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Research Paper

Measurement of semiochemical release rates with a dedicated environmental control system

Heping Zhu [a,*], *Harold W. Thistle* [b], *Christopher M. Ranger* [a], *Hongping Zhou* [c], *Brian L. Strom* [d]

[a] *USDA-ARS Application Technology Research Unit, Wooster, OH, USA*
[b] *USDA Forest Service, Morgantown, WV, USA*
[c] *Nanjing Forestry University, Nanjing, Jiangsu, China*
[d] *USDA Forest Service, Pineville, LA, USA*

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Insect semiochemical dispensers are commonly deployed under variable environmental conditions over a specified period. Predictions of their longevity are hampered by a lack of methods to accurately monitor and predict how primary variables affect semiochemical release rate. A system was constructed to precisely determine semiochemical release rates under environmentally-controlled conditions. Three dissimilar types of solid matrix, passive emission semiochemical dispensers (P339 Sirex, Beetleblock-MCH, W230 terpinolene) were selected to verify the system capabilities. The rate of mass loss for each semiochemical was measured inside a 0.11 m^3 air sealed reservoir. Each product was tested at five ambient temperatures and three values of relative humidity. Temperatures were maintained at their set points within ±1.0 °C and relative humidity within ±0.4%. Mass losses for the relatively large P339 Sirex dispensers were linear over the test period; losses for the smaller Beetleblock-MCH and W230 terpinolene dispensers fell sharply over the first 10 h of exposure and then fell linearly with exposure time. Test results demonstrated that release rates of the three semiochemicals at the linear fall stage increased exponentially as ambient temperature increased, and those rates were not apparently affected by relative humidity. Compared to release rates measured under field conditions, determination of semiochemical release rates was more precise and consistent with this dedicated, controlled environmental system. Semiochemical release rates measured with this system should provide a baseline for predicting performance and useful lifetime of semiochemical devices deployed for pest management in agriculture and forestry.

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1. Introduction

The use of conventional pesticides has raised concerns over potential contamination of the environment. Consequently, bio-pesticides, which are considered safer and have minimal non-target impacts, have been integrated with other disciplines to provide reliable and eco-friendly pest management tools for effective pest control (Wall, 1989). Applications of semiochemicals to attract or repel insects in specific areas, or

* *Corresponding author.*
E-mail address: heping.zhu@ars.usda.gov (H. Zhu).
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to disrupt their mating have increased rapidly as a pest management strategy (Clarke et al., 1999; Holsten, Shea, & Borys, 2003). For example, the control of codling moth via mating disruption in apple orchards of the north-western United States increased from 1000 ha in 1991 to 45,000 ha in 2000 (Brunner et al., 2002; Thomson, 1997).

Semiochemicals are chemicals emitted by living organisms that induce a behavioural or physiological response in other individuals. Due to their reduced environmental impacts and non-target effects, semiochemicals are used in a variety of scenarios for insect pest management (Heuskin, Verheggen, Haubruge, Wathelet, & Lognay, 2011). They are used to capture insects that spread diseases, determine the timing and necessity of insecticide applications, track pest population and dispersal, detect and monitor economically important pests (attractants or synergists), and protect tree resources in areas of particularly high value (anti-aggregants or disruptants) (Baker, 2008; Oehlschlager, Chinchilla, Castillo, & Gonzalez, 2002; Ridgway, Inscoe, & Dickerson, 1990; Wall, 1990). For instance, insect chemical attractants are regularly used to monitor flight activity and dispersal for efficient timing of insecticide applications, detecting non-native species, disrupting mate-finding capabilities, and attracting beneficial insects for the biological control of pestiferous insects (Baker, 2008; Heuskin et al., 2011; Oehlschlager et al., 2002; Ridgway et al. 1990).

Efforts are also underway to identify repellent compounds as alternatives to the more indiscriminate conventional pesticides for pest management purposes (Wall, 1989). Repellents can be integrated with attractants as part of a 'push–pull' strategy, whereby they are used to 'push' insect pests away from a crop and attractants are simultaneously used to 'pull' them into traps or areas where they can be killed (Cook, Khan, & Pickett, 2007).

A variety of devices and formulations have been developed for releasing semiochemicals that essentially fall into three main categories, namely, solid matrix dispensers, liquid formulations, and reservoirs of formulations (Heuskin et al., 2011). Pest management applications demand that devices be inexpensive and rugged, leading to the development of solid matrix passive dispensers (or first-order emitters) (Holsten et al., 2003). Solid matrix dispensers release their contents by evaporation through a permeable membrane that encapsulates a chemical reservoir (e.g., bubble cap or pouch) (Hayes, Strom, Roton, & Ingram, 1994; Ross, Daterman, & Gibson, 2002).

However, one of the limitations of solid matrix dispensers is the difficulty in maintaining a constant release rate (i.e., zero-order release kinetics) (Heuskin et al., 2011). Krüger and Tolmay (2002) noted that release rates from dispensers are heavily dependent on the diffusion speed of the compound through the matrix and the evaporation rate of the compound into the air. Diffusion speed is influenced by a variety of characteristics associated with the dispenser, including type, size, and shape of the matrix, along with the distribution of the semiochemical in the matrix (Golub, Weatherston, & Benn, 1983; Heuskin et al., 2011; Hofmeyr & Burger, 1995). Evaporation rate of the compound is mainly influenced by abiotic parameters such as air temperature, relative humidity, wind speed, and the physical properties of the semiochemical (Alfaro-Cid et al., 2009). Among those parameters, temperature might be one of the most important abiotic factors (Atterholt, Delwiche, Rice, & Krochta, 1999; Bradley, Suckling, McNaughton, Wearing, & Karg, 1995; Johansson et al., 2001; Shem, Shiundu, Gikonyo, Ali, & Saini, 2009; Van der Kraan & Ebbers, 1990). These devices characteristically release less chemical with time and release rates are influenced by heat, ventilation, humidity, membrane permeability and contact area with the liquid in the dispenser.

It is a goal of pest management programs to optimise dispenser performance, thereby promoting predictable and efficient use of semiochemicals with minimally adequate release rates for controlling a specific insect population and activity over a specified time frame. However, dispensers are often exposed to large environmental variations with many uncertainties, which leads to unpredictable performance and uncertain replacement schedules (Progar, 2005). Release rates of commercial semiochemical dispensers are usually provided by the manufacturer, having been determined in a laboratory setting at a single temperature point in the product lifetime. The utility of these measurements for predicting field performance is uncertain, depending on many factors, some intrinsic to the device (e.g., stability of release as the reservoir empties) and some meteorological. Less frequently, field evaluations have been made by investigators to estimate *in situ* performance. This approach is time-consuming and results are affected by many uncontrollable environmental variables (Doane, 1999). Consequently, test results are not well understood despite providing estimates of the useful life of dispensers under the observed field conditions (Strom & Clarke, 2011).

Because there is not a quantified target for the optimal release of semiochemicals against most insects, practitioners are primarily interested in knowing the useful lifetime of a semiochemical product in order to develop an efficient replacement schedule under local field conditions (Shorey, Sisk, & Gerber, 1996). Therefore, a greater understanding of the processes at work in semiochemical release rates with an accurate measurement under controlled conditions and field deployment is needed. Once primary factors are better understood, development of predictive models for the performance of different devices under different field conditions can proceed.

The primary goal of this research was to develop an understanding of the meteorological mechanisms affecting the release rates of solid matrix, passive emission semiochemicals from dissimilar, commercially available dispensers. The specific objective was to develop an environmentally-controlled system that maintained constant and precisely-controlled ambient air temperature and relative humidity, thereby allowing an accurate description of their effects on semiochemical release rates.

2. Materials and methods

A dedicated system was constructed to measure semiochemical release rates under controlled ambient temperature and relative humidity conditions. Primary components of