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Fuscumol and fuscumol acetate are general attractants for many species of cerambycid beetles in the subfamily Lamiinae

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Abstract

(*E*)-6,10-dimethyl-5,9-undecadien-2-ol (fuscumol) is an important component of male-produced aggregation pheromones for several species of cerambycid beetles in the genus *Tetropium* (subfamily Aseminae/Spondylidinae). Here, we describe the experiments that tested the hypothesis that fuscumol and/or fuscumol acetate also are general attractants for species in the cerambycid subfamily Lamiinae. At field sites in northwestern Indiana and central Texas (USA), panel traps baited with fuscumol or its acetate captured 331 lamiine beetles, compared to 11 beetles captured in control traps. Three species were attracted to traps baited with fuscumol as a single component, whereas another four species were attracted to fuscumol acetate alone. Surprisingly, fuscumol acetate also attracted two species in the subfamily Cerambycinae: *Xylotrechus colonus* (Fabricius) (males of which produce a pheromone composed only of stereoisomers of 2,3-hexanediol and 3-hydroxyhexan-2-one), and *Obrium maculatum* (Olivier) (for which a pheromone has yet to be identified). In an independent field experiment in east-central Illinois (USA), traps baited with fuscumol and/or its acetate captured 136 beetles of eight lamiine species, all but one species of which were also captured in the other experiment. Blending fuscumol and its acetate did not inhibit responses of species to either of the individual compounds, but synergized their activity for one species. Our results support the hypothesis that fuscumol and fuscumol acetate are widespread pheromone components or attractants for a variety of cerambycid species, especially lamiines in the tribe Acanthocinini.

Introduction

Volatile aggregation pheromones produced by males, and sex pheromones produced by females have been described recently for several species of cerambycid beetles (e.g., Millar et al., 2009; Ray et al., 2009, 2011; Rodstein et al., 2011). Male beetles of the subfamily Cerambycinae emit pheromones that attract both sexes when on larval host plants (Lacey et al., 2004), suggesting that these pheromones may signal the presence of breeding material that is scarce and ephemeral (Hanks, 1999). Similarly, beetles of the genus *Tetropium* (subfamily Aseminae/Spondylidinae; Monné & Hovore, 2005; Bousquet et al., 2009) are only attracted to aggregation pheromones when odors of host plants are present (Silk et al., 2007).

There appears to be considerable parsimony within the family Cerambycidae in relation to pheromone biosynthesis and closely related species of cerambycids often share pheromone components or even produce pheromones of

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identical composition. For example, (*R*)-3-hydroxyhexan-2-one is a common, and often the sole component of volatile pheromones of many species in the large subfamily Cerambycinae (Hanks et al., 2007; Millar et al., 2009; Ray et al., 2009). This similarity in pheromone composition across cerambycine species can result in simultaneous attraction of multiple species to traps baited with a single synthetic pheromone component. Thus, in field bioassays, racemic 3-hydroxyhexan-2-one and the structurally related 2,3-hexanediols serve as general attractants for many cerambycine species, and may even attract species that do not actually produce them (Lacey et al., 2004; Hanks et al., 2007). In a different subfamily, the Prioninae, the female-produced pheromone of *Prionus californicus* Motschulsky (3,5-dimethyldodecanoic acid; Rodstein et al., 2011) has been shown to attract males of seven congeners (Barbour et al., 2011). Similarly, in the subfamily Lamiinae, 2-(undecyloxy)-ethanol not only serves as the male-produced aggregation pheromone for *Monochamus galloprovincialis* (Olivier) (Pajares et al., 2010), but also attracts both sexes of other congeners (Teale et al., 2011; unpubl.).

(*E*)-6,10-dimethyl-5,9-undecadien-2-ol (fuscumol) has been identified as a male-produced aggregation pheromone for the invasive European cerambycid *Tetropium fuscum* (Fabricius) and its North American congener *Tetropium cinnamopterum* (Kirby) (Silk et al., 2007). It also attracts and is likely a pheromone component for another European species, *Tetropium castaneum* (L.) (Sweeney et al., 2010). In addition, this same compound has been identified as a pheromone component for two South American species in the subfamily Lamiinae: *Hedypathes betulinus* (Klug) (Fonseca et al., 2010) and *Steirastoma breve* (Sulzer) (Liendo et al., 2005; C Liendo, pers. comm.). Males of both species also produce (*E*)-6,10-dimethyl-5,9-undecadien-2-one (common name: geranylacetone; Fonseca et al., 2010; C Liendo, pers. comm.) and *H. betulinus* produces (*E*)-6,10-dimethyl-5,9-undecadien-2-yl acetate ('fuscumol acetate'; Fonseca et al., 2010). These findings suggest that fuscumol and its analogs may be common pheromone components for a diversity of species across subfamilies of the Cerambycidae. In fact, in recent years, we have consistently captured several lamiine species in traps baited with the blend of fuscumol and its acetate during field trials in east-central Illinois that targeted asemine species (RF Mitchell, unpubl.). Herein, we describe experiments, conducted in Indiana, Illinois, and Texas, that specifically address the hypothesis that fuscumol and fuscumol acetate represent another widespread motif for cerambycid beetle pheromones, analogous to the 3-hydroxyalkan-2-one and 2,3-alkanediol motifs.

Materials and methods

Synthesis of compounds

Geranylacetone (97 g, 0.5 mol; Aldrich Chemical, Flavor and Fragrance Division, Milwaukee, WI, USA) was purchased as a 1:1.25 mixture of (*Z*)- and (*E*)-isomers due to the prohibitive cost of the pure (*E*)-isomer. Lithium aluminum hydride (6.3 g, 166 mmol) was added in portions over 20 min to 1 l of dry ether at 0 °C under argon atmosphere. Geranylacetone in 100 ml dry ether was added dropwise to the resulting slurry over 40 min, and the mixture was warmed to room temperature overnight, during which time, it became viscous. After checking that the reduction was complete using thin layer chromatography on silica gel [the reactant and product had virtually identical retention times by gas chromatography (GC) on a DB-5 column], the magnetic stir-bar was replaced with a mechanical stirrer, and the mixture was cooled in an ice-bath while adding, sequentially and dropwise, 6.64 ml water (caution: vigorous hydrogen evolution!), 5 ml aqueous 20% NaOH, and 23.5 ml water. The mixture was stirred for an additional 20 min, during which time, the metal salts formed a granular white precipitate. The mixture was filtered with suction, rinsing the filter cake with ether. The filtrate was extracted with water and brine, then dried over anhydrous Na_2SO_4, and concentrated on a rotary evaporator at room temperature. The residue was purified by Kugelrohr distillation (oven temperature ca. 80 °C, 0.2 mm Hg), yielding racemic fuscumol [hence (*E/Z*)-fuscumol] as a clear, colorless oil [94.6 g, 97% yield, >98% chemically pure by GC, 1:1.25 mixture of racemic (*Z*)- and (*E*)-isomers]. The nuclear magnetic resonance (NMR) and mass spectra were analogous to those recently reported (Fonseca et al., 2010; Sweeney et al., 2010).

(*E/Z*)-Fuscumol acetate was synthesized by adding (*E/Z*)-fuscumol (44 g, 224 mmol) to a solution of pyridine (20.2 ml, 250 mmol) and methylene chloride (400 ml), and the mixture was stirred and cooled in an ice-bath while acetyl chloride (17.8 ml, 250 mmol) was added dropwise. The mixture was then warmed to room temperature and stirred overnight. The small excess of acetyl chloride was destroyed by addition of ethanol (1.4 g, 30 mmol), followed by stirring for an additional 4 h. The mixture was then poured into water and the layers were separated. The aqueous layer was extracted with ether and the combined organic extracts were washed successively with water, 1 M HCl, saturated aqueous $NaHCO_3$, and brine. After drying over anhydrous Na_2SO_4, the solution was concentrated by rotary evaporation followed by Kugelrohr distillation of the residue (oven temperature ca. 80 °C, 0.15 mm Hg), yielding (*E/Z*)-fuscumol acetate (52.4 g, 98%, >98% pure by GC).

Mass and NMR spectra were analogous to those reported in Fonseca et al. (2010).

Field bioassays

Two experiments were conducted to test for attraction of lamiine species to (*E/Z*)-fuscumol and its acetate. Experiment 1 tested for attraction of beetles to each compound separately, and was replicated at study sites in northwestern Indiana and central Texas. Experiment 2 was similar in design but included a 1:1 blend of (*E/Z*)-fuscumol and its acetate to test whether the combination inhibited or enhanced attraction, and was conducted in east-central Illinois. We used black cross-vane flight intercept traps (Panel Trap model; AlphaScents, Portland, OR, USA) that were coated with Fluon® PTFE (AGC Chemicals Americas, Exton, PA, USA) to enhance trapping efficiency (Graham et al., 2010). Traps were suspended from frames constructed of PVC pipe (see Graham et al., 2010). Pheromone lures were polyethylene sachets (Bagettes™ model 14770, 5.1 × 7.6 cm; Cousin, Largo, FL, USA) loaded with 25 mg of synthetic pheromone diluted in 1 ml of 95% ethanol, or 1 ml of neat ethanol (control). Ethanol is an efficient carrier for these compounds, and does not attract cerambycid beetles in these doses (e.g., Hanks et al., 2007). We collected beetles from traps at intervals of 1–3 days, at which time, treatments were rotated within transects. Lures were examined when traps were checked, and replaced when visibly depleted, usually after ca. 1 week. Captured beetles were sexed, usually by the relative length of the antennae to the body, and by the length of the fifth abdominal sternite (see volumes indexed in Linsley & Chemsak, 1997). Representative specimens of all species were pinned and retained for further study and voucher specimens were deposited when necessary with the collection of the Illinois Natural History Survey, Champaign, IL, USA.

Experiment 1 consisted of a single block of three traps (10 m apart) at each field site that were baited with (*E/Z*)-fuscumol, (*E/Z*)-fuscumol acetate, or with a control lure of 95% ethanol. There were two study sites in Indiana (Tippecanoe County), both in Martell Forest, a mixed-hardwood forest of 150 ha (site 1: 40°26′31.38″N, 87°2′1.37″W; site 2: 40°26′10.69″N, 87°2′18.20″W). The experiment was conducted from 25 May to 17 September 2010 (air temperature 8.3–35 °C, 44 cm total precipitation; Weather Underground, Ann Arbor, MI, USA). In Texas (Erath County), there were three study sites: (1) a residential area in Stephenville (32°13′26.40″N, 98°13′15.10″W) that was dominated by ornamental pecan trees [*Carya illinoinensis* (Wangenh.) K. Koch], (2) a lumber yard surrounded by pasture (32°9′35.18″N, 98°11′21.09″W), and (3) a wetland with stands of *Quercus stellata* Wangenh., *Celtis laevigata* Willd., and *Prosopis glandulosa* Torr., that was the property of Texas AgriLife Research and Extension Center (32°14′27.7965″N, 98°11′18.7731″W). The experiment was conducted from 24 May to 8 June 2010 (air temperature 21–34 °C, skies usually clear, 2 cm total precipitation; Weather Underground).

Experiment 2 included the same treatments as Experiment 1, but lures were loaded with 100 mg of synthetic pheromone and included a treatment that was a blend of (*E/Z*)-fuscumol and its acetate (100 mg of each pheromone component in 95% ethanol). There were two study sites in Illinois: (1) Allerton Park (Piatt County: 39°59′11.01″N, 88°39′3.75″W), a mixed-hardwood forest of 600 ha, and (2) a residential neighborhood in Urbana (Champaign County; 40°5′49.30″N, 88°12′11.33″W). There were two blocks of treatments at the Allerton site and one block at the residential site. The experiment was conducted from 26 May to 16 August 2010 (air temperature 13–35 °C, 35.2 cm total precipitation; Weather Underground).

Statistical analysis

We tested the differences between treatments, separately for each state and blocked by site and date, using the nonparametric Friedman's test (Proc FREQ, option CMH; SAS Institute, 2001) because data violated the equal variances assumption of ANOVA (Sokal & Rohlf, 1995). Differences between pairs of means were tested with the REGWQ means-separation test to control maximum experiment-wise error rates (Proc GLM; SAS Institute, 2001). Data for site and date replicates were included in the analysis based on a threshold number of specimens (1–4, depending on abundance of the species) so as to optimize sample size per replicate while maintaining sufficient replication for a robust analysis. We also tested for deviations from a 1:1 sex ratio using χ^2 tests.

Results

In Experiment 1, traps in Indiana and Texas caught a total of 336 beetles of 12 lamiine species in four tribes (Table 1), with 87% of the trapped beetles being in the tribe Acanthocinini. For each of the seven species that were best represented (Table 1), traps baited with (*E/Z*)-fuscumol or (*E/Z*)-fuscumol acetate captured significantly more beetles than did control traps. We include trap catch data for the remaining five species, even though treatment means were not significantly different, because they suggest leads for follow-up investigations.

Of the best represented species captured in Indiana (Figure 1A), three were attracted to (*E/Z*)-fuscumol (*Astylidius parvus*, *Leptostylus transversus*, *Sternidius alpha*), and two species were attracted to (*E/Z*)-fuscumol

Table 1 Total number of cerambycid beetles in the subfamily Lamiinae that were captured in northwestern Indiana and central Texas during Experiment 1

Tribe	Species	Site	Fuscumol	Fuscumol acetate	Control	Total (%♀)	Friedman's Q (P)
Acanthocinini	*Astyleiopus variegatus* (Haldeman)	TX	1	22	0	23 (73[1])	15.3 (<0.001)
	Astylidius parvus (LeConte)	IN	59	0	0	59 (40)	50.3 (<0.001)
	Graphisurus fasciatus (DeGeer)	IN	10	33	1	44 (58)	28.6 (<0.001)
	Graphisurus despectus (LeConte)	IN	2	10	2	14 (58)	ns
	Leptostylus transversus (Gyllenhal in Schoenherr)	IN	8	1	2	11 (22)	10.9 (0.004)
	Lepturges angulatus (LeConte)	IN	0	4	1	5 (50)	ns
		TX	1	79	0	80 (91[1])	37.3 (<0.001)
	Lepturges confluens (Haldeman)	IN	1	5	0	6[2]	ns
	Sternidius alpha (Say)	IN	23	2	0	25 (40)	35.4 (<0.001)
		TX	8	8	0	16[2]	6.8 (0.033)
	Urgleptes facetus (Say)	IN	0	8	0	8[2]	ns
Acanthoderini	*Aegomorphus modestus* (Gyllenhal in Schoenherr)	IN	0	29	2	31 (37)	22.6 (<0.001)
Pogonocherini	*Ecyrus arcuatus* Gahan	TX	6	1	0	7[2]	ns
Pteropliini	*Ataxia crypta* (Say)	TX	3	4	0	7[2]	ns
	Total		122	206	8	336	

Fuscumol and fuscumol acetate consist of racemic blends of their (*E*)- and (*Z*)-isomers. Treatment means for the best represented species are presented in Figure 1. Sex ratio calculated across treatments, exclusive of control. ns, not significant (P>0.05).
[1]Significantly different from 1:1 (χ^2 test: P<0.05).
[2]Sex of beetles indeterminate or not recorded.

acetate (*Graphisurus fasciatus*, *Aegomorphus modestus*). *Sternidius alpha* also was captured in Texas, but there it was attracted equally to (*E/Z*)-fuscumol and the acetate (Figure 1B). Two other species that were captured in significant numbers in Texas responded only to (*E/Z*)-fuscumol acetate (Figure 1B; *Astyleiopus variegatus*, *Lepturges angulatus*). For most of the species, males and females were attracted in similar numbers to (*E/Z*)-fuscumol or its acetate (Table 1), but the sex ratio was significantly female-biased for *A. variegatus* and *L. angulatus*.

Unexpectedly, two species of the subfamily Cerambycinae also were attracted in large numbers to traps baited with these compounds. In Indiana, we caught 70 *Xylotrechus colonus* (Fabricius) (sex ratio = 43% female, not significantly different from 1:1; $\chi^2 = 1.29$, d.f. = 1, P = 0.26), with significantly greater numbers in the (*E/Z*)-fuscumol acetate treatment (Figure 2; Friedman's $Q_{2,18} = 10.0$, P = 0.0067). In Texas, we captured 31 *Obrium maculatum* (Olivier) (sex ratio = 43% female, not significantly different from 1:1; $\chi^2 = 0.14$, d.f. = 1, P = 0.71), with significantly greater numbers in the (*E/Z*)-fuscumol acetate treatment, and intermediate numbers in the (*E/Z*)-fuscumol treatment (Figure 2; Friedman's $Q_{2,21} = 10.1$, P = 0.006).

During Experiment 2, traps in Illinois captured 145 beetles of 9 species (Table 2), all but one of which [*Oplosia nubila* (LeConte)] also were captured during Experiment 1. The data were consistent with Experiment 1 in indicating a preference for (*E/Z*)-fuscumol acetate by *A. variegatus*, *G. fasciatus*, and *L. angulatus*, and a preference for (*E/Z*)-fuscumol by *A. parvus* (Figure 3; compare with Figure 1). The addition of the blend of (*E/Z*)-fuscumol and its acetate to the bioassay revealed that *A. variegatus* was more attracted to the blend than to (*E/Z*)-fuscumol acetate alone (Figure 3). However, blending the two compounds did not influence the responses of *G. fasciatus* and *L. angulatus* compared to (*E/Z*)-fuscumol acetate, nor the response of *A. parvus* compared to (*E/Z*)-fuscumol (Figure 3; compare with Figure 1). Our findings suggest that these species are attracted despite the presence of these other compounds, and in some cases may be more attracted. Sexes of the four species responded equally to all treatments (Table 2).

Finally, the fact that we caught 14 of the cerambycine *X. colonus* in Experiment 2 provided further evidence that it is attracted to (*E/Z*)-fuscumol and its acetate: eight were caught in traps baited with (*E/Z*)-fuscumol, three with the acetate, and two with the blend, compared to a single beetle in control traps ($\chi^2 = 12.1$, d.f. = 1, P<0.001).

Discussion

Our hypothesis was supported by the significant attraction of beetles of seven species in four tribes of the Lamiinae to

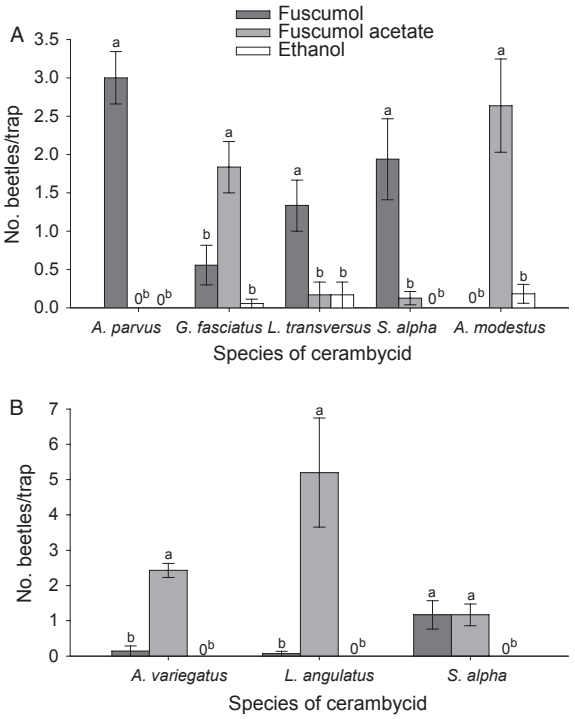

Figure 1 Mean (± SE) number of beetles captured (per trap and count period) during Experiment 1 in: (A) northwestern Indiana and (B) central Texas. Fuscumol and fuscumol acetate consist of racemic blends of their (*E*)- and (*Z*)-isomers. Means with different letters within species are significantly different (REGWQ means-separation test: $P<0.05$).

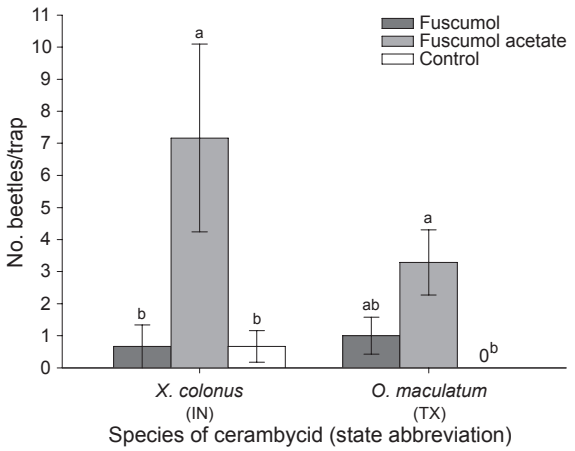

Figure 2 Mean (± SE) number of beetles captured (per trap and count period) in northwestern Indiana (IN) and central Texas (TX) during Experiment 1 for two species in the subfamily Cerambycinae. Fuscumol and fuscumol acetate consist of racemic blends of their (*E*)- and (*Z*)-isomers. Means with different letters within species are significantly different (REGWQ means-separation test: $P<0.05$).

ethanol solutions of (*E/Z*)-fuscumol, (*E/Z*)-fuscumol acetate, or a mixture of the two compounds. Few beetles were captured by control traps baited with ethanol, but ethanol may still have enhanced the attractiveness of the other lures (e.g., Sweeney et al., 2010). In most cases, both sexes responded in approximately equal numbers, suggesting that these compounds serve as aggregation attractants, if not pheromones. Whether there was indeed a sex bias in the responses of two species at some field sites cannot be determined because we had no independent measure of the sex ratio of the local populations at the times that bioassays were conducted.

Although fuscumol is an aggregation pheromone for some species in the subfamily Aseminae/Spondylidinae, we did not trap any beetles of that subfamily in Texas, Indiana, or Illinois, even though one species of *Tetropium* and other asemine/spondylidine genera have been recorded from these regions (volumes indexed in Linsley & Chemsak, 1997). However, the activity of fuscumol for species in this subfamily may be strongly synergized by volatile terpenoids produced by host plants (which were not included in our trap lures), as shown for *Tetropium* species (Silk et al., 2007; Sweeney et al., 2010). In addition, the presence of (*Z*)-fuscumol in the inexpensive blend of fuscumol stereoisomers that we used in our trials may have affected the response to the (*E*)-isomer.

Both sexes of *A. modestus* responded to (*E/Z*)-fuscumol acetate. This species is in the same tribe as *H. betulinus* and *S. breve* (Acanthoderini; Yanega, 1996), males of which produce fuscumol, and in the case of *H. betulinus*, fuscumol acetate (Fonseca et al., 2010; C Liendo, pers. comm.). This suggests that fuscumol or its acetate may be pheromone components for other species in that tribe as well. However, it must be noted that we have yet to confirm that fuscumol or related compounds are produced by any of the species captured during our study. Nevertheless, the generalized activity of (*E/Z*)-fuscumol and (*E/Z*)-fuscumol acetate across many lamiine species in several tribes, and in three regions of the USA, suggests that the basic structure of fuscumol represents another shared motif of pheromones in the Cerambycidae. It seems likely that fuscumol and its acetate serve as pheromones that signal the presence of larval hosts as well as serving a sexual function, as appears to be the case for cerambycine species (Lacey et al., 2004).

Attraction of the cerambycines *X. colonus* and *O. maculatum* to (*E/Z*)-fuscumol and its acetate provides further evidence that the biological activity of these compounds extends across subfamily lines. We have found the same to be true for stereoisomers of 2,3-hexanediol, which are common pheromone components of male cerambycines (Lacey et al., 2004, 2009) but which also serve as female-produced sex pheromones for several *Tragosoma* species in the sub-

Table 2 Total number of cerambycid beetles in the subfamily Lamiinae that were captured in east-central Illinois during Experiment 2

Tribe	Species	Fuscumol	Fuscumol acetate	Blend	Control	Total (%♀)	Friedman's Q (P)
Acanthocinini	*Astyleiopus variegatus*	1	5	12	1	19 (64)	14.0 (0.003)
	Astylidius parvus	5	1	9	0	15 (43)	20.8 (<0.001)
	Graphisurus fasciatus	4	26	15	5	50 (50)	22.3 (<0.001)
	Leptostylus transversus	1	1	0	2	4[1]	ns
	Lepturges angulatus	3	19	16	0	38 (48)	21.2 (<0.001)
	Lepturges confluens	2	2	1	0	5[1]	ns
	Sternidius alpha	2	0	6	1	9[1]	ns
Acanthoderini	*Aegomorphus modestus*	0	5	0	0	5 (80)	ns
Total		18	59	59	9	145	

Fuscumol and fuscumol acetate consist of racemic blends of their (*E*)- and (*Z*)-isomers, and the 'Blend' treatment consists of equal parts of (*E*/*Z*)-fuscumol and (*E*/*Z*)-fuscumol acetate. Treatment means for the best represented species are presented in Figure 3. Sex ratio calculated across treatments, exclusive of control. ns, not significant (P>0.05).
[1]Sex of beetles indeterminate or not recorded.

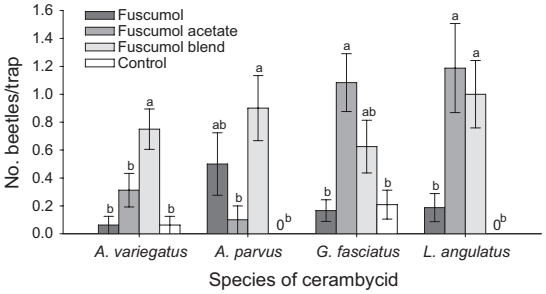

Figure 3 Mean (± SE) number of beetles captured (per trap and count period) in east-central Illinois during Experiment 2 for four lamiine species (see Table 2) that also were captured in Experiment 1 (see Figure 1). Fuscumol and fuscumol acetate consist of racemic blends of their (*E*)- and (*Z*)-isomers, and the fuscumol blend consists of equal parts of (*E*/*Z*)-fuscumol and (*E*/*Z*)-fuscumol acetate. Means with different letters within species are significantly different (REGWQ means-separation test: P<0.05).

family Prioninae (AM Ray, unpubl.). At present, we know nothing of the pheromone of *O. maculatum*, which may include fuscumol or related compounds. However, the pheromone of male *X. colonus* appears to be composed of (*R*)- and (*S*)-3-hydroxyhexan-2-one, and (2*S*,3*S*)- and (2*R*,3*R*)-2,3-hexanediol, with no trace of fuscumol or related compounds (Lacey et al., 2009). This suggests that fuscumol and its acetate mediate a variety of interactions within and among multiple sympatric species. For example, fuscumol acetate may act as a kairomone that is exploited by *X. colonus* to find suitable host plants for oviposition, which would be consistent with its highly polyphagous nature (volumes indexed in Linsley & Chemsak, 1997).

Pheromones of cerambycid beetles currently are being developed as management tools for endemic species that are important pests (Maki et al., 2011), as well as for quarantine applications (e.g., Nehme et al., 2010; Barbour et al., 2011; Teale et al., 2011). Furthermore, synthetic pheromones of cerambycids will be deployed by USDA-APHIS for monitoring of exotic species nationwide in 2012 (V Mastro, pers. comm.). Fuscumol and its acetate will be included in these surveillance efforts because they will attract species that do not respond to the synthetic pheromones that target cerambycines (e.g., 3-hydroxyalkan-2-ones and corresponding diols) or species of lamiines other than those in the tribe Monochamini that use 2-(undecyloxy)-ethanol as a pheromone (Millar et al., 2009; Pajares et al., 2010; Teale et al., 2011). Our results confirm that lures containing the inexpensive blend of fuscumol stereoisomers would be effective for monitoring a number of lamiine species, as well as some cerambycine species. Preliminary experiments have indicated that the presence of the (*Z*)-isomer does not influence the attraction of lamiine species to the (*E*)-isomer (LM Hanks, unpubl.).

In summary, this study has provided the key initial data to drive more comprehensive follow-up studies by demonstrating that fuscumol, fuscumol acetate, and related isomers attract multiple cerambycid species from different tribes and subfamilies. Traps baited with these compounds can be used to capture live beetles of both sexes, providing a means to determine whether these compounds are part of the pheromone, or whether the beetles are instead exploiting the signals of other species. This research will lay the groundwork for identifying the multiple functions of these compounds in structuring cerambycid communities.

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