.** Catches of *Monochamus galloprovincialis* in Sierra Espuña, Murcia, Spain to multiple-funnel traps baited with host volatile blend alone or with *Ips* spp. semiochemicals. Components are Tu, turpentine; aP,  $\alpha$ -pinene; Et, ethanol; Id, ipsdienol; Is, ipsenol; cV, *cis*-verbenol; Mb, 2-methyl-3-butenol. For each sex, bars followed by the same letter are not significantly different. Tukey's test,  $P > 0.05$ . ANOVA statistics are: experiment 3: males  $F = 9.19$ ,  $d.f. = 9$ ,  $P < 0.0001$ ,  $n = 7$ ; females  $F = 10.57$ ,  $d.f. = 9$ ,  $P < 0.0001$ ,  $n = 7$ ; experiment 4: males  $F = 21.45$ ,  $d.f. = 9$ ,  $P < 0.0001$ ,  $n = 7$ ; females  $F = 19.81$ ,  $d.f. = 9$ ,  $P < 0.0001$ ,  $n = 7$

| Experiment | Treatments                  | Number of beetles captured (mean $\pm$ SE) |                               |
|------------|-----------------------------|--|-------------------------------|
|            |                             | <i>Temnochila coerulea</i>                 | <i>Thanasimus formicarius</i> |
| 1          | Tu + Et/CRV                 | 16.14 $\pm$ 6.81 ab                        | 0.00 $\pm$ 0.00 a             |
|            | Tu + Et/MF                  | 9.42 $\pm$ 2.65 a                          | 0.00 $\pm$ 0.00 a             |
|            | Tu + Et + Id + cV + Mb/CRV  | 42.14 $\pm$ 11.89 c                        | 2.14 $\pm$ 1.06 b             |
|            | Tu + Et + Id + cV + Mb/MF   | 30.42 $\pm$ 9.59 bc                        | 1.43 $\pm$ 0.48 b             |
| 2          | aP + Et/CRV                 | 4.29 $\pm$ 1.43 a                          | 0.71 $\pm$ 0.29 ab            |
|            | aP + Et/MF                  | 3.86 $\pm$ 1.37 a                          | 0.14 $\pm$ 0.14 a             |
|            | aP + Et + Id + Is + Mb/CRV  | 12.86 $\pm$ 4.56 a                         | 2.00 $\pm$ 0.54 ab            |
|            | aP + Et + Id + Is + Mb/MF   | 9.86 $\pm$ 3.11 a                          | 3.86 $\pm$ 2.09 b             |
| 3          | Tu + Et                     | 14.00 $\pm$ 2.91 a                         |                               |
|            | Tu + Et + Is                | 31.85 $\pm$ 12.23 a                        |                               |
|            | Tu + Et + Id + Is           | 28.86 $\pm$ 4.05 a                         |                               |
|            | Tu + Et + Id + cV + Mb      | 22.86 $\pm$ 5.03 a                         |                               |
| 4          | aP + Et                     | 2.71 $\pm$ 0.61 a                          |                               |
|            | Is                          | 2.00 $\pm$ 0.38 a                          |                               |
|            | aP + Et + Is                | 4.71 $\pm$ 1.41 ab                         |                               |
|            | aP + Et + Is + Id + Is + Mb | 6.71 $\pm$ 1.46 b                          |                               |

Tu, turpentine; aP,  $\alpha$ -pinene; Et, ethanol; Is, ipsenol; Id, ipsdienol; cV, *cis*-verbenol; Mb, 2-methyl-3-butenol. For each experiment and species, means followed by the same letter are not significantly different. Tukey's test,  $P > 0.05$ . ANOVA statistics are: *T. coerulea*: experiment 1,  $F = 9.46$ , d.f. = 9,  $P < 0.0001$ ,  $n = 7$ ; experiment 2,  $F = 5.00$ , d.f. = 9,  $P = 0.0018$ ,  $n = 7$ ; experiment 3,  $F = 2.01$ , d.f. = 9,  $P = 0.0987$ ,  $n = 7$ ; experiment 4,  $F = 3.47$ , d.f. = 9,  $P = 0.0119$ ,  $n = 7$ ; *T. formicarius*: experiment 1,  $F = 15.47$ , d.f. = 9,  $P < 0.0001$ ,  $n = 7$ ; experiment 2,  $F = 2.18$ , d.f. = 9,  $P = 0.0766$ ,  $n = 7$ .

**Table 2.** Catches of bark beetle predators in Sierra de la Culebra, Zamora (exp. 1 and 2) and in Sierra Espuña, Murcia (exp. 3 and 4), Spain, in cross-vane (CRV) or multiple-funnel (MF) traps baited with different combinations of host and *Ips* spp. semiochemicals

stimuli ( $\alpha$ -pinene and ethanol) alone did not captured many beetles (fig. 2). Traps baited with ipsenol alone captured six times more beetles than those baited with the host blend alone. A synergistic effect was observed when both baits were released together. Catches of both male and female *M. galloprovincialis* obtained by host stimuli plus ipsenol were two times higher than those resulting from the sum of catches obtained by the host stimuli alone and ipsenol alone. Addition of the full blend of *Ips* spp. components, ipsdienol, ipsenol, *cis*-verbenol and methyl-butenol, to  $\alpha$ -pinene and ethanol significantly raised the catches (3.6 times) of both sexes compared with those in traps releasing  $\alpha$ -pinene, ethanol and ipsenol.

Two major bark beetle predators, *Temnochila coerulea* (Trogossitidae) and *Thanasimus formicarius* (Cleridae), were also captured (table 2). *Temnochila coerulea* trap catches were high during the first half of the summer in both sites (experiments 1 and 3) but catches dropped notably during the second half. A clear kairomonal response of this species to bark beetle semiochemicals was found in experiment 1 (site 1, early summer) but in the other tests no significant differences occurred between baits releasing the host blend alone or supplemented with bark beetle compounds, although mean values were always higher in the later case. Fewer *T. formicarius* were trapped than *T. coerulea* in site 1; however this predator was also attracted to bark beetle blends. No effect of trap type on trap catches was observed for either of these predators.

#### 4 Discussion

Our results extend to *M. galloprovincialis* the kairomonal response to bark beetle pheromones found for other *Monochamus* species in North America (BILLINGS and CAMERON, 1984; BILLINGS, 1985; ALLISON et al., 2001,

2003). In all experiments, addition of blends of *Ips* spp. pheromone components greatly increased attraction to host volatiles. Ipsenol, the sole pheromone component tested individually, was attractive to both sexes of *M. galloprovincialis*, corroborating the previous finding by ALLISON et al. (2003) that this compound is a kairomone for *M. scutellatus* and *M. clamator*. Even ipsenol alone was more attractive to *M. galloprovincialis* than  $\alpha$ -pinene plus ethanol, and a synergistic effect was found when the three compounds were released together (experiment 4; fig. 2). Notably, a very high number of beetles were captured with the full blend of  $\alpha$ -pinene, ethanol, ipsenol, ipsdienol, *cis*-verbenol and methyl-butenol (experiment 4; fig. 2). The significance of this result is enhanced by the fact that *M. galloprovincialis* populations in the trapping area were estimated to be of moderate to low level, based on the existing breeding material. The practical application of a six-component lure is unclear. Although very effective in attracting *M. galloprovincialis*, it may be too complex and costly for use in operational monitoring or mass trapping programmes. However, it may be possible to improve this bait by reducing the number of components without lowering its effectiveness.

Host monoterpenes and ethanol are known to attract several woodborers infesting stressed or moribund conifer trees. In Japan, the vector of the pine wilt disease *Monochamus alternatus* Hope, was attracted to a blend of 10 monoterpenes (IKEDA et al., 1980, 1981). The North American pine sawyers *Monochamus carolinensis* (Olivier) and *M. titillator* were captured in higher numbers in traps baited with turpentine plus ethanol than in those baited with turpentine alone (FATZINGER, 1985). In another study, trap catches of *M. carolinensis* were unaffected by the addition of ethanol to turpentine, while attraction of *M. titillator* was enhanced (PHILLIPS et al., 1988). CHÉNIER and PHILOGÈNE (1989) found that  $\alpha$ -pinene was more attractive to

*M. scutellatus* than a blend of other minor turpentine components ( $\beta$ -pinene, 3-carene, limonene, myrcene and camphene) and stated that  $\alpha$ -pinene and ethanol acted synergistically, although this result was not clear-cut. In our experiments, host volatile baits, whether turpentine plus ethanol or  $\alpha$ -pinene plus ethanol, had very little effect on *M. galloprovincialis* trap catches. Release rates were quite high and comparable with North American studies that did observe an effect (ALLISON et al., 2001, 2003). It is possible that the low catches observed in this study may be the result of the low population levels in the study area. In any case, a synergism was observed between  $\alpha$ -pinene and ethanol and ipsenol (experiment 4; fig. 2). Consequently, host volatiles should be considered an integral component of effective baits for mass-trapping *M. galloprovincialis*. The possibility that only  $\alpha$ -pinene is required to enhance the response deserves further testing.

All the four bark beetle components in the most attractive bait are emitted in the pheromonal signals from European Ipin species infesting pines [e.g. *Ips sexdentatus* (Boerner), *Ips acuminatus* (Gyllenhal), *Ips mansfeldii* (Watchl) and *Ips (Orthotomicus) erosus* (Wollaston) (KOHLE et al., 1988, 1993)]. These are generally secondary species breeding in stressed, fallen or dying trees, but some may become primary attackers and kill healthy trees when favourable conditions (drought, windthrown trees, forest fires) allow populations to reach outbreak levels. Dispersal flights of these species widely overlap spatially and temporally with that of *M. galloprovincialis* during the summer, so it would be advantageous for the pine sawyers to respond kairomonally to the pheromonal signals released by these secondary bark beetles. On the contrary, primary bark beetles obligatorily attack standing, living trees, although they do not always succeed in killing them. In that sense, signals from these primary attackers would be less reliable indicators of suitable host material for woodborers and this may explain the lack of response by North American *Monochamus* to *Dendroctonus* spp. pheromones (ALLISON et al., 2003). In North America, ipsenol significantly enhanced attraction of both sexes of *M. clamator* and of *M. scutellatus* males to host volatiles. Similarly, ipsdienol also increased the response of *M. clamator* to the host blend. However, only the response of *M. scutellatus* females was significantly higher to traps baited with both ipsenol and ipsdienol than to each individually added to the host blend (ALLISON et al., 2003). In our case, ipsenol was attractive to *M. galloprovincialis*, either released alone (experiment 4; fig. 2) or when combined with the host blend (experiments 3 and 4; fig. 2). Addition of ipsdienol to the host plus ipsenol bait did not increase response (experiment 3; fig. 2). The other two components of the highly attractive bait, *cis*-verbenol and methyl-butenol, were only tested in blends so it is difficult to know their role in attraction. Specific tests to ascertain the individual role of these components are needed.

Multiple-funnel traps were as effective as cross-vane traps for trapping *M. galloprovincialis* in experiments 1 and 2, and captured a sizeable number of these beetles in experiments 3 and 4. Both traps presented a similar

black silhouette to the insects but trapping surface of cross-vane traps was 32% greater (5717 cm<sup>2</sup> vs. 7540 cm<sup>2</sup>). MOREWOOD et al. (2002) studied the reasons of the lower efficacy of multiple-funnel traps with dry collection cups compared with cross-vane traps when capturing *Monochamus* spp. (McINTOSH et al., 2001). They observed that the poorer performance of the multiple-funnel traps was the result of the escape of the insects from the dry cups and not to the falling outside of the funnel column. In our experiments, beetles were prevented from escaping by killing them with a small block of insecticide. Thus, the light, easy-to-use, standard multiple-funnel trap seems effective enough for operational trapping of *M. galloprovincialis*, but escape of captured insects must be somehow avoided (insecticide, water filling, etc.). However this requirement would lead to the elimination of non-target insects, particularly bark beetle predators. Kairomonal responses of bark beetle natural enemies to bark beetle semiochemicals and host volatiles are well known (e.g. DAHLSTEN, 1982; GRÉGOIRE et al., 1992; ROSS and DATERMAN, 1995; DAHLSTEN et al., 2003; SCHROEDER, 2003). In this study high numbers of *T. coerulea* and *T. formicarius* were attracted and subsequently killed in traps baited with these stimuli. Thus, if these stimuli were used for trapping *M. galloprovincialis*, bark beetle predators would also be removed along with the target species. This may have negative effects on bark beetle population dynamics. Minimizing the capture of predators is then required and some simple modifications of trap design have already been tested (ROSS and DATERMAN, 1998). For example, differences in size between these species could allow using a screen filter of appropriate size within the collection cup, retaining *Monochamus* beetles and leaving predators to escape through the open drainage hole in the bottom.

Results presented here shows the potential of attractive baits containing host volatiles and *Ips* semiochemicals (experiment 4) deployed in multiple-funnel traps for operational monitoring and trapping of *M. galloprovincialis*. However, improvement of the lure (i.e. reduction of components) and trap modification should be studied before a trap-out programme for this species is considered.

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