Control of slugs in a multi-trophic context: Using friends to manage foes

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Final Report

Objectives

Adopting a holistic approach, the objectives of the project were articulated into two complementary fields; ground beetles and molluscucidal nematodes, respectively.

Despite their great potential in complementing slug control, very little is known about the preying behavior of ground beetles on slugs in soybeans. We therefore *proposed* to assess the response of these beneficial insects to various environmental cues. This objective is being achieved by pursuing the following *specific aims*:

1. Assessing the response of ground beetles to different soybean cultivars suffering or not from slug damage
2. Characterize the volatile blends ground beetles are responding to.
3. Assess ground beetle preferences for slugs with different vigor status

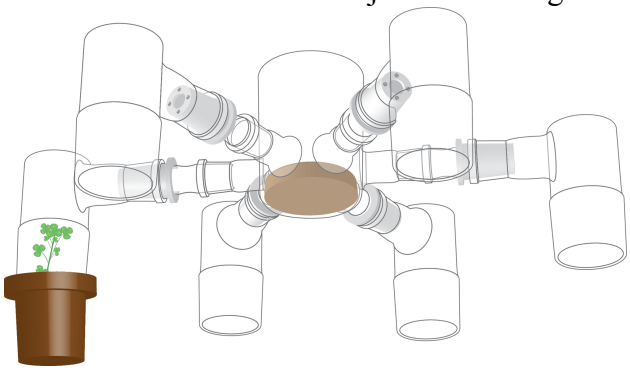

Figure 1. Drawing of the modified olfactometer (without the cardboard shade). This glass device was set such that each pot (at the end of the arms) will lay on top of container. All containers were filled with potting mix. One arm covered a container with a soybean plant and a slug, the second next arm covered a container with a soybean plant only and the last second next arm covered a container with a slug only. All remaining empty arms will cover control containers (potting mix only). Ground beetles will be individually released in the center of this arena and allowed to choose one treatment.

Results

In a series of olfactometer experiments (Fig. 1), we have demonstrated that ground beetles are indeed responding to plant volatiles emitted by soybean

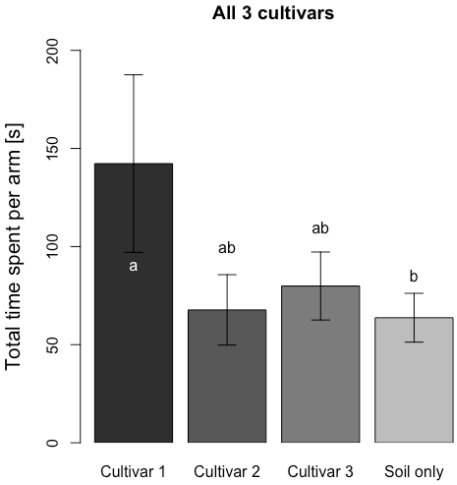

Figure 2. *Response of the predatory beetle when exposed to three soybean cultivars. Bars indicate SEM and letters statistical differences.*

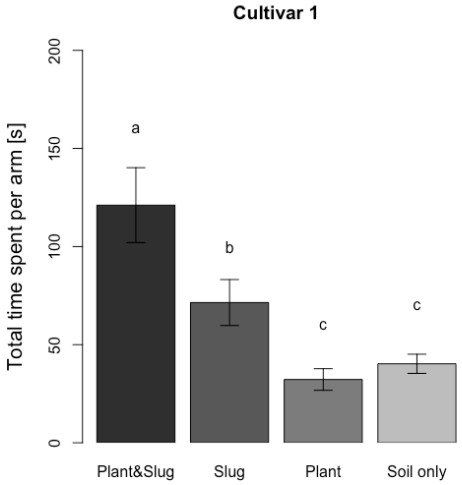

Figure 3. *Response of the predatory beetle when exposed to cultivar 1 damaged by slug, cultivar 1 only, slug only and soil only. Bars indicate SEM and letters statistical differences.*

fed on by slugs. We have tested three cultivars together in on olfactometer setting (Fig. 2), and the beetles appeared to preferentially choose Cultivar 1 from Cultivar 2 and 3. These two last cultivars didn't attract the ground beetle significantly more than the empty control arms.

In a second set of experiments, we have tested the beetle response to either a soybean plant damaged by a slug, a healthy soybean plant, a slug only, and soil only. Again, differences were observed between cultivars. The beetles were spending significantly more time in the arm with the damaged Cultivar 1 than in any other arm (Fig. 3). Slugs only were more appealing to the predatory insects than the plant alone or bare soil, and no distinction could be made between healthy plants and bare soil (Fig. 4). Similar behavior was recorded with Cultivar 2 (Fig. 4), however, when exposed to Cultivar 3, the predatory beetles didn't express any preference of the proposed treatments, even for the slugs alone (Fig. 5).

The volatiles emitted from the damaged plants, the healthy plants and the slugs only are currently collected and analyzed (Fig. 6 shows preliminary data).

We are currently designing experiments to better understand the mechanistic of the defense induction by slugs in soybean (along with the volatile collection and analyzes).

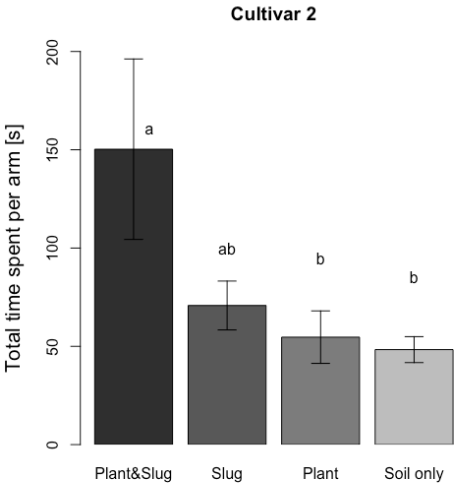

Figure 4. *Response of the predatory beetle when exposed to cultivar 2 damaged by slug, cultivar 2 only, slug only and soil only. Bars indicate SEM and letters statistical differences.*

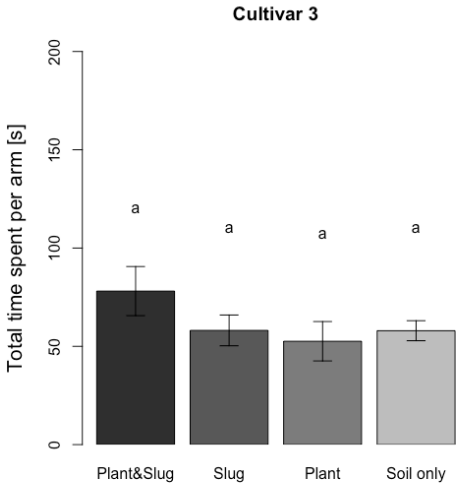

Figure 5. *Response of the predatory beetle when exposed to cultivar 3 damaged by slug, cultivar 3 only, slug only and soil only. Bars indicate SEM and letters statistical differences.*

Conclusions

Based on the data collected, it seems very clear that predatory ground beetles do respond to soybean cues emitted after slug damage. However not all cultivars are equally defended against slug herbivory as some were not recruiting the natural enemies of the mollusk herbivores. This has never been demonstrated with slugs before and will therefore be a nice addition to the current body of literature. In addition, this information can be useful to breeders and growers willing to use ecosystem services to manage slugs in soybean. More has to be done to really understand these interactions but this first step is very promising and opens a lot of new avenues both in research and applications. One avenue could be to use cover crops to conserve ground beetle populations over winter.

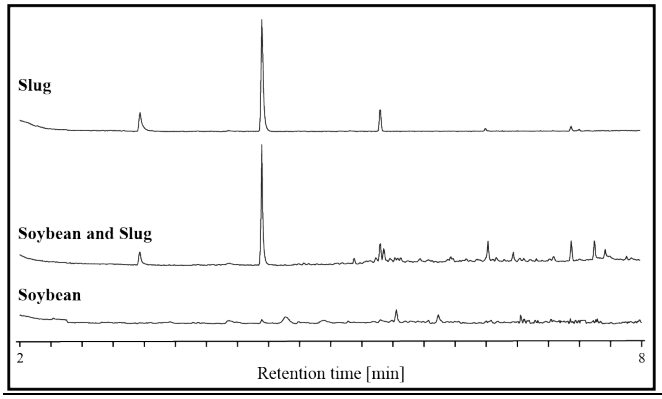

Figure 6. *Chromatograms of slug only, slug-induced soybean, undamaged soybean. Each peak represents a single volatile organic compound. Differences can be observed between each treatment suggesting that the ground beetles could indeed use plant volatiles to locate slug-damaged soybean. Many of the compounds still remain unknown (especially in the slug only treatment).*

Deliverables

Item	Number	Details
YouTube Video	1	https://www.youtube.com/watch?v=fSMX74XhSbI
Oral presentations	5	• Hiltpold, I. (2018). Plant volatile organic compounds: a smelly tool towards sustainable insect pest management. EEOB Department Semiar Series. Columbus, OH, USA, seminar. • Hiltpold, I. (2018). Chemical Ecology in Pest Management, a Holistic Approach. Department Entomology Semiar Series. College Park, MD, USA, seminar. • Hiltpold, I. (2019). From the darkness of the underground to brightness of the blue sky, a chemical journey through a plant. COST FA1405: "Phytobiomes and plant health: from basics to applications". Thessaloniki, Greece, talk (keynote) • Hiltpold, I, Cissel, W. and Kunkel, B.A. (2019) AgWeek 2019. Delaware • Hiltpold, I. (2019). Chemical ecology in pest management: A tool across various ecospheres. ESA Eastern Branch Meeting. Blacksburg, VA, talk (invited).
Poster presentations	2	• Fedirko, T. J., B. A. Kunkel, W. Cissel and I. Hiltpold (2019). A smell that makes carabids run: Tritrophic interactions between slugs, soybean and ground beetles. ESA Eastern Branch Meeting. Blacksburg, VA • Fedirko, T. J., B. A. Kunkel, W. Cissel and I. Hiltpold (2019). A smell that makes carabids run: Tritrophic interactions between slugs, soybean

and ground beetles. UD CANR Graduate Research Meeting

Still to be completed

We have now collected dozens of volatile samples from each cultivar damaged or undamaged by slugs as well as from slugs only. These samples are currently analyzed on a GC-MS. Once analyzed this final data set will be added to the manuscript intended to be submitted for publication in the Journal of Chemical Ecology.