INTRODUCTION

There is a pressing need in Europe to prepare for the potential invasion of the emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Buprestidae, Coleoptera) from European Russia (Baranchikov, Mozolevskaya, Yurchenko, & Kenis, 2008) as it may significantly change the environment in urban areas, forests and other agroecosystems where ash stands occur (Straw, Williams, Kulinich, & Gninenko, 2013). There are similar risks presented by other jewel beetles (Buprestidae, Coleoptera), including the introduction of populations into areas where local host plants have no evolutionarily history of adaptation to the pest, or because of climatic changes in already inhabited areas. The latter appears evident in both North America and Europe for species such as the goldspotted oak borer, *Agrilus auroguttatus* Schaeffer (Coleman & Seybold, 2011), the black-banded oak borer *Coraebus florentinus* Herbst (Buse, Griebeler, & Niehuis, 2013; Koltay & Leskó, 1991) and the cypress jewel beetle *Ovalisia festiva* L. (Nitzu, Dobrin, Dumbravă, & Gutue, 2016; Razinger, Žerjav, & Modic, 2013).

Abstract

There is an urgent need in Europe to prepare resources for the arrival of the emerald ash borer, *Agrilus planipennis* (Buprestidae, Coleoptera) from European Russia, and possibly other invasive jewel beetles. A lightweight, easy to handle, non-sticky trap could facilitate monitoring and detection to derive information about emerald ash borer and other jewel beetle populations. In two experiments carried out over two consecutive years in an oak forest, a new non-sticky multi-funnel trap design with a light-green (sometimes described as fluorescent yellow) visual cue was developed. Altogether, there were 238 (2018) and 194 (2019) specimens captured often (2018) and eight (2019) *Agrilus* species, eight of which are oak-related and one (*A. convexicollis*) was linked to ash. The new light-green multi-funnel trap performed similarly to the sticky design with a similar coloured surface. Our results suggest that the new trap design may be suitable for catching a wide range of buprestid species. It may also have the potential to be further optimized with respect to visual and olfactory cues, which would provide an even more useful tool for monitoring both invasive and indigenous buprestids.

KEYWORDS

*Agrilus*, buprestidae, Europe, green, multi-funnel, visual
Efficient tools for the recognition of jewel beetle presence or changes in their population dynamics (including establishment at newly invaded sites) are currently missing. This is due to jewel beetles being small, swift flyers and because the larvae develop hidden under the bark of trees, resulting in their presence being invisible to unexperienced eyes (Chamorro et al., 2015; Muskovits & Hegyessy, 2002). Similar problems are faced by phytosanitary inspectors during visual inspections of wood packaging materials at ports of entry and other high-risk sites. Due to such difficulties, EAB infestations often go undetected during initial colonization resulting in insidious damage (Haack et al., 2002). By the time the characteristic D-shaped exit holes are recognized and the emerging adults are noticeable at ground level, the tree is already significantly damaged. Furthermore, the EAB mating system does not typically involve long-range pheromones, which can often be useful for detecting some individuals in sparse populations.

Monitoring methods currently in use for EAB include purple and green sticky prism traps (Francese, Crook, et al., 2010a; Francese, Fraser, et al., 2010b), and sometimes green or purple Lindgren multi-funnel traps (Francese, Fraser, Lance, & Mastro, 2011). The US federal government EAB monitoring system is based on purple prism traps with an estimated use of approximately 12 000 traps yearly (APHIS, 2018). These sticky traps have overwhelming operational costs, so a more user-friendly trap would be helpful to program managers, surveyors and researchers (Francese et al., 2011). Non-sticky trap designs can make handling and identification of specimens far easier (Domingue et al., 2013), and they are more suitable for quantitative comparisons than sticky designs (Wall, 1989). The efficacy of such traps would not rely on the residual strength of the adhesive, and there is less likelihood that trap saturation would affect future catches. Furthermore, sticky traps also catch a significant number of non-target insects. These incidental catches result in reduction of the sticky surface and require additional labour if the surface is to remain clear (Lelito et al., 2007). In addition, because the area of sticky surface is reduced by each trapped insect, this is an inherent disadvantage compared with non-sticky traps, which have a constant catching capacity over time (Wall, 1989).

The objective of this study was to initiate development of a non-sticky trap type with a similar efficacy to sticky traps. The intention was also for the trap to be easy to handle and relatively inexpensive,
thus being more economical for monitoring and detecting jewel beetle populations on a regular basis.

As attractant cues, light-green (sometimes called fluorescent yellow) and purple colours were trialled. The tested light-green was a similar hue to that previously found to be the strongest general attractant for a wide range of *Agrilus* spp. in Europe (Domingue et al., 2013). The purple colour was the same as that previously tested by Brown et al. (2017). In 2018, sticky and non-sticky traps, with or without light-green colouration, were compared; in 2019, the light-green, transparent and purple versions of the non-sticky design were compared.

2 | MATERIALS AND METHODS

2.1 | Trap type

2.1.1 | Sticky trap (PAL and PALz)

Sticky cloak traps were prepared from transparent (PAL) or light-green painted (PALz) plastic sheets (CSALOMON® PAL and PALz cloak traps; 23 × 36 cm sticky surface; Plant Protection Institute, CAR HAS, Budapest, Hungary, www.csalonmontraps.com; Tóth et al., 2003). One side was covered with sticky material (Tangletrap Insect Trap Coating, The Tanglefoot Company). When deploying the traps, the sticky sheet was folded with the sticky side facing outward and the rear edges fastened together with clips, forming a "cloak-like" structure (Figure 1a,b).

2.1.2 | Multi-funnel traps (MULT, MULTz and MULTp)

The upper funnels of the commercial CSALOMON® VARb3 funnel trap (produced by Plant Protection Institute, Centre for Agricultural Research, Budapest, Hungary, www.csalonmontraps.com; Imrei, Tóth, Tolasch, & Francke, 2002; Schmera et al., 2004) were multiplied, so that four funnels were built up in a vertical tier approximately 5 cm above each other (Figure 1c–e). The insides of the funnels were painted light-green (MULTz), purple (MULTp) or left clear (MULT) (Figure 1). For the reflectance spectra of the light-green colour, refer to Schmera et al. (2004), Tóth, Schmera, and Imrei (2004) and Jenser, Szita, Szénási, Vörös, and Tóth (2010); for that of the purple colour, refer to Figure 2 and Brown et al. (2017). The lower funnel and catch container were the same as in the VARb3 trap. The inside of all the funnels was coated with Teflon® (95% polytetrafluoroethylene-based spray; B'laster Corporation) to increase trapping efficiency (Graham & Poland, 2012); and a 1 × 1 cm piece of Vaportape® insecticidal strip (Hercon Environmental Inc) was placed in the collection bucket. The MULT trap designs weigh about 410 g.

Both the sticky and multi-funnel traps were suspended by a piece of wire attached to an "R"-shaped rigid metal wire hook (about 80 g), suitable for hanging on the higher branches of trees. A 20 cm long rigid wire hook was fixed at right angles to the end of a 7 m long pole (carbon-fibre telescopic fishing stick). With this pole, we were able to easily hang the traps at a height of about 4–5 m, where the population density of flying jewel beetles was expected to be greater.

The experiments were conducted from 22 June to 18 July 2018 and from 20 June to 11 July 2019, Budapest, in Hungary (Coordinates: 47.549012, 18926949). The selected time period is known over multiple experiments to correspond to the peak period of adult bustard activity in this region (Domingue et al., 2011, 2013, 2014, 2016). Traps were set up along the edge of an old sessile oak forest (*Quercus petraea* [Matt.] Liebl.). In an open field neighbouring the oak forest, there were also sporadic European ash (*Fraxinus excelsior* L.) saplings. Five traps (2018) or four traps (2019) (replicates) of each treatment (trap type and colour combination) were tested operating one at each block. Traps were installed in a randomized block design. Both traps and blocks were spaced 10–15 m apart, and traps were suspended from branches at a height of 4–5 m in a single row. Traps were inspected once a week, whereupon the insects caught were removed and later identified to species in the laboratory (Imrei et al., 2018; Muskovits & Hegyessy, 2002).

2.2 | Statistics

Catch data were analysed by the non-parametric Kruskal–Wallis test (Kruskal & Wallis, 1987) because the data did not fulfil requirements for a parametric analysis. When the Kruskal–Wallis test indicated significant differences, pairwise comparisons were performed with Mann–Whitney U tests (Zar, 1999) using the software packages StatView® v4.01 and SuperANOVA® v1.11 (Abacus Concepts Inc). The combination of trap type and colour was the independent variable, while all statistical procedures were conducted on the catch per trap per trap inspection data units as response variables.

3 | RESULTS

Altogether, there were 238 (2018) and 194 (2019) jewel beetle specimens caught, of ten (2018) and eight (2019) *Agrilus* species (Table 1). All but one of the beetles were caught in traps (sticky
PALz and non-sticky MULTz traps), while the remaining single *Agrilus viridis* specimen was caught in a transparent PAL trap. No catches were recorded in transparent MULT or purple MULTP traps.

Five (2018) and six (2019) *Agrilus* species were caught in sufficient numbers for statistical analysis (catches containing over 16 specimens of one species).

In 2018, catches of *Agrilus obscuricollis* Kiesenwetter, *A. graminis* Laporte et Gory, *A. angustulus* (Illiger), *A. laticornis* (Illiger) and *A. convexicollis* Redtenbacher showed very similar patterns, being caught in light-green PALz or MULTz traps in significantly larger numbers than in the transparent controls (PAL and MULT) (Figure 3). Catches in PALz and MULTz traps were equally high. In 2018, the remaining five species were caught in lower numbers; therefore, catches of *Agrilus litura* Kiesenwetter, *A. viridis* L., *A. sulcicollis* Lacordaire, *A. derasofasciatus* Lacordaire and *A. hastulifer* Ratzeburg were pooled for analysis. The pooled statistics for these species showed the same pattern: catches were significantly higher in both sticky and non-sticky light-green traps, compared with the transparent controls.

As expected, the sticky traps (PALz and PAL) caught a wide range of other insect taxa (predominantly Diptera), which occurred independently to the trap colour cue. However, hardly any insects other than jewel beetles were caught in the light-green MULTz traps. The transparent non-sticky traps caught only a few Diptera.

In 2019, catches of the four species *A. obscuricollis*, *A. graminis*, *A. angustulus* and *A. laticornis* were again significantly higher in non-sticky light-green traps, compared with the non-sticky transparent control and the newly tested non-sticky purple traps (Figure 4). *A. litura* and *A. olivicolor* were caught in MULTz light-green traps in significantly larger numbers, compared with transparent or purple traps. Numbers of other species were too low for statistical analysis even when pooled (six specimens altogether, of which five were *A. convexicollis*), so confirmation of the previous year’s results was not possible for these species.

### TABLE 1

| *Agrilus* species | Total catches 2018 | Total catches 2019 |
|------------------|--------------------|--------------------|
| *A. obscuricollis* Kiesenwetter | 68                 | 97                 |
| *A. graminis* Laporte et Gory | 52                 | 10                 |
| *A. laticornis* (Illiger) | 30                 | 33                 |
| *A. angustulus* (Illiger) | 31                 | 15                 |
| *A. convexicollis* Redtenbacher | 26                 | 5                  |
| *A. litura* Kiesenwetter | 13                 | 16                 |
| *A. olivicolor* Kiesenwetter | 0                  | 17                 |
| *A. viridis* L. | 6                  | 1                  |
| *A. sulcicollis* Lacordaire | 5                  | 0                  |
| *A. derasofasciatus* Lacordaire | 4                  | 0                  |
| *A. hastulifer* Ratzeburg | 3                  | 0                  |

Note: Bold italic values indicates that statistical tests were performed on pooled data.

### DISCUSSION

Results suggest that the newly developed non-sticky MULTz trap design is suitable for catching *Agrilus* jewel beetles. Efficacy of the MULTz trap was similar (even higher in absolute numbers caught) to that of sticky traps (PALz). Jewel beetle catches free from sticky residue are highly advantageous as there is no need to clean them with chemicals before identification. The maintenance and operation of a non-sticky trap in the field is also much easier and more straightforward than sticky traps.

The attractiveness of the light-green colour to the seven predominant *Agrilus* species caught in our experiments was clearly demonstrated. The pooled data of the remaining five species suggest that their capture is also facilitated by the effect of the light-green visual cue. On several occasions, similarly coloured trap surfaces have been shown to stimulate the attraction of jewel beetles in Hungarian oak forests (Domingue et al., 2013). Results of this research confirm these earlier findings for *A. graminis*, *A. angustulus*, *A. laticornis* and *A. sulcicollis*.

In the United States, both purple and green 12-unit Lindgren multi-funnel traps were as good as, or better than, the current standard purple prism traps at catching EAB (Crook et al., 2014; Francese et al., 2011). However, in this study the non-sticky MULTp purple traps did not catch *Agrilus* specimens at all. In larger multi-funnel traps with 12 or 16 funnel units, EAB catches were significantly greater, compared to smaller counterparts with four or eight funnels (Francese, Rietz, & Mastro, 2013). Because *Agrilus* catches significantly increase with the placement of the trap at heights from 1.5 m to 13 m for EAB in the United States (Francese, Fraser, et al., 2010b; Francese et al., 2008; Ryall et al., 2012), from 3 m to 10 m for *A. laticornis* in the UK (Brown et al., 2017) and from 1.5 m to 15 m for *A. convexicollis* in Italy (Rassati et al., 2019), a lighter trap design such as ours may be very helpful to optimize catches. These traps can be handled more easily and lifted with less effort to higher branches and thus positively contribute to effective monitoring. A Lindgren multi-funnel trap (Francese et al., 2011) that consists of 12 funnels, a lid and a catch container weighs about 1,193 g. The mass increases to at least 1,350 g when 150–200 ml of propylene glycol is added to the collection cup as a surfactant and preservative. The MULTz traps weigh about 410 g and have no need for additional liquids; thus, they weigh less than one third of a Lindgren multi-funnel trap. The lighter MULTz trap is easy to place (with the aid of the pole) on branches as high as 4–6 m (without the use of ropes or climbers). To compare the monitoring efficacy of MULTz versus Lindgren multi-funnel trap, further studies should be performed to assess whether relative detection abilities remain adequate in the new design.

The colour of a Lindgren multi-funnel trap is determined by painting or moulding the entire surface. In the MULTz trap, the changeable upper parts reduce the cost of a colour change and allow for
inexpensive flexibility depending on the trapping purpose. The importance of colour choice is supported by earlier findings. Numbers of male EAB beetles caught were much higher in green traps than in purple traps, regardless of height or trap type (Francese, Fraser, et al., 2010b; Francese et al., 2013). On the contrary, purple traps were found to be more attractive to females, showing female-specific sensitivity in the red regions of the spectrum at 640–670 nm (Francese, Crook, et al., 2010a; Francese et al., 2013). In Europe, purple traps attracted 2–3 times more adults of the beech-infesting *A. viridis*, with high (>95%) female ratios, when compared to green traps in the same study. Furthermore, purple prism traps caught *A. biguttatus* and *A. sulcicollis* in oak forests in the UK (Brown et al., 2017) and *C. undatus* in a cork oak forest in Spain (Fürstenau, Quero, Riba, Rosell, & Guerrero, 2015). In our study, no *Agrilus* specimens were caught using purple traps.
Eight out of eleven Agrilus species trapped in this study were linked to oaks (Muskovits & Hegyessy, 2002). A. obscurociliis, A. graminis, A. angustulus, A. litura, A. laticornis and A. olivicolor were caught in relatively large numbers, and A. sulcicollis and A. hastulifer were caught in small numbers. All species are common across Europe, except for A. litura, which occurs more often in Central and Eastern Europe according to Muskovits and Hegyessy (2002). A. convexicolliis was caught in significant numbers in light-green traps of both types, confirming a report from Slovakia where it was almost exclusively caught in traps with a green visual cue (Rhaïnds et al., 2017), and a report from Italy where catches in green multi-funnel Lindgren traps were higher than in purple traps of the same design (Rassati et al., 2019). A. angustulus and A. graminis are also recorded from the Russian Far East, although both are described as Western Palearctic species (Jendek & Nakladal, 2019).

In Western Russia, A. convexicolliis has also been collected from EAB-infested, declining green ash (Fraxinus pennsylvanica L.) trees (Orlova-Bienkowskaja, 2015; Orlova-Bienkowskaja & Volkovitsh, 2015). As our results indicate that MULTZ traps are suitable for trapping A. convexicolliis, they may have a practical benefit in future monitoring surveys for this species, which is common in stressed but living hosts all over Europe (Muskovits & Hegyessy, 2002).

A. viridis, a common European and North American species (Muskovits & Hegyessy, 2002), which was caught in small numbers in this study, has a wide range of hosts. At high population densities, it is described as a pest of common beech (Fagus sylvatica L.) (Molnár, Bruck-Dyckhoff, Petercord, & Lakatos, 2010), although no beech trees are known to exist in the vicinity of the experimental site. Finally, the larvae of A. dersasfasciatus commonly develop in the woody parts of grape species (Vitis vinifera, V. sylvestris) all over Europe according to Muskovits and Hegyessy (2002). It is important to note that all of these were caught in the PALz traps.

The MULTZ traps form a good basis for further trap optimization. Efficacy may be improved by further improving the green colouration and by adding combinations of other attractive visual (Crook et al., 2009; Gwynne & Rentz, 1983; Lelito et al., 2007) or olfactory cues. The latter may be plant-related (de Groot et al., 2008; Grant, Poland, Ciaramitaro, Lyons, & Jones, 2011; Grant, Ryall, Lyons, & Abou-Zaïd, 2010) or beetle-related (Bartelt, Cosse, Zilkowski, & Fraser, 2007; Silk et al., 2011). Selectivity may also be improved as our understanding increases with respect to both the generalities of buprestid behaviour and the complexities of the communication systems of each jewel beetle species.

ACKNOWLEDGEMENTS

The project was supported by research grants from the Higher Education Institutional Excellence Program of the Hungarian Ministry of Human Capacities within the framework of plant breeding and plant protection researches (20430-3/2018/FEKUTSTRAT) at Szent István University (to JF and ZL), the János Bolyai Research Scholarship of the Hungarian Academy of Sciences and the UNKP Bolyai + fellowship of the Hungarian Ministry of Human Capacities to JF. The work at Rothamsted Research forms part of the Smart Crop Protection (SCP) strategic programme (BBS/OS/CP/000001) funded through Biotechnology and Biological Sciences Research Council’s Industrial Strategy Challenge Fund.

CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTION

ZI, MT, MD, VJ, PG and ZL conceived research. ZL, JF, ZI, EM, JM conducted the experiment. MT, ZI and MD contributed material. ZI, MT, ZL and EM analysed data and conducted statistical analyses. ZL, ZI, MT, VJ, PG, MB, MD and JF wrote the manuscript. MT and ZI secured funding. All authors read and approved the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available at http://doi.org/10.6084/m9.figshare.10007645 (2018) and at http://doi.org/10.6084/m9.figshare.11317073 (2019).

ORCID

Zoltán Imrei https://orcid.org/0000-0002-2839-8239

REFERENCES

APHIS (2018). Emerald ash borer survey guidelines: United States Department of Agriculture Animal and Plant Health Inspection Service, USDA APHIS PPQ.

Baranchikov, Y., Mozolevskaya, E., Yurchenko, G., & Kenis, M. (2008). Occurrence of the emerald ash borer, Agrilus planipennis in Russia and its potential impact on European forestry. OEPP/EPPO Bulletin, 38, 233–238.

Bartelt, R. J., Cosse, A. A., Zilkowski, B. W., & Fraser, I. (2007). Antennally active macrolide from the emerald ash borer Agrilus planipennis emitted predominantly by females. Journal of Chemical Ecology, 33(7), 1299–1302. https://doi.org/10.1007/s10886-007-9316-z

Brow, N., Jeger, M., Kirk, S., Williams, D., Xu, X. M., Pautasso, M., & Denman, S. (2017). Acute oak decline and Agrilus biguttatus: The co-occurrence of stem bleeding and D-shaped emergence holes in Great Britain. Forests, 8(3), 87. https://doi.org/10.3390/f8030087

Buse, J., Griebeler, E. M., & Niehuis, M. (2013). Rising temperatures explain past immigration of the thermophilic oak-inhabiting beetle Coraebus florentinus (Coleoptera: Buprestidae) in south-west Germany. Biodiversity and Conservation, 22(5), 1115–1131. https://doi.org/10.1007/s10531-012-0395-y

Chamorro, M. L., Jendek, E., Haack, R. A., Petrice, T. R., Woodley, N. E., Konstantinov, A. S., … Lingafelter, S. W. (2015). Illustrated guide to the emerald ash borer Agrilus planipennis Fairmaire and related species (Coleoptera, Buprestidae) [WWW document]. Retrieved from https://www.fs.usda.gov/treesearch/pubs/49163

Coleman, T. W., & Seybold, S. J. (2011). Collection history and comparison of the interactions of the goldspotted oak borer, Agrilus auruguttatus Schaeffer (Coleoptera: Buprestidae), with host oaks in Southern California and southeastern Arizona, USA. Coleoptera Bulletin, 65, 93–108.

Crook, D. J., Francese, J. A., Rietz, M. L., Lance, D. R., Hull-Sanders, H. M., Mastro, V. C., … Ryall, K. L. (2014). Improving detection tools for emerald ash borer (Coleoptera: Buprestidae): Comparison of multi-funnel traps, prism traps, and lure types at varying population densities. Journal of Economic Entomology, 107(4), 1496–1501. https://doi.org/10.1603/ec14041
Grant, G. G., Ryall, K. L., Lyons, D. B., & Abou-Zaid, M. M. (2010). Differential response of male and female emerald ash borers (Col., Buprestidae) to (Z)-3-hexenyl and manuka oil. *Journal of Applied Entomology*, 134(1), 26–33. https://doi.org/10.1111/j.1439-0418.2009.01441.x

Gwynne, D., & Rentz, D. (1983). Beatles on the bottle: Male buprestids mistake stubbies for females (Coleoptera). *Australian Journal of Entomology*, 22(1), 79–80. https://doi.org/10.1111/j.1440-6055.1983.tb01846.x

Haack, R. A., Jendek, E., Liu, H. P., Marchant, K. R., Petrice, T. R., Poland, T. M., & Ye, H. (2002). The emerald ash borer: A new exotic pest in North America. *Newsletter of the Michigan Entomological Society*, 47, 1–5.

Imrei, Z., Lohonyai, Z., Muskovits, J., Fal, J., Tóth, M., & Domíngue, M. (2018). Dataset of “First results in developing a non-sticky trap design for monitoring jewel beetles.” figshare.com. 10.6084/m9.figshare.10007645

Imrei, Z., Tóth, M., Tolash, T., & Franczke, W. (2002). 1.4-Benzoquinone attracts males of *Rhizotrogus vernus* Germ. *Zeitschrift Für Naturforschung C*, 57(1–2), 177–181. https://doi.org/10.1515/znc-2002-1-229

Jendek, E., & Nakladal, O. (2019). Taxonomic, distributional and biological study of the genus *Agrilus* (Coleoptera: Buprestidae). *Part II. Zootaxa*, 4554(2), 401–459. https://doi.org/10.11646/zootaxa.4554.2.5

Jenser, G., Szita, É., Szénási, Á., Vörös, G., & Tóth, M. (2010). Monitoring the population of vine thrips (*Drepananthrips retueri* Uzer) (Thysanoptera: Thripidae) by using fluorescent yellow sticky traps. *Acta Phytopathologica Et Entomologica Hungarica*, 45, 329–335.

Kolay, A., & Leskó, K. (1991). Adatok a sávos tölgybogár (*Coraebus bifasciatus* Oliv.) hazai tömeges előfordulásához [Data to the mass occurrence of *Coraebus bifasciatus* Oliv. in Hungary]. Erdészeti Lapok, 126, 333–334.

Kruskal, W. H., & Wallis, W. A. (1987). Citation classic - use of ranks in one-criterion variance analysis. *Current Contents/Arts & Humanities*, 40, 20.

Lelito, J. P., Fraser, I., Mastro, V. C., Tumlinson, J. H., Böröczky, K., & Molnár, M., Bruck-Dyckhoff, C., Petercord, R., & Lakatos, F. (2010). The role of *Agrilus viridis* in the mass mortality of beech. *Növényvédelem*, 46, 522–528.

Muskovits, J., & Hegyessy, G. (2002). *Jewel beetles of Hungary (Coleoptera: Buprestidae)*. Nagykővárosi, Hungary: Grafon Kiadó.

Nitzu, E., Dobrin, I., Dumbravă, M., & Gutue, M. (2016). The range expansion of *Ovalisia festiva* (Linnaeus, 1767) (*Coleoptera: Buprestidae*) in Eastern Europe and its damaging potential for cupressaceae. *Travaux Du Muséum National D'Histoire Naturelle*, 58, 51–57. https://doi.org/10.1515/travmu-2016-0006

Orlóva-Bienkowskaja, M. J. (2015). Cascading ecological effects caused by the establishment of the emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae) in European Russia. *European Journal of Entomology*, 112(4), 778–789. https://doi.org/10.14411/eje.2015.102

Orlova-Bienkowskaja, M. J., & Volkovitsh, M. G. (2015). Range expansion of *Agrilus convexicollis* in European Russia expedited by the invasion of the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae). *Biological Invasions*, 17(2), 537–544. https://doi.org/10.1007/s10530-014-0762-6

Rassati, D., Marini, L., Marchioro, M., Rapuzzi, P., Magnani, G., Poloni, R., … Sweeney, J. (2019). Developing trapping protocols for wood-boring beetles associated with broadleaf trees. *Journal of Pest Science*, 92, 267–279. https://doi.org/10.1007/s10905-018-0984-y

Razinger, J., Žerjav, M., & Modic, Š. (2013). *Thuja occidentalis* L. is commonly a host for cypress jewel beetle (*Ovalisia festiva* L.) in Slovenia. *In: Zbornik predavanj v referatov* 11. Slovenskega posvetovanja o
varstvu rastlin z mednarodno udeležbo Bled, 5.–6. marec 2013, Plant Protection Society of Slovenia.

Rhainds, M., Kimoto, T., Galko, J., Nikolov, C., Ryall, K., Brodersen, G., & Webster, V. (2017). Survey tools and demographic parameters of Slovakian Agrilus associated with beech and poplar. *Entomologia Experimentalis Et Applicata*, 162(3), 328–335. https://doi.org/10.1111/eea.12546

Ryall, K. L., Silk, P. J., Mayo, P., Crook, D., Khrimian, A., Cosse, A. A., ... Scarr, T. (2012). Attraction of *Agrilus planipennis* (Coleoptera: Buprestidae) to a volatile pheromone: Effects of release rate, host volatile, and trap placement. *Environmental Entomology*, 41(3), 648–656. https://doi.org/10.1603/en11312

Schmera, D., Tóth, M., Subchev, M., Sredkov, I., Szarukán, I., Jermy, T., & Szentesi, A. (2004). Importance of visual and chemical cues in the development of an attractant trap for Epicometis (Tropinota) hirta Poda (Coleoptera : Scarabaeidae). *Crop Protection*, 23(10), 939–944. https://doi.org/10.1016/j.cropro.2004.02.006

Silk, P. J., Ryall, K., Mayo, P., Lemay, M. A., Grant, G., Crook, D., ... Magee, D. (2011). Evidence for a volatile pheromone in Agrilus planipennis Fairmaire (Coleoptera: Buprestidae) that increases attraction to a host foliar volatile. *Environmental Entomology*, 40(4), 904–916. https://doi.org/10.1603/en11029

Straw, N. A., Williams, D. T., Kulinch, O., & Gninenko, Y. I. (2013). Distribution, impact and rate of spread of emerald ash borer Agrilus planipennis (Coleoptera: Buprestidae) in the Moscow region of Russia. *Forestry*, 86(5), 515–522. https://doi.org/10.1093/forestry/cpt031

Tóth, M., Schmera, D., & Imrei, Z. (2004). Optimization of a chemical attractant for Epicometis (Tropinota) hirta Poda. *Zeitschrift Für Naturforschung C*, 59(3–4), 288–292. https://doi.org/10.1515/znc-2004-3-429

Tóth, M., Sivcev, I., Ujváry, I., Tomasek, I., Imrei, Z., Horváth, P., & Szarukán, I. (2003). Development of trapping tools for detection and monitoring of Diabrotica v. virgifera in Europe. *Acta Phytopathologica Et Entomologica Hungarica*, 38(3), 307–322. https://doi.org/10.1556/APhyt.38.2003.3-4.11

Wall, C. (1989). *Monitoring and spray timing*. New York, NY: Wiley.

Zar, J. H. (1999). *Biostatistical analysis*, 4th ed. Englewood Cliffs, NJ: Prentice Hall.

How to cite this article: Imrei Z, Lohonyai Z, Muskovits J, et al. Developing a non-sticky trap design for monitoring jewel beetles. *J Appl Entomol*, 2020;144:224–231. https://doi.org/10.1111/jen.12727