Field Screening of Known Pheromone Components of Longhorned Beetles in the Subfamily Cerambycinae (Coleoptera: Cerambycidae) in Hungary

Zoltán Imrei[a,*], Jocelyn G. Millar[b], Gergely Janik[c], and Miklós Tóth[a]

[a] Plant Protection Institute, Agricultural Research Centre, Hungarian Academy of Sciences, 15 Herman Otto Street, H-1525 Budapest, Hungary. Fax: +36-1-391-8655. E-mail: imrei@hotmail.com
[b] Department of Entomology, University of California, Riverside, CA 92521, USA
[c] Forestry Research Institute, Department of Forest Protection, 18 Hegyalja Road, H-3232 Mátrafüred, Hungary

* Author for correspondence and reprint requests

Z. Naturforsch. **68 c**, 236 – 242 (2013); received April 27/July 30, 2012

Five compounds known to be pheromone components of longhorned beetles (Coleoptera: Cerambycidae) in the subfamily Cerambycinae were field-tested as attractants and possible pheromones for the cerambycid fauna of Hungary. Nine cerambycid species were caught in baited traps. Large numbers of both sexes of the cerambycine species *Molorchus umbellatarum* Schreb. were caught in traps baited with (2*R**,3*S**)-octanediol, while the diastereomeric (2*R**,3*R**)-octanediol was to some extent attractive as well. This is the first report on an aggregation attractant and a likely pheromone for a species in the cerambycine tribe Molorchini. The results of our study support the hypothesis that the diol/hydroxyketone pheromone motif is characteristic of and highly conserved within the subfamily Cerambycinae. Intraspecific chemical communication is summarized for the subfamily Cerambycinae, and possible links between taxonomy, insect behaviour, and pheromone structures are described.

Key words: Cerambycinae, Clytini, Pheromone Trapping

Introduction

Males of a number of species of longhorned beetles (Coleoptera: Cerambycidae) in the subfamily Cerambycinae have been reported to produce sex or aggregation pheromones consisting of 3-hydroxy-2-alkanones, 2-hydroxy-3-alkanones, and isomers of 2,3-alkanediols, with chain lengths of 6, 8, or 10 carbon atoms (*e.g.* Iwabuchi *et al.*, 1987; Kuwahara *et al.*, 1987; Fettköther *et al.*, 1995; Nakamuta *et al.*, 1997; Hall *et al.*, 2006; Hanks *et al.*, 2007; Lacey *et al.*, 2004, 2008, 2009). These reports from beetles native to several continents, including Europe, North America, and Asia, suggested that the diol/hydroxyketone pheromone motif is characteristic of and highly conserved within the subfamily Cerambycinae (Lacey *et al.*, 2004; Hanks *et al.*, 2007). The objective of the work described here was to further test this hypothesis by bioassaying the most common of these compounds as attractants and possible pheromones for the cerambycid fauna of Hungary. Here, we report the results from screening five of these compounds in field-trapping experiments at several sites in Hungary.

Material and Methods

Trap type

Field tests were carried out with VARb3 modified funnel traps from the CSALOMON® trap family produced by the Plant Protection Institute, Hungarian Academy of Sciences, Budapest, Hungary, www.julia-nki.hu/traps (Imrei *et al.*, 2001; Schmera *et al.*, 2004). This trap design, with a fluorescent yellow upper funnel and a vertical plastic sheet mounted in the funnel for interception of flying insects, has been shown to be effective in catching the cerambycine species *Plagionotus floralis* Pallas (Toshova *et al.*, 2010). In the present experiments, to reduce the chances of confounding effects from visual stimuli, the yellow upper funnel was replaced with a transparent funnel. The pheromone dispenser (see below) was suspended from the vertical plastic sheet, so that it hung in the middle of the funnel opening.

Pheromone lures

Pheromone release devices consisted of small polyethylene Ziploc bags (5 cm x 7.5 cm; #018161A; Fisher Scientific, Pittsburgh, PA, USA) containing 50 mg of a single pheromone component dissolved in 1 ml of isopropanol. Pheromone solutions were prepared in advance and kept at –18 °C until needed. Dispensers were loaded with a pipette at field sites immediately before being deployed.

Racemic (2*R**,3*S**)-hexanediol, (2*R**,3*R**)-octanediol, and (2*R**,3*S**)-octanediol were synthesized from (*Z*)-2-hexene, (*E*)-2-octene, and (*Z*)-2-octene by osmium tetroxide-catalyzed oxidation with *N*-methylmorpholine oxide as the terminal oxidant, as described by Lacey *et al*. (2004).

Racemic 3-hydroxy-2-hexanone was synthesized from 1-hexyn-3-ol (GFS Chemicals, Powell, OH, USA), according to the procedure reported by Leal *et al.* (1995), with a modification to increase the yield. In short, a dry 2-l flask equipped with a $CaCl_2$ drying tube was charged with MeOH (300 ml), 14% (w/v) BF_3 in MeOH, and red HgO (1 g). The mixture was stirred until the HgO dissolved, then cooled to 0 °C, and 1-hexyn-3-ol (110 g, 1.12 mol) was added dropwise over 3 h. The mixture was warmed slowly to room temperature overnight, giving a clear brown solution. The solution was cooled in an ice bath, resulting in some precipitation, and 200 ml of 1 M aqueous HCl were added over 30 min with vigourous stirring. The mixture was warmed to room temperature overnight, then 300 ml of brine were added. The mixture was extracted with diethyl ether (3 x 250 ml), and the combined diethyl ether layers were washed sequentially with saturated aqueous $NaHCO_3$ and brine. The resulting solution was dried over anhydrous Na_2SO_4 and then concentrated in a rotary evaporator without heating at a vacuum of ~46.7 kPa. The resulting yellow oil was concentrated further at ~2.7 kPa with a short Vigreux column, warming the distillation flask to ~35 °C. The remaining yellow liquid was then Kugelrohr-distilled at ~1.2 kPa, warming the oven to ~65 °C, and collecting the distillate (85 g, 65%) in a bulb cooled in a dry ice/acetone bath. The retention time matched that of an authentic sample, and the NMR and mass spectra matched those previously reported (Lacey *et al.*, 2007). Racemic 3-hydroxy-2-octanone was synthesized in analogous fashion starting from 1-octyn-3-ol (GFS Chemicals).

Field tests

Experiments were conducted at five sites in Hungary (Table I). Traps were set up in a randomized complete block design, with two blocks per site spaced 10–15 m apart and hung from vegetation at a height of ~1.5 m. Traps were inspected once weekly, when captured insects were collected. Lures were replaced every second week. Captured beetles were identified to species using the key of Kaszab (1971). Voucher specimens have been submitted to Mr. József Muskovits (taxonomy expert, 9 Tardoskedd street, H-1113 Budapest, Hungary).

Statistics

Trap catch data were analysed by the non-parametric Kruskal-Wallis test (Kruskal and Wallis, 1952) because the data did not fulfil requirements for a parametric analysis. When Kruskal-Wallis tests indicated significant differences, pairwise comparisons were performed with Mann-Whitney U-tests (Zar, 1999). All statistical procedures were conducted using the software packages StatView® v4.01 and SuperANOVA® v1.11 (Abacus Concepts Inc., Berkeley, CA, USA).

Table I. Field testing sites.

Experiment	Site	Site description	Period
1	Budapest, Julianna major	Old oak forest	May 25–September 8, 2011
2	Mátrafüred	Old beech forest	June 2–August 10, 2011
3	Mátrafüred	Old oak forest[a]	June 15–August 10, 2011
4	Pusztazámor	Mixed forest edge along an alfalfa field (walnut, ash, maple, oak, elm)[b]	May 24–June 21, 2011
5	Sukoró	Poplar forest	June 21–August 9, 2011

[a] This site was chosen because it was observed to have a good population of *Cerambyx scopolii* Füssly.
[b] This site was chosen because of an observed high population density of *Plagionotus floralis* Pallas.

Results and Discussion

A total of nine cerambycid species were trapped in the field trials (Table II), seven of which were from the subfamily Cerambycinae. Single individuals of a lamiine and a prionine species also were caught, but these were likely random catches, particularly as 3,5-dimethyldodecanoic acid recently has been identified as the likely sex pheromone of the prionine species, *Prionus coriarius* L. (Barbour *et al.*, 2011). No beetles were caught in any control traps or in any traps baited with (2*R**,3*S**)-hexanediol.

In Experiment 1, large numbers of both sexes of the cerambycine species *Molorchus umbellatarum* Schreb. were caught in traps baited with (2*R**,3*S**)-octanediol (Fig. 1). This is the first report of an aggregation attractant and likely pheromone for a species in the cerambycine tribe Molorchini. Traps baited with the diastereomeric (2*R**,3*R**)-octanediol also caught a total of 19 specimens over three experiments (Table II). Because both diastereomers were to some extent attractive to *M. umbellatarum*, inhibition of attraction by one or more stereoisomers seems unlikely, and in fact, the pheromone may turn out to be a blend of 2,3-octanediol stereoisomers. Inhibition between stereoisomers has been previously reported for the North American species *Neoclytus acuminatus acuminatus* F., whereby the response to its pheromone, (2*S*,3*S*)-hexanediol, was inhibited by one or both of the diastereomeric (2*R*,3*S*)- or (2*S*,3*R*)-hexanediols (Lacey *et al.*, 2004).

Whereas no other cerambycine species was caught in significant numbers, the fact that all of these species were captured in traps baited with a specific compound is suggestive. For example, 6 specimens of *Pronocera angusta* Kriechb.

Table II. Cerambycid specimens caught in 5 field experiments.

Species	Subfamily, tribe	Experiment	3-Hydroxy-2-hexanone	3-Hydroxy-2-octanone	(2*R**,3*S**)-Hexanediol	(2*R**,3*R**)-Octanediol	(2*R**,3*S**)-Octanediol
Molorchus umbellatarum Schreb.	Cerambycinae, Molorchini	1		2		16	158
		2				2	1
		4				1	
Pronocera angusta Kriechb.	Cerambycinae Callidiini	1	4				
		2	2				
Xylotrechus arvicola Olivier	Cerambycinae Clytini	1		1			
		4		2			
Xylotrechus antilope Schönh.	Cerambycinae Clytini	2		1			
Plagionotus detritus L.	Cerambycinae Clytini	1	1				
Cerambyx scopolii Füssly	Cerambycinae Cerambycini	3	1				
		4		1			
Stenocorus quercus Goeze	Cerambycinae Rhagiini	4		1			
Leiopus nebulosus L.	Lamiinae Acanthocinini	1		1			
Prionus coriarius L.	Prioninae Prionini	1					1

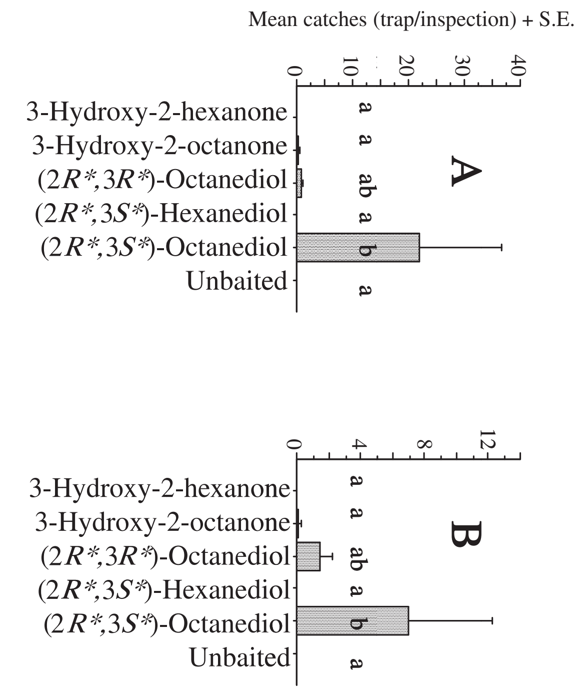

Fig. 1. *Molorchus umbellatarum* catches in Experiment 1: (A) males; (B) females. A total of 92 male and 69 female beetles were caught in the test. Columns with the same letter within one diagram are not significantly different (P = 0.05), Kruskal-Wallis followed by Mann-Whitney U-test.

were caught in traps baited with 3-hydroxy-2-hexanone in two experiments (Table II). Three specimens of *Xylotrechus arvicola* Olivier were captured in two experiments in traps baited with 3-hydroxy-2-octanone, whereas a single specimen of the congener *Xylotrechus antilope* Schönh. was caught in a different experiment, also in a trap baited with 3-hydroxy-2-octanone (Table II). Single specimens of the cerambycine species *Plagionotus detritus* L. and *Stenocorus quercus* Goeze were caught in traps baited with 3-hydroxy-2-hexanone and 3-hydroxy-2-octanone, respectively, and each trap baited with these two compounds caught one individual of *Cerambyx scopolii* Füssly in two different experiments (Table II). It is also noteworthy that no *Plagionotus floralis* (Pallas) was caught in Experiment 4, in which traps were placed along the edge of an alfalfa field with a large population of this species (Z. Imrei personal observation), suggesting that if this species does use an attractant pheromone, it is not one of the compounds that were deployed in these field trials.

To date, only species in the cerambycid subfamily Cerambycinae have been reported to be attracted in significant numbers by 2,3-alkanediols or 3-hydroxyalkan-2-ones*. Our results add further support to the hypothesis that the hydroxyketone and diol pheromone structures are highly conserved within this subfamily (Lacey *et al.*, 2004; Hanks *et al.*, 2007). For comparative purposes, the published literature on known or likely cerambycine pheromones is summarized in Table III. Thus, in the tribe Callidiini to which *Pronocera angusta* belongs, 3-hydroxy-2-hexanone has been reported as a pheromone or attractant for all three of the other species in this tribe for which pheromones have been reported, and two of the species also produce 2,3-hexanediols (Table III). Another *Phymatodes* species (*P. decussatus* LeConte) was reported to be attracted by a mixture of hydroxyhexanone compounds (Hanks *et al.*, 2007).

Within the tribe Clytini, for all five *Xylotrechus* spp. for which pheromones have been reported, at least one 3-hydroxy-2-alkanone with a chain of 6, 8, or 10 carbon atoms was found (Table III). Five additional species in the tribe use only the C_6 hydroxyketones or diols. Within this tribe, it is also interesting to note that the C_8 and C_{10} compounds are sex pheromones reported to attract only females, whereas the C_6 compounds appear to be aggregation pheromones attractive to both sexes. This does not appear to hold for species in other tribes, where C_6 compounds are reported to attract only females in the tribes Curiini (Lacey *et al.*, 2004), Anaglyptini (Nakamuta *et al.*, 1997), and Callidiini (Schröder *et al.*, 1994; Fettköther *et al.*, 1995; Hanks *et al.*, 2007). Both C_6 and C_8 compounds were identified from males of *Anaglyptus subfasciatus* Pic (Nakamuta *et al.*, 1997).

To date, no diol, dione, or hydroxyketone compounds with chains shorter than 6 carbon atoms or longer than 10 carbon atoms have been identified from any cerambycid species, but shorter-chain compounds of other structural classes are known. For example, in the tribe Callidiini, 1-butanol was reported as a male-produced sex pheromone component of *Hylotrupes bajulus* L. (Reddy *et*

*Since the final revision to this manuscript was submitted, Ray *et al.* (2012) have reported that several species in the Prionine genus *Tragosoma* use isomers of 2,3-hexanediols as female-produced sex pheromones.

al., 2005), and (*R*)-2-methylbutan-1-ol was shown to be an aggregation pheromone component of *Phymatodes lecontei* Linsley (Hanks *et al.*, 2007).

The species caught in largest numbers in the present study, *Molorchus umbellatarum*, occurs in southern, central, and eastern Europe and ranges as far as the Caucasus and Iran (Kaszab, 1971). Its larvae develop in plants of the family Rosaceae, including wild rose (*Rosa canina* L.), hawthorn (*Crataegus* spp.), and dewberry (*Rubus* spp.), apple (*Malus domestica* L.), and the family Oleaceae, including privet (*Ligustrum* spp). The adult beetles are active from May to June, appearing on flowering shrubs, trees, and herbaceous plants of the family Apiaceae.

Although only a few specimens of *Pronocera angusta* were caught, the species is reported to be rare in central Europe, but it is known from south-eastern Europe and Russia. Its larvae develop in Norway spruce (*Picea abies* L.), European silver fir (*Abies alba* Mill.), and probably in common larch (*Larix decidua* Mill.) (http://www.cerambyx.uochb.cz/pronang.htm). The larvae feed subcortically in recently dead branches of living trees, developing for two years and pupating in the sapwood. The adults fly from May to August, and they apparently do not feed on pollen or nectar from flowers.

Xylotrechus arvicola occurs in Europe throughout the Caucasus, Iran, and North Africa (Kaszab, 1971). The larvae develop in dead or damaged branches of oak (*Quercus* spp.), lime (*Tilia* spp.), hornbeam (*Carpinus betulus* L.), poplar (*Populus* spp.), beech (*Fagus sylvatica* L.), elm (*Ulmus* spp.), chestnut (*Castanea sativa* Mill.), apple, plum (*Prunus domestica* L.), dewberry, and hawthorn. The adults appear in June and July, associated with host plants. Ocete *et al.* (2008) reported that the species is becoming increasingly important as a pest of vineyards in Spain.

Several of the species trapped in the present study, including *Molorchus umbellatarum*, *Xylotrechus arvicola*, *Xylotrechus antilope*, *Plagiono-*

Table III. 2,3-Alkanediol (OL), hydroxyketone (HK), and 2,3-alkanedione (ON) pheromone components from cerambycine species and their functional role (AGR, attracting both sexes; SEX, attracting only one sex).

Species	Tribe	Role	C_6			C_8		C_{10}			Reference
			OL	HK	ON	OL	HK	OL	HK	ON	
Demonax balyi Pascoe	Clytini	SEX							•		Hall *et al.* (2006)
Megacyllene caryae Gahan	Clytini	AGR	•								Lacey *et al.* (2008)
Neoclytus acuminatus acuminatus F.	Clytini	AGR	•								Lacey *et al.* (2004)
Neoclytus mucronatus mucronatus F.	Clytini	AGR		•							Lacey *et al.* (2007)
Neoclytus modestus modestus Fall	Clytini	AGR		•							Hanks *et al.* (2007)
Sarosesthes fulminans F.	Clytini	AGR	•	•							Lacey *et al.* (2009)
Xylotrechus chinensis Chevrolat	Clytini	SEX				•	•				Kuwahara *et al.* (1987); Iwabuchi *et al.* (1987)
Xylotrechus colonus F.	Clytini	AGR	•	•							Lacey *et al.* (2009)
Xylotrechus nauticus Manner.	Clytini	AGR		•	•						Hanks *et al.* (2007)
Xylotrechus pyrrhoderus Bates	Clytini	SEX				•	•				Sakai *et al.* (1984); Iwabuchi *et al.* (1985)
Xylotrechus quadripes Chevrolat	Clytini	SEX				•			•	•	Rhainds *et al.* (2001); Hall *et al.* (2006)
Anaglyptus subfasciatus Pic	Anaglyptini	SEX		•			•				Leal *et al.* (1995); Nakamuta *et al.* (1997); Hanks *et al.* (2007)
Hylotrupes bajulus L.	Callidiini	SEX	•	•							Schröder *et al.* (1994); Fettköther *et al.* (1995)
Phymatodes lecontei Linsley	Callidiini	AGR		•							Hanks *et al.* (2007)
Pyrrhidium sanguineum L.	Callidiini	SEX	•	•							Schröder *et al.* (1994)
Curius dentatus Newman	Curiini	SEX	•								Lacey *et al.* (2004)

tus detritus, and *Cerambyx scopolii* are listed in the EPPO Pest Quarantine Data Retrieval System (EPPO, 2011) as being significant or possibly important invasive or endemic pest species. Our results represent a first step towards gaining a better understanding of the chemical communication used by these species, and may help to develop monitoring tools and control methods for these and related species.

Acknowledgements

We are indebted to Mr. József Muskovits, expert in cerambycid taxonomy, who confirmed the identifications of the *Molorchus* specimens. This work was partially funded by USDA-APHIS cooperative agreement 10-8100'-1422-CA and by OTKA grant K 104294 of HAS and by OTKA grant K 68618 of HAS.

Barbour J. D., Millar J. G., Rodstein J., Ray A. M., Alston D. G., Rejzek M., Dutcher J. D., and Hanks L. M. (2011), Synthetic 3,5-dimethyldodecanoic acid serves as a general attractant for multiple species of *Prionus* (Coleoptera: Cerambycidae). Ann. Entomol. Soc. Am. **104**, 588 – 593.

EPPO (2011), PQR – EPPO database on quarantine pests (available online). http://www.eppo.org

Fettköther R., Dettner K., Schröder F., Meyer H., Francke W., and Noldt U. (1995), The male pheromone of the old house borer *Hylotrupes bajulus* L. (Coleoptera: Cerambycidae): identification and female response. Experientia **51**, 270 – 277.

Hall D. R., Cork A., Phythian S. J., Chittamuru S., Jayarama B. K., Venkatesha M. G., Sreedharan K., Vinod Kumar P. K., Seetharama H. G., and Naidu R. (2006), Identification of components of male-produced pheromone of coffee white stemborer, *Xylotrechus quadripes*. J. Chem. Ecol. **32**, 195 – 219.

Hanks L. M., Millar J. G., Moreira J. A., Barbour J. D., Lacey E. S., McElfresh J. S., Reuter F. R., and Ray A. M. (2007), Using generic pheromone lures to expedite identification of aggregation pheromones for the cerambycid beetles *Xylotrechus nauticus*, *Phymatodes lecontei*, and *Neoclytus modestus*. J. Chem. Ecol. **33**, 889 – 907.

Imrei Z., Tóth M., Tolasch T., and Francke W. (2001), 1,4-Benzoquinone attracts males of *Rhizotrogus vernus* Germ. Z. Naturforsch. **57c**, 177 – 181.

Iwabuchi K., Takahashi J., Nakagawa Y., and Sakai T. (1985), Electroantenogram responses of grapeborer *Xylotrechus pyrrhodeus* Bates (Coleoptera: Cerambycidae) to its male sex pheromone components. J. Chem. Ecol. **11**, 819 – 828.

Iwabuchi K., Takahashi J., and Sakai T. (1987), Occurrence of 2,3-octanediol and 2-hydroxy-3-octanone, possible male sex-pheromone in *Xylotrechus chinensis* Chevrolat (Coleoptera, Cerambycidae). Appl. Entomol. Zool. **22**, 110 – 111.

Kaszab Z. (1971), Cincérek – Cerambycidae. Fauna Hungariae, Vol. 106. Akadémiai Press, Budapest, Hungary.

Kruskal W. and Wallis W. A. (1952), Use of ranks in one-criterion variance analysis. JASA **47**, 583 – 621.

Kuwahara Y., Matsuyama S., and Suzuki T. (1987), Identification of 2,3-octanediol, 2-hydroxy-3-octanone and 3-hydroxy-2-octanone from male *Xylotrechus chinensis* Chevrolat as possible sex-pheromones (Coleoptera, Cerambycidae). Jpn. Soc. Appl. Entomol. Zool. **22**, 25 – 28.

Lacey E. S., Ginzel M. D., Millar J. G., and Hanks L. M. (2004), Male-produced aggregation pheromone of the cerambycid beetle *Neoclytus acuminatus acuminatus*. J. Chem. Ecol. **30**, 1493 – 1507.

Lacey E. S., Moreira J. A., Millar J. G., Ray A. M., and Hanks L. M. (2007), Male-produced aggregation pheromone of the longhorned beetle *Neoclytus mucronatus mucronatus*. Entomol. Exp. Appl. **122**, 171 – 179.

Lacey E. S., Moreira J. A., Millar J. G., and Hanks L. M. (2008), A male-produced aggregation pheromone blend consisting of alkanediols, terpenoids, and an aromatic alcohol from the cerambycid beetle *Megacyllene caryae*. J. Chem. Ecol. **34**, 408 – 417.

Lacey E. S., Millar J. G., Moreira J. A., and Hanks L. M. (2009), Male-produced aggregation pheromones of the cerambycid beetles *Xylotrechus colonus* and *Sarosesthes fulminans*. J. Chem. Ecol. **35**, 733 – 740.

Leal W. S., Shi X., Nakamuta K., Ono M., and Meinwald J. (1995), Structure, stereochemistry, and thermal isomerization of the male sex pheromone of the longhorn beetle *Anaglyptus subfasciatus*. Proc. Natl. Acad. Sci. USA **92**, 1038 – 1042.

Nakamuta K., Leal W. S., Nakashima T., Tokoro M., Ono M., and Nakanishi M. (1997), Increase of trap catches by a combination of male sex pheromones and floral attractant in the longhorn beetle, *Anaglyptus subfasciatus*. J. Chem. Ecol. **23**, 1635 – 1640.

Ocete R., Lara M., Maistrello L., Gallardo A., and López M. A. (2008), Effect of *Xylotrechus arvicola* (Olivier) (Coleoptera, Cerambycidae) infestations on flowering and harvest in Spanish vineyards. Am. J. Enol. Viticult. **59**, 88 – 91.

Ray A. M., Barbour J. D., McElfresh J. S., Moreira J. A., Swift I., Wright I. M., Zunic A., Mitchell R. F., Graham E. E., Alten R. L., Millar J. G., and Hanks L. M. (2012), 2,3-Hexanediols as sex attractants and a female-produced sex pheromone for cerambycid beetles in the prionine genus *Tragosoma*. J. Chem. Exol. **38**, 1151 – 1158.

Reddy G. V. P., Fettköther U., Noldt U., and Dettner K. (2005), Capture of female *Hylotrupes bajulus* as influenced by trap type and pheromone blend. J. Chem. Ecol. **31**, 2169 – 2177.

Rhainds M., Lan C. C., King S., Gries R., Mo L. Z., and Gries G. (2001), Pheromone communication and mating behaviour of coffee white stem borer, *Xylotrechus quadripes* Chevrolat (Coleoptera: Cerambycidae). Appl. Entomol. Zool. **36**, 299 – 309.

Sakai T., Nakagawa Y., Takahashi J., Iwabuchi K., and Ishii K. (1984), Isolation and identification of the male sex pheromone of the grape borer *Xylotrechus pyrrhoderus* Bates (Coleoptera: Cerambycidae). Chem. Lett. **13**, 263 – 264.

Schmera D., Tóth M., Subchev M., Sredkov I., Szarukán I., Jermy T., and Szentesi Á. (2004), Importance of visual and chemical cues in the development of an attractant trap for *Epicometis (Tropinota) hirta* Poda (Coleoptera: Scarabaeidae). Crop Prot. **23**, 939 – 944.

Schröder F., Fettköther R., Noldt U., Dettner K., König W. A., and Francke W. (1994), Synthesis of (3*R**)-3-hydroxy-2-hexanone, (2*R**,3*R**)-2,3-hexanediol and (2*S**,3*R**)-2,3-hexanediol, the male sex pheromone of *Hylotrupes bajulus* and *Pyrrhidium sanguineum* (Cerambycidae). Liebigs Ann. Chem., 1211 – 1218.

Toshova T. B., Atanasova D. I., Tóth M., and Subchev M. A. (2010), Seasonal activity of *Plagionotus* (*Echinocerus*) *floralis* (Pallas) (Coleoptera: Cerambycidae, Cerambycinae) adults in Bulgaria established by attractant baited fluorescent yellow funnel traps. Acta Phytopathol. Hun. **45**, 391 – 399.

Zar J. H. (1999), Biostatistical Analysis, 4th ed. Prentice Hall, Englewood Cliffs, NJ, USA.