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Responses of Pseudovadonia livida adults to olfactory and visual cues

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Abstract

Pseudovadonia livida (F.) (Coleoptera Cerambycidae Lepturinae) is a widely distributed and common species across Europe. This study was undertaken to investigate some aspects of the sensory and behavioural ecology of P. livida adults in relation to flowering plants they visit. First, their electroantennogram (EAG) responses to 42 synthetic plant volatile compounds were recorded. The antennae gave the strongest EAG responses to methyl anthranilate, methyl salicylate and 2-phenylethyl alcohol. In a field trapping experiment, P. livida beetles preferred fluorescent yellow and yellow traps over white, blue and transparent traps. When we compared different chemical lures, loaded with EAG-active compounds and their blends, in fluorescent yellow traps, we found that the beetles responded stronger to the two-component blend of methyl anthranilate and 2-phenylethyl alcohol than to other lures tested. In a subsequent experiment testing different ratios of these two compounds, the highest number of P. livida adults was recorded in traps baited with a ratio of 1:1 (100 mg of each compound) of methyl anthranilate and 2-phenylethyl alcohol, followed by traps with the 10:1 ratio. Thus, 1:1 and 10:1 blends of methyl anthranilate and 2-phenylethyl alcohol in fluorescent yellow traps are suitable for detection and monitoring of P. livida.

Key words: Pseudovadonia livida, Cerambycidae, Lepturinae, floral compounds, electrophysiology, field responses, visual cues, 2-phenylethyl alcohol, methyl anthranilate, attractant trap.

Introduction

Chemical communication of Cerambycidae has been a subject of numerous studies and resulted in the discovery of chemical signals for several hundred species, including attractants (floral, trunk, leaf and smoke volatiles, bark beetle pheromones), repellents and deterrents, sex pheromones (short-range or contact pheromones and long-range sex pheromones), aggregation pheromones, trail pheromones, oviposition stimulants, marking pheromones and defensive compounds (Allison et al., 2004; Lacey et al., 2008; Francke and Dettner, 2005; Pajares et al., 2010; Teale et al., 2011; Hoover et al., 2014). Most studies on the chemical ecology of Cerambycidae relate to species of economic importance, mainly those regarded as pests in the subfamilies Cerambycinae and Lamiinae, which attack living or recently killed trees. Such efforts aim to develop semiochemical-based tools for detection (including detection of invasive species), monitoring and control purposes (Allison et al., 2004; 2014).

Presently, little is known about the chemical signals involved in inter- and intraspecific communication of Lepturinae species. Long-range female-produced sex pheromones have been identified for Ortholeptura valida (LeConte) (Ray et al., 2011) [(Z)-11-octadecen-1-yl acetate], Desmacerus californicus californicus Horn (Ray et al., 2012) and Desmocerus aureipennis aureipennis Chevrotail (Ray et al., 2014) [(R)-desmolactone]. Ray et al. (2014) demonstrated that several Desmocerus species and subspecies have been attracted to the same sex attractant in the field, (R)-desmolactone. According to the literature, some Lepturinae species are attracted to monoterpens (α-pinene, β-pinene, 3-carene, camphene, limonene and myrcene) and other host plant volatiles (ethanol, benzyl acetate, 2-methyl-3-buten-2-ol), as well as turpentine and bark beetle pheromones. Also, there are species which use host volatiles in combination with bark beetle pheromones (Sweeney et al., 2014; Handley et al., 2015; El-Sayed, 2016). Attraction to floral scent compounds (benzyl acetate, methyl benzoate, methyl phenylacetate and linalool) have been reported for several species in the Pidonia genus in Japan (Sakakibara et al., 1998). Pseudovadonia livida (F.) (Lepturinae Lepturini) occurs in the Palaeartic region and its distribution covers almost the whole of Europe (except Finland, Norway, Sweden), Siberia, North-western China, Caucasus, Transcaucasia and the Middle East (Syria, Lebanon, Israel, Iran) (Özdikmen and Turgut, 2009; Shapovalov, 2012). The soil-dwelling larvae feed externally between dead or dying roots and root stalks of grasses, and on hyphae of underground parts of the saprophytic fungus Marasmius oreades (Bolton) Fries (Agaricales Marasmiaceae) Burakowski, 1979). P. livida adults visit flowers of members in the Adoxaceae (Sambucus), Apiaceae (Aegopodium, Chaerophyllum, Daucus, Heracleum), Asteraceae (Achillea, Anthemis, Matricaria, Leucanthemum, Tanacetum), Cistaceae (Cistus), Dipsacaceae (Scaevola), Euphorbiaceae (Euphorbia), Hydrophyllaceae (Phacelia), Rosaceae (Aruncus, Filipendula, Rosa, Rubus) and Rubiaceae (Gallium) families, where
they mate and feed (Nikolova, 1968; Feldmann, 2001; Filimonov and Udanov, 2002; Petanidou, 2003; Marti nov and Pisarenko, 2004; Brelih et al., 2006; Nappini and Bracalini, 2008; Faggi et al., 2010; Cihan et al., 2013). In Bulgaria, *P. livida* is widely distributed (Angelov, 1995; Migliaccio et al., 2007). Nikolova (1968) reports that the adults damage flowers of the oil-bearing Damask rose, *Rosa damascena Mill.*, and the “dog rose” *Rosa canina* L. in Bulgaria, but there are no recent records for such damage. Recently, Leontyeva (2013) reported *P. livida* as part of the fauna of an alfalfa crop, *Medicago sativa* L. (Fabaceae), in Tatarstan (Russia).

In a field trial, testing combinations of synthetic floral compounds and visual stimuli (colours) for the Lucerne longicorn, *Plagionotus florialis* (Pallas), in an alfalfa crop in Sofia, Bulgaria, apart from the target species, relatively high catches of *P. livida* adults were registered (Toshova et al., 2010). To date, the sensory and behavioural ecology of adults of this species have not been studied. The objectives of the present studies were: 1) to measure the antennal responses of adults to a range of synthetic floral volatiles by electroantennography (EAG), 2) to assess the visual responses of *P. livida* to differently coloured traps, and 3) to test the behavioural responses of *P. livida* to the most active EAG compounds in field trapping trials.

**Materials and methods**

**Test compounds**

Synthetic compounds were purchased from commercial sources (Sigma-Aldrich Kft, Budapest, Hungary) and were over 95% pure as stated by the supplier. A total of 42 compounds from different chemical classes (table 1) were used for EAG recordings, the majority commonly found in flowers (Knudsen et al., 2006). Green leaf volatiles that are produced by flowers (Kunin, 1984; 1995; Bialecki and Smadja, 2006) were also included.

**Electroantennography (EAG)**

*P. livida* adults were hand-collected on flowers of randomly chosen specimens of *Matricaria trichophylla* (Boiss.) Boiss. and *Achilea* sp in fields belonging to Training and Experimental Field Station (University of Forestry) in Vrazhdebna suburb of Sofia, on 16 and 22 June 2009.

EAG responses from six male and two female *P. livida* antennae (one antenna per specimen) to 42 synthetic compounds were recorded using a Syntech (Kirchzarten, Germany, www.syntech.nl) equipment comprising of micromanipulators, a CS-05 stimulus air controller and an IDAC signal connection box for data acquisition. EAG signals and data were analysed using a customized software package (EAG for Windows, 1999, Syntech). The antennae were excised and mounted between Ag-AgCl glass electrodes filled with Ringer solution (Roelops, 1984).

Each compound was diluted in hexane to give a 1 µg/1 µl solution. Test solutions (10 µl) were applied onto pieces of folded filter paper (1.5 × 1.5 cm), which were then inserted into glass Pasteur pipettes (Brand) after complete evaporation of the solvent and used as stimulus cartridges. The cartridges were only used on the same day for recordings from one or two antennae and fresh cartridges were prepared thereafter.

The stimuli were delivered in a random order into a constant 2 L/min airstream and applied (2 sec duration) at 30-40 s intervals. The hexane control (10 µl) was applied before and after stimulation with each test chemical. Nonanol can cause obvious EAG responses on *P. livida* and it is a compound with medium molecular weight and volatility (table 1) (Raguso et al., 1996), so it was chosen as a standard stimulus and presented at the beginning and end of the replicate, as well as in between each group of 9-11 test compounds.

**Field experiments**

Field tests were carried out in Training and Experimental Field Station (University of Forestry) in Vrazhdebna, Sofia in 2009-2011, using CSALOMON® VARb3 modified funnel traps produced by the Plant Protection Institute (CAR HAS, Budapest, Hungary, www.csalomontraps.com). A small piece (1 cm × 1 cm) of insecticidal strip (Vaportape II, Hercon®, Emigsville, USA; active ingredient 10% dichlorvos) was placed into the catch container as a killing agent for captured insects.

Traps were set up in blocks and each block comprised one of each treatment. The distance between traps within a block was 7-10 m and the distance between blocks was 100-200 m. Traps were attached to wooden poles and set up at ground level in sunny places. The crops at the test site were alfalfa *M. sativa*, grape *Vitis vinifera* L. and wheat *Triticum aestivum* L. There were also meadows of mixed plant species.

For preparing the bait dispensers, a 1 cm piece of dental roll (Celluron®, PAUL HARTMANN AG, Heidenheim, Germany) was placed into a polyethylene bag made of 0.02 mm linear polyethylene foil. The polyethylene sachets were ca. 1.5 × 1.5 cm. The dispenser was attached to a plastic strip (8 × 1 cm) for easy handling when assembling the traps. For making the baits, the required amount of each synthetic compound was loaded on the dental roll, and the opening of the polythene bag was heat-sealed. Each lure was wrapped individually in a piece of aluminum foil and stored at −10 °C before use. For experiments 2 and 3, lures were replaced with fresh ones after three weeks.

Experiment 1 tested the colour preference of *P. livida*, using traps without chemical lures, from 19 May to 3 August 2009. The treatments were funnel traps with transparent, white, blue, yellow or fluorescent yellow upper parts. Treatments were set up in five blocks. The distance within a block was 7-10 m and the distance between blocks was 100-200 m. Traps were attached to wooden poles and set up at ground level in sunny places. The crops at the test site were alfalfa *M. sativa*, grape *Vitis vinifera* L. and wheat *Triticum aestivum* L. There were also meadows of mixed plant species.

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Experiment 1 tested the colour preference of *P. livida*, using traps without chemical lures, from 19 May to 3 August 2009. The treatments were funnel traps with transparent, white, blue, yellow or fluorescent yellow upper parts. Treatments were set up in five blocks. The light reflectance of the coloured sheets was recorded by an Ocean Optics USB 2000+ portable spectrophotometer using R200-7-UV-VIS reflection probe, PX-2 pulsed Xenon lamp and WS-1 diffuse reflectance white standard. Light reflectance spectra were recorded from 275 nm to 800 nm at 0.2 nm intervals and data were processed by the software SpectraSuite. Raw data were imported and saved in *.xls format and the means were calculated in Excel for five measurements, which were
(100 mg of each), their binary combinations in a ratio of 1:1 (200 mg total load) and ternary combination in a ratio 1:1:1 (300 mg total load) were tested. Transparent traps were used from 2 June to 11 June 2010 and no catches of *P. livida* were recorded during this period, although adults of this species were observed in the field in the close vicinity (< 10 m) of the traps on two sam-

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<th>Molecular weight</th>
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<td>176</td>
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<td>methyl eugenol</td>
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<td>C\textsubscript{15}H\textsubscript{14}</td>
<td>204</td>
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</table>

– Boiling point data not available.
Sampling dates, 7 June and 11 June 2010. On 11 June 2010 we replaced the transparent upper parts of the traps with fluorescent yellow parts and they operated until 29 July 2010. Transparent and fluorescent yellow traps without lures were used as control traps in both trapping periods, respectively. Treatments were set in four blocks.

Experiment 3 was carried out from 7 June to 8 August 2011. The following ratios of methyl anthranilate and 2-phenylethyl alcohol, respectively, were tested: 1) 10:1 (110 mg total load), 2) 1:1 (200 mg total load) and 3) 1:10 (110 mg total load). For all treatments, fluorescent yellow traps were used. Treatments were set up in four blocks.

Traps were checked every 2–7 day. All cerambycid species captured during this study were identified to species according to Angelov (1995). Captured *P. livida* beetles were sexed using a character on the metathoracic sternite and the shape of the terminal abdominal sternite (Angelov, 1995).

**Statistics**

**E A G t e s t**

Student *t* test was used to compare the EAG responses of males and females to the compounds tested, and those elicited by the nonanal standard and hexane control. Taking into account the differences of volatility of the compounds tested, and to reduce variability in responses (millivolts) among preparations, EAG responses were normalized with respect to the standard by subtracting the value of the hexane control and then expressing the corrected mean EAG values (mV) as a percentage of the standard. In this normalization procedure, the responses to the standard were defined as 100%.

The EAG data were analyzed using a linear mixed model containing compound class (aliphatic compounds, aromatic compounds and terpenoids) as fixed effects and compound as random effects. The EAG values (in % of standard) were transformed using $Y = \text{sign}(\text{EAG}) \times \sqrt{\text{EAG}}$ to reduce skewness in the response variable. The transformed value is $\text{sign}(\text{EAG})$ times the square-root of the absolute EAG value, where $\text{sign}(\text{EAG})$ equals $-1$, $0$ or $1$ if EAG $< 0$, $= 0$ or $> 0$ respectively. Examination of residual plots for the fitted model supported the data transformation used.

For all chemical class × compound combinations, the predicted means were subsequently ranked by using Fisher’s Least Significant Difference (LSD) ranking for all compound class × compound combinations. A package `asreml` (Butler, 2009) under R (R Core Team, 2015) was used to fit this model.

**E x p e r i m e n t 1**

To investigate the relationship between the numbers of beetles caught and trap colour, a Poisson log linear analysis with effects for date and colour, allowing for possible over-dispersion, was used. The colour effects, with four degrees of freedom after adjusting for a baseline effect, were further separated into effects BTW vs FY (a contrast for blue, transparent and white versus fluorescent yellow and yellow colours), F vs Y (a contrast for fluorescent yellow versus yellow) and Within BTW (comparisons across blue, transparent and white on two degrees of freedom). Over-dispersion is included to allow for variation in results greater than expected for usual Poisson variation (e.g. variation attributable to date × colour interactions).
Table 2. Effect of trap colour on *P. livida* catches (analysis of deviance for fitted model); Vrazhdebna, Sofia, 26 May - 30 June, 2009, n = 5. For abbreviations, see materials and methods, Experiment 1.

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<tr>
<th></th>
<th>df</th>
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<td>Date</td>
<td>4</td>
<td>110.14</td>
<td>115</td>
<td>345.20</td>
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<td>114</td>
<td>225.11</td>
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<td>187.30</td>
<td>13.18</td>
<td>&lt; 0.001</td>
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<td>Within BTW</td>
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<td>2.77</td>
<td>111</td>
<td>184.53</td>
<td>0.48</td>
<td>0.618</td>
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Figure 2. Relative EAG responses of *P. livida* adults (mean ± SE) to 10 µg doses of synthetic compounds of different chemical classes. A) aromatic compounds, B) terpenoids, C) aliphatic compounds; n = 5-8. Responses were normalized to the standard (10 µg of nonanal). Response bars, which are not significantly different (*P* > 0.05; LSD test) are marked with the same group line and letter.
Figure 3. Mean catches of *P. livida* in fluorescent yellow traps without lure and in traps with methyl anthranilate, methyl salicylate and 2-phenylethyl alcohol and their blends. Vrazhdebna, Sofia, 11 June – 9 July, 2010, *n* = 4. Plus (+) and minus (-) below the bars indicate presence and absence of chemical compounds in the treatment, respectively. Bars marked with the same letter are not significantly different (*P* < 0.05, LSD test).
With the exception of the trap with a lure of methyl salicylate only, all baited traps captured significantly higher number of *P. livida* adults than unbaited traps (figure 3). Catches of females in traps baited with methyl anthranilate and 2-phenylethyl alcohol were significantly higher than those in the other baited traps. Catches of males in traps baited with both these compounds were not significantly different from those baited with either compound alone, or the combination of methyl salicylate and 2-phenylethyl alcohol. The ratio of females to males caught within traps was not significantly different across dates ignoring treatment \(F_{7, 99} = 1.896, P = 0.07\), nor significantly different across treatments adjusted for date \(F_{7, 92} = 1.513, P = 0.17\).

**Experiment 3**

Comparing three different ratios of methyl anthranilate and 2-phenylethyl alcohol in fluorescent yellow traps, the highest number of *P. livida* adults was recorded in traps with a ratio of 1:1, followed by traps with the 10:1 ratio (figure 4). The treatment had significant effects, after adjusting for date effects, on female \(F_{2, 97} = 6.208, P = 0.003\), male \(F_{2, 97} = 10.218, P < 0.001\) and total \(F_{2, 97} = 9.798, P < 0.001\) catches.

In this experiment, there was a significant treatment effect, after adjusting for date effects, on the proportion of females caught \(F_{2, 97} = 3.763, P = 0.036\). This significant difference results from the significantly fewer females than males caught with methyl anthranilate and 2-phenylethyl alcohol in ratio of 1:1. For methyl anthranilate and 2-phenylethyl alcohol in ratio of 1:10 or 10:1, the numbers of females to males are not significantly different.

The seasonal flight of *P. livida* in Sofia, as registered by trap catches in 2009-2011, took place between the end of May - second part of July. The earliest catches were registered between 26 May - 3 June 2009, whereas the latest catches between 15-22 July 2010. The peak of the flight was in June.

Several other cerambycid species were also caught during the study. The most abundant was *P. florals* with a total of 530 specimens in 2010 and 94 specimens in 2011. For this species, there were no significant differences between catches in traps with different treatments (Experiment 2: \(F_{7, 310} = 1.587, P = 0.139\) and Experiment 3: \(F_{2, 168} = 0.628, P = 0.536\)). The earliest catches of *P. florals* were recorded in the middle of June and the latest at the beginning of August 2011. Other species recorded were: Chlorophorus sartor (Muller) (two specimens, 21-28.06.2010 and two specimens, 11-18.07.2011), C. varius (Muller) (one specimen, 8-11.07.2011 and one specimen, 11-18.07.2011), Clytus rhanni Germar (21 specimens 11.06.-10.07.2010 and nine specimens, 13.06.-01.08.2011) (Cerambycinae), Leptura quadrifrons L. (one specimen, 28.06.-01.07.2010), Stenurella bifasciata (Muller) (one specimen, 25-28.06.2010) and Stenurella melanura (L.) (one specimen, 7-10.06.2011 and one specimen, 1-8.08.2011) (Lepturinae).

**Discussion**

This study is the first to document the EAG and behavioural responses of *P. livida* adults to floral volatile compounds, as well as the effect of their interaction with visual stimuli (colour) on trap catches. *P. livida* antenna responded strongly to compounds associated with flowers (methyl anthranilate, methyl salicylate, 2-phenylethyl alcohol, eugenol) rather than to compounds usually emitted from foliage [green leaf volatiles, e.g., \((E)-2\text{-hexenal}, (Z)-3\text{-hexen-1-ol}, (E)-2\text{-hexen-1-ol}\)]. The benzenoids, methyl salicylate and 2-phenylethyl alcohol, are among the most common compounds in the floral scent of many plant species in more than 40 plant families (Knudsen et al., 2006). 2-Phenylethyl alcohol is the dominant floral scent compound in the oil-bearing Damask rose blossoms (Oka et al., 1999; Sakai et al., 2007; Baldermann et al., 2009, Rusanov et al., 2011a; 2011b). There are previous records that this compound is attractive to other insects, including scarabs (*Hoplia communis* Waterhouse and *Oxythreus* spp., Scarabaeidae) (Imai et al., 1998; Vuts et al., 2008; 2012), dipterans (*Hylemya antiqua* Meigen and *Hylemya platura* Meigen, Anthomyiidae) (Ishikawa et al., 1983) and lepidopterans [*Trichopistes ni* (Hubner) and *Pieris rapae* (L.)] (Haynes et al., 1991; Honda et al., 1998). In Cerambycidae, 2-phenylethyl alcohol has been identified in the aggregation pheromone of *Megacyllene caryae* (Gahan) males (Lacey et al., 2008) and in male sex pheromone of the coffee white stemborer, *Xylotrechus quadripes* Chevrolet (Hall et al., 2006). The same compound is an aggregation pheromone for females, males and 5th-instar nymphs of the Western boxelder bug, *Boisea rubrolineata* (Barber) (Heteroptera Rhopalidae), and it serves as a sex attractant pheromone for males (Schwarz and Gries, 2010).

Imai et al. (1997) reported methyl anthranilate to be an efficient kairomone attractant for *Anomala rafocura* Motchulsky (Scarabaeidae) and when applied in combination with the female sex pheromone, it increased traps catches. This compound attracted several species of flower thrips (Murai et al., 2000; Imai et al., 2001) and it is utilized in the chemical communications of ants (El-Sayed, 2016). In addition, methyl anthranilate is known as a repellent for insects and some vertebrates (Pankiw, 2009).

The importance of visual cues in insect host location has been well documented (Prokopy and Owens, 1983; Reeves, 2011), colour being an important attractant cue for many flower-visiting insects (Vrdoljak and Samways, 2011). In our study, trap colour had significant effect on *P. livida* catches in unbaited traps. We established that the fluorescent yellow colour of the upper part of the trap was highly attractive to *P. livida* adults, followed by the yellow colour. Spectral analysis showed that the fluorescent yellow color reflected light in a similar pattern to yellow colour from 500-560 nm with two peaks of reflectance, but the former colour was of higher intensity and this might be an explanation for higher catch in fluorescent yellow traps. Similar preference for fluorescent yellow has been documented for the alfalfa longhorn beetle, *P. floralis* (Imrei et al., 2014), two *Oxythreus* species (Coleoptera Cetoniidae) (Vuts et
al., 2008; 2012), the pollen beetle *Meligethes aeneus* F. (Coleoptera Nitidulidae) (Döring et al., 2012), the European cherry fruit fly, *Rhagoletis cerasi* (L.) and the olive fruit fly *Bactrocera oleae* (Rossi) (Diptera Tephritidae) (Economopoulos, 1977; Tóth et al., 2004), psyllid species (*Ctenarytaina eucalypti* Maskell and *Ctenarytaina spatulata* Taylor) (Hemiptera Psyllidae) (Brennan and Weinbaum, 2001), and thrips (Thysanoptera) (Al-Ayedh and Al-Doghairi, 2004; Jenser et al., 2010). When studying diversity of beetles by coloured traps,

**Figure 4.** Mean catches of *P. livida* in fluorescent yellow traps with different ratios of methyl anthranilate and 2-phenylethyl alcohol. Vrazhdebna, Sofia, 7 June - 8 July 2011, n = 4. For further details, see figure 3.
Sakalian et al. (1993) and Hilszczani and Plewa (2009) reported on more catches of *P. livida* in yellow traps than in traps with other colours, but they have not tested fluorescent yellow colour.

Several studies on flower-visiting insects have shown a different role of olfactory and visual cues in attraction and feeding, and they also demonstrated their integration in many cases. When studying the behaviour of two sphingid species in the wind tunnel, Balkenius et al. (2006) have shown that the behaviour of the diurnal species *Macroglossum stellatarum* (L.) is strongly affected by visual cues, whereas that of the nocturnal *Deilephila elpenor* (L.) by olfactory stimuli. Olfactory and visual cues attract the nocturnal hawkmoth *Manduca sexta* (L.) within the 5 m range of a flower and integration of both types of stimulus is critical in the feeding behaviour (Raguso and Willis, 2002). Hirota et al. (2012) demonstrated that swallowtail butterflies and hawkmoths primarily use colour as a cue to find flowers, with contrasting preferences toward reddish and yellowish hues, respectively. The floral scent produced by the inflorescences of *Lysichiton americanus* Hulsen et St John (Araceae) induced searching behavior in *Pellecomatum testaceum* (Mannerheim) (Staphyliniidae) for yellow objects (Pellmyr and Patt, 1986).

In our study, the visual stimulus (colour) had a primary role in the attraction of *P. livida* beetles to the traps. However, adding of chemical stimuli, methyl anthranilate and 2-phenylethyl alcohol, increased catches significantly. Similarly, Imrei et al. (2014) demonstrated that the visual stimulus, i.e., fluorescent yellow colour, has a dominant role in the attraction of *P. florals* adults, but the presence of a synthetic chemical lure comprising (E)-anethol, 1-phenylethyl alcohol and 3-methyl-eugenol increases the effect of the visual stimulus. Recently, Lyu et al. (2015) reported that the combination of visual and olfactory cues of host plants attracted more *Anoplophora glabripennis* (Motschulsky) (Cerambycidae) adults than either cue alone. In the pest control practice, visual stimuli are used most frequently in combination with chemical stimuli, thereby enhancing the efficacy of the application of a behavioural manipulation method (e.g., attractant traps) in insect pest management over the use of either stimulus type alone (Foster and Harris, 1997).

In Bulgaria, according to Angelov (1995), *P. livida* is active in June and July. Our results show that adults appear at the end of May and can be found in the field until the end of July, with the peak flight period in June. According to Šabanoğlu (2013), adults of this species are active from May to September in Turkey. In Sicily (Italy), *P. livida* adults appear from May to June (La Mantia et al., 2010). In Germany, *P. livida* fly from the beginning of June to the beginning of August (Feldmann, 2001).

In conclusion, our results offer an insight into the sensory biology of *P. livida* adults, indicating that both trap colour and lure composition are important for field attraction. From a practical point of view, combination of methyl anthranilate and 2-phenylethyl alcohol in a ratio of 1:1 in fluorescent yellow traps is recommended for the detection and monitoring of local population outbreaks of *P. livida*. In addition to this, De Cáceres et al. (2010) reported *P. livida* among the group of indicator species that indicate habitat alteration. The potential of this species as a single indicator for habitat quality need to be assessed.

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