Final Report to the Pennsylvania Soybean Promotion Board

Developing a biologically based management strategy for slugs in no-till soybeans:

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The goal of this one-year proposal (2010-2010) was to begin to develop tactics for managing slugs in Pennsylvania's no-till soybean acreage. This effort resulted directly from a request from Board Chairman John Yocum to develop a slug proposal to try to help all the soybean growers that are suffering from slugs.

According to many no-till soybean growers, slugs are the most problematic animal pest that attacks their crops. When slug populations are large, growers have few options to slow them down, because aside from tillage, very few commercially available slug-control tools are available. Of the tools that grower can use, efficacy varies widely based on conditions and growers have expressed limited confidence in their effectiveness. Exacerbating slug problems is our limited knowledge of their life history and nutritional needs. Our project conducted some basic research to better understand slug biology, their feeding behavior, with the expectation that a better understanding of their life history may lead to viable cultural control options.

The specific objectives of our proposals were to:

1. Determine the influence of slug feeding on soybean yield
2. Determine feeding preferences for slugs among soybeans, various cover crop species, and common weed species.
3. Identify natural enemies of slugs in PA soybean fields.

Below I will address the progress made toward each objective.

1. Determine the influence of slug feeding on soybean yield

To determine the influence of slugs on soybean yield, we had planned on establishing a replicated field experiment using field cages that we would stock with at least four densities of slugs on different young soybean growth stages. Unfortunately, Spring 2010 quickly turned dry and we were unable to reliably find slugs in our research fields. Therefore, we move our effort into a greenhouse, where we conducted a similar experiment with potted soybeans. Unexpectedly, we then ran into much trouble confining slugs to particular plants and recovering them reliably. Slug turn out to be adept escape artists and can get out of most cage designs we developed, often escaping pots by digging through the soil and out the drain holes at the bottom of pots. Once we figured this out and plugged the drain holes, slugs appeared to prefer being deep in the pot and fed very little on our soybean plants.

Despite these difficulties, we were able to learn some valuable information about the influence of slugs feeding on soybean yield. Most importantly, slugs have quite a

variable influence on yield (Fig. 1). Specifically, we found no relation between plant productivity and slug damage; our experiment revealed consistent plant mass across a range of damage to young soybean plants. Not represented in this figure are the few plants whose cotyledons were completely eaten by slugs and the plants died. Such descriptive results are supported by farmers who say that stand count is the variable that matters the most with slugs. Partially damaged plants can recover as long as their growing tip is in tact, but crop productivity most often suffers when plant are killed by slugs.

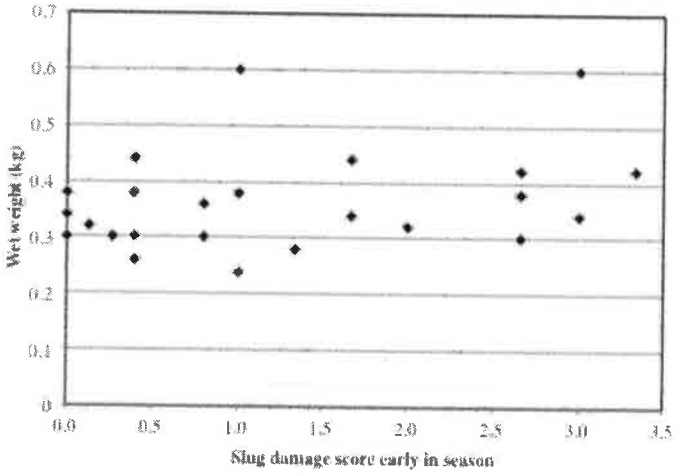

Figure 1. Relationship between plant mass and early season damage by slugs

2. Determine feeding preferences for slugs among soybeans, various cover crop species, and common weed species.

To determine feeding preferences for slugs, we grew three individuals of each of two plant species per pot (six plants per pot) in a greenhouse. Pots were translucent deli containers (6" wide × 6" tall) with lids used to prevent slugs from escaping. Seeds were planted in a circle around the edge of the container, alternating between the two plant species. Plants exposed to slugs were seedlings less than 4" tall and were exposed to one slug. At the end of four days, we counted the number of seedlings with any slug damage as our response variable. Despite our goal to characterize the feeding preference of multiple slug species, the logistics of the feeding trials restricted us to using only the most economically important slug species in Pennsylvania, the gray garden slug *Deroceras reticulatum*. We were able to test the feeding preference of the gray garden slug between soybeans and each of the following: cereal rye (*Secale cereale*), triticale (*Triticale hexaploide*), Italian ryegrass (*Lolium multiflorum*), and lambsquarters (*Chenopodium album*).

Gray garden slugs showed significant preferences in three of our four comparisons, preferring soybean over Italian ryegrass ($F_{1,49} = 40.3$, $P < 0.0001$), soybean over lambsquarters ($F_{1,17} = 29$, $P = 0.00006$), but cereal rye over soybean ($F_{1,57} = 3.9$, $P <$

0.05). Gray garden slugs seemed to show an equal preference for triticale and soybeans, though we only conducted a few rounds of this comparison.

These results, despite being based on fewer comparison that anticipated, are quite promising for our goal of developing cultural management strategy for slugs. Because gray garden slugs, the most economically important slug species in Pennsylvania, prefers cereal rye over soybeans, it may be possible to interseed rye among soybean rows to provide an alternative food source for slugs and reduce damage to the cash crop. This approach would be particularly appealing when using glyphosate-resistant soybeans, because the rye could be killed midway through June to prevent competition between the crop and interseeded species.

3. Identify natural enemies of slugs in PA soybean fields.

To identify natural enemies of slugs in PA, we live trapped predators in no-till soybean fields at Penn State's research farm in Centre County using pitfall traps. We checked these traps regularly to ensure that predators did not eat each other, and returned any captured natural enemies back to the lab. We caught sufficient numbers of four predator species: wolf spider (genus *Hogna*), larvae of the cantharid, or solider beetle, *Chauliognathus pensylvanicus* and two carabid or ground beetle species, *Pterostichus melanarius* and *Chlaenius tricolor*. Interestingly *P. melanarius* is an exotic species that was accidentally introduced into North America whereas *C. tricolor* is native to the United States; their two potential prey, gray garden slug (*D. reticulatum*) and marsh slug (*D. laeve*) also originate from Europe and North America, respectively. We had hoped to include other predators including firefly larvae and harvestmen, but our traps did not yield significant numbers of individuals of these species.

Prior to using predators in feeding assays with slugs, we starved them for one day, and then released them individually into small arenas with single slugs of the two different species, and recorded whether they killed the slug. To determine if predators can protect plants from slug damage, we also confined slugs in plastic containers (described above) with four germinating soybean seeds. Cotyledon-stage soybeans were exposed to slugs alone or with an individual of each predator species.

Slugs survived well in our predation arena by themselves, indicating that mortality was not inflicted by the experimental setup (Fig. 2, 3). Cantharid beetle failed to kill any slugs of either species in our trials (Fig 2, 3) despite being identified as slug predators in several references. When slugs, however, were combined with wolf spiders or the two carabid beetle species, significant slug mortality occurred. Somewhat surprisingly, wolf spiders attacked and ate slugs of both species (Fig. 2, 3); spiders are not known as slug predators and are thought to prefer arthropod prey. Our results clearly indicate that theses spiders will eat slugs under some conditions. Both ground beetle species were effective predators of both slug species (Fig. 2, 3), but *C. tricolor* appeared to be a slightly better predator (Fig. 2, 3) and was particularly effective against marsh slugs, its co-evolved prey, killing all it encountered. Importantly, both ground beetle species significantly protected seedlings when they were combined with soybeans (Fig. 4) suggesting that if sufficient beetle species were present in agricultural fields soybean seedlings may be protected. Consistent with our predation assays, when left alone with

seedling or when combined with soldier beetle larvae, slugs were free to decimate the soybean seedlings; Wolf spiders offered a low level of protection for seedlings (Fig 4).

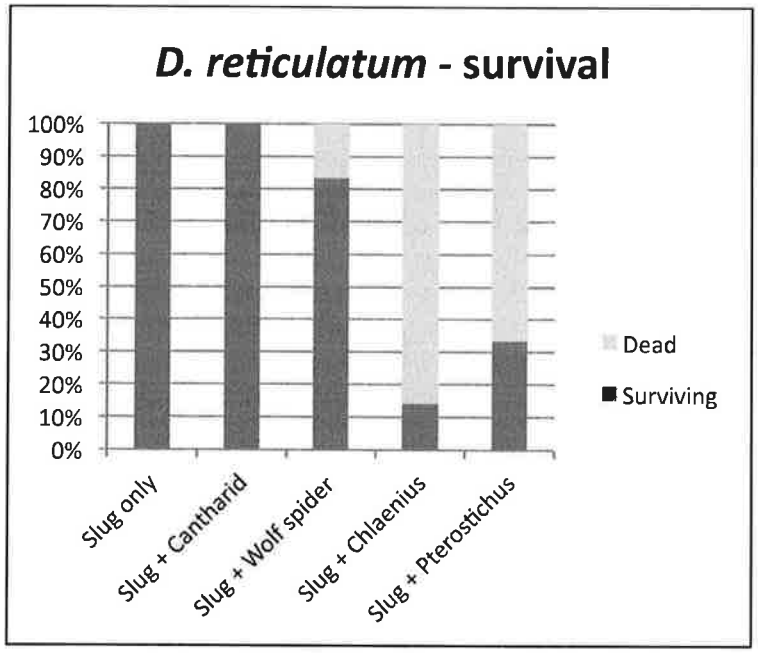

Figure 2. Survival of gray garden slugs (*Deroceras reticulatum*) when confined alone or with one of four predators, cantharid (solider beetle) larvae, wolf spider, or the ground beetles *Chlaenius tricolor* and *Pterostichus melanarius*. Each trial included at least 14 individual slugs.

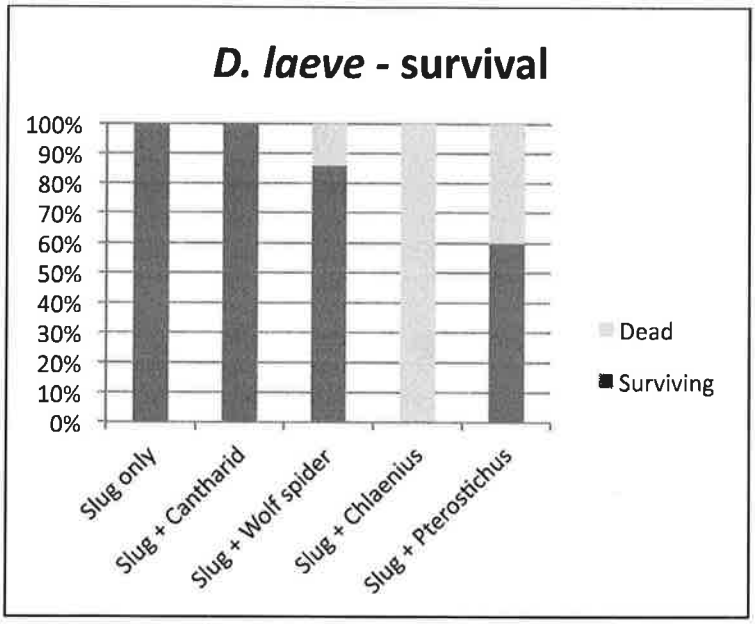

Figure 3. Survival of marsh slugs (*Deroceras laeve*) when confined alone or with one of four predators, cantharid (solider beetle) larvae, wolf spider, or the ground beetles *Chlaenius tricolor* and *Pterostichus melanarius*. Each trial included at least 14 individual slugs.

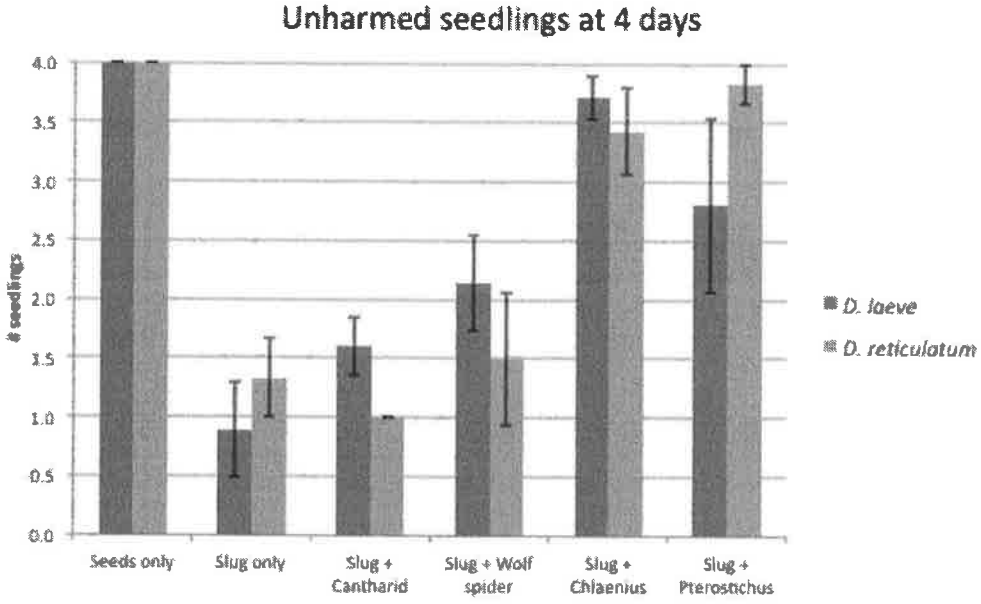

Figure 4. No. of soybean seedling surviving following four days of exposure to nothing, a marsh (*D. laeve*) or gray garden (*D. reticulatum*) slug alone, or slugs and one of four predators, cantharid (solider beetle) larvae, wolf spider, or the ground beetles *Chlaenius tricolor* and *Pterostichus melanarius*. Each trial included at least 10 individual slugs.

Conclusions

Taken together the results of experiments thus far indicate that slugs can kill soybean seedlings, but members of the soil arthropod community can impose significant mortality on slugs and protect seedlings under controlled conditions. The important next step for our research is to assess the utility of these predators under field conditions, determine how to foster their populations in the field, and understand the response of their populations of rye cover crop or interseeded rye (from Objective 2). We will propose some of these activities to the Pennsylvania Soybean Promotion Board in 2012 as we continue our effort to develop a biologically based management strategy for slugs in no-till cropping systems.

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2 August 2011

Pennsylvania Soybean Board
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Executive Director Herr:

In response to your letter dated 6 July 2011, the following is my interim report for the project **Exploring the roles of natural enemies and weeds in slug control in no-till soybeans in Pennsylvania**, which the Soybean Board was generous enough to fund this year.

While the cool and wet conditions this past spring appeared favorable for slugs, populations of slugs did not seem as severe statewide as they were in previous years. The exact cause for these apparently low populations is unclear, but the hot and dry temperatures from 2010 could have played a role. Nevertheless, before 2011's hot weather arrived and dried out fields, a significant number of soybean fields experienced slug damage, underscoring the need for research like ours.

Despite the heat, we made good progress with our project. Our plots planted to cover crop saw significant levels of slug feeding and natural enemy activity. The natural enemies we found in plots were primarily various species of ground beetles, wolf spiders, and harvestmen. We have yet to complete our identification of all the species, but are working on these samples this summer. In greenhouse work with some of these predators, we are finding that indeed some species are quite capable of protecting soybean plants. By growing soybeans in well controlled plastic arenas and introducing slugs, it is easy see the damage that slugs can cause; however, releasing two different species of ground beetles in these arenas substantially reduced slug feeding and in some cases nearly eliminated damage. We have more work to do on this portion of the project, but the results are promising.

The other portion of our project was to determine the influence of small amounts of weeds on the amount of damage that slugs cause to soybeans. This portion of our project experience some difficulty when temperature reached into the 90s in late May and early June, but we have plans to further explore this question when slug populations return in autumn.

All in all I am please with the progress my team is making. If you require more details, please let me know. Thank you very much for your generous support.

Best regards,

John Tooker
Assistant Professor & Extension Specialist