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Journal
Proceedings of the Vertebrate Pest Conference, 28(28)

ISSN
0507-6773

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Publication Date
2018

DOI
10.5070/V42811004

New Long-Life Semiochemical Lures for Rats

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ABSTRACT: Olfactory lures are important pest control tools, being widely used to attract animals to detection devices, traps, and poisons. For small mammals, like commensal rodents, almost all lures are foods. For invertebrates, however, semiochemical lures predominate and have done so for decades. Semiochemical lures overcome the inherent limitations of food-based lures, such as their perishability and inconsistent odour properties, and poor performance when foods are abundant. They can also provide benefits like low cost, ease of handling, and in-field longevity. Semiochemical lures for rodents would be a major advance, like that achieved for invertebrate monitoring and control, but their discovery has been constrained by the complexity of the challenge. Our research group is the first to achieve animal response-guided semiochemical lure discovery. We statistically integrated rapid field-based bioassays with scent chemical profiling and partial least squares regression to identify and test a suite of new single- and multi-compound rat lures. Field trials identified a tetrad and dyad mixture as the best performing lures, with an attraction rate of 0.61 and 0.60, respectively, compared to an attraction rate of 0.55 for the peanut butter standard. In total, 17 compound-based lures performed statistically as well as the peanut butter standard. We are currently working with an industry partner to encapsulate the lures as consumable, cost-effective pest-control products. Semiochemical lures will be particularly useful for multi-kill traps, toxic bait delivery devices, and remote monitoring devices that could operate for long periods without intervention. These devices offer substantial control program cost reductions but require long-life lures to realise their full potential.

KEY WORDS: attraction, compound, encapsulation, formulation, lure, olfactory, rat, *Rattus*, rodent, semiochemical

Proc. 28th Vertebr. Pest Conf. (D. M. Woods, Ed.)
Published at Univ. of Calif., Davis. 2018. Pp. 20-22.

INTRODUCTION

Olfactory lures are important animal pest control tools, being widely used to attract target species to detection devices, traps, and poisons (Rosell and Kvinlaug 1998, Apfelbach et al. 2005, Kok et al. 2013). For invertebrates, the use of volatile semiochemicals as lures predominates and has been well exploited for decades (Witzgall et al. 2010). However, for vertebrates like commensal rodents, olfactory lures are commonly foods like peanut butter; but these are perishable and require frequent replenishment, factors that decrease control operation efficacy and increase costs (Parshad 2002, Astua et al. 2006, Murphy et al. 2014).

Semiochemical lures overcome the inherent limitations of food-based lures, such as their perishability and inconsistent odour properties, while offering benefits such as long-life, ease of handling and storage, and sometimes sex and/or behaviour-specific responses (Turkowski et al. 1979, Torto 2009, Shivik et al. 2014). Semiochemical lures for commensal rodents would be a major advance, like that achieved for invertebrate monitoring and control, but their discovery has been constrained by the complexity of the challenge (Albone et al. 1986, Linklater et al. 2013).

In this paper we detail our ongoing development of semiochemical lures for rats (*Rattus* spp.) that builds on our identification of five attractive single compound semiochemicals (Jackson et al. 2016). We detail the use of bioassays to present all possible multi-component blend combinations comprising the five attractive semiochemicals. Our objective was to quantify the behavioural responses of rats to blend combinations, with the aim of identifying beneficial synergistic relationship that may increase attraction to the lures over-and-above that seen for single compounds. We provide summarised results and detail about our ongoing lure encapsulation and product development.

METHODS AND MATERIALS

Five single compound semiochemicals (codes A, B, C, F, and I) at their optimal concentration (Jackson et al. 2016) were selected as the individual components for our multicomponent blend trials. All possible dyad (10 lures), triad (10 lures), tetrad (five lures), and pentad (one lure) combinations, along with the five single compound lures, were created and presented to wild, free-ranging rats. Results are presented using lure codes. For example, the code ABC would denote a three-component blend containing compounds A, B, and C.

Field Trials

Lures comprising semiochemicals were mixed in a neutral carrier medium and presented to wild, free-ranging rats in 1.7 mL Eppendorf microtubes secured to the inside wall of tracking tunnels using a cable tie. Inked cards were placed in each tunnel to quantify the visitation and identity of species visiting lures. Lures were randomly assigned along a single spatially stratified transect, with a minimum 50 m spacing between tunnels. The number of transect strata varied between trials according to site conditions (i.e., track length and accessibility). A control (carrier medium only) and standard (peanut butter) were also randomly assigned to each transect. The order of treatments within transects was randomised for each trial. All lures were left *in situ* for two rain-free nights.

Lures were scored using the presence of rat tracks on inked cards to provide a proportion of inked cards receiving a visit for each lure and hereafter termed the "attraction rate." For example, an attraction rate of 0.50 would indicate exactly half of the tracking tunnels for a specific lure received a positively verified rat visitation. Binomial tests were used to compare the tracking rate of each individual lure against peanut butter at the end of the trial period. Binomial tests were run in R (R Core Team 2016). Twenty trials were undertaken at independent sites across the Greater Wellington region and Richmond Range (Nelson, New Zealand) between 11 November 2015 and 7 July 2016.

RESULTS

The tetrad lure ABCF was the top performing lure, with an attraction rate of 0.61 while BI and BFI were the second and third best performing lures, with attraction rates of 0.60 and 0.55, respectively. The attraction rate for the control and peanut butter standard were 0.25 and 0.55, respectively. The attraction rate for seven lures (BI, BFI, ABCI, I, ABFI, ABCFI, and C) were statistically similar to the top performing tetrad lure ABCF. No multicomponent blend statistically outperformed the single compound lures I (attraction rate 0.50) and C (attraction rate 0.45). In total, 17 compound-based semiochemical lures (14 blends and three single compound lures) performed statistically as well as the peanut butter standard ($P > 0.05$) in this study.

DISCUSSION

Fourteen simple mixtures and three single compound lures are responsible for eliciting attraction equivalent to peanut butter in this study. Although some multi-component blends achieved higher attraction rates than the single compound lures, thus hinting at synergistic effects between compounds, two single compound lures (I and C) were statistically as effective as multicomponent blended lures at attracting rats. Our findings suggest the development of semiochemical lures for rats may not require complex multicomponent blends. This may be important as the formulation and encapsulation of single compounds or simple binary mixtures is likely to be simpler than more complex multicomponent blends.

Semiochemicals need to be formulated in such a way as to ensure optimal release rates given the desired period over which the lure is required to work. This requires an understanding of each compound's unique rate of diffusion through a given matrix. Once known, subtle changes in the formulation's characteristics, amounts and technological application method are required to optimise release rates to ensure the correct concentration for each component is emitted. In addition, the chosen formulation/encapsulation technology needs to protect the active ingredients from environmental, biological, and chemical degradation; themselves be non-reactive to the compounds they encapsulate; and protect the compounds against factors like rain, ultra-violet light, large fluctuations in temperature, and biological attack (Mafra-Neto et al. 2014). Thus, single compounds or binary mixtures like BI, may prove to be extremely useful as lures as they will likely be easier to formulate, encapsulate, and dispense.

We are currently trialling two state-of-the-art encapsulation technologies (controlled release emulsion and diffusion membrane/reservoir lures) for their appropriateness, as different environments and context (in-doors, out-of-doors, urban, rural, and conservation estate) will necessitate different application technologies. Our semiochemical lures will improve the effectiveness and scale of pest mammal suppression and detection, especially at low and invading densities, by overcoming the current limitations of food-based lures (Turkowski et al. 1979, Shivik et al. 2014). They will be applicable to current biosensor, monitoring, trapping, and bait technologies and will help emerging technologies (e.g. self-resetting multi-kill traps, toxin delivery devices, and automated remote sensing technologies) realise their potential. They will provide cost efficiencies and be effective over a greater variety of circumstances and environments and provide the suite of benefits commonly associated with invertebrate lures.

ACKNOWLEDGEMENTS

We would like to express our thanks to Jess Russell, Skyler Suhrer, and Alex Verry for their assistance with fieldwork. This research was made possible by a Victoria Doctoral Scholarship.

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