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Evaluating Molluscicides and Carabid Predation of Slugs in Soybeans

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Introduction

Slugs are well-known pests in gardens and high price products such as fruit and vegetables grown in greenhouses. However, in field crops such as soybeans and corn they are emerging pests. In soybeans, slugs feed on germinating seeds, seedlings and foliage causing reduction of plant densities or replanting. Slug outbreaks can reduce plant population densities and damage to plants beyond the point of recovery. Slugs become a major threat when temperatures are moderate and rains are present, usually in spring and into early summer. Slugs tend to be most active and thrive when weather conditions are cool and wet and they are very active at night. Slug damage is often mistaken for the damage of other pests like the bean leaf beetle or corn ear maggots. Oftentimes, when farmers notice slug presence in soybeans it is too late and there is no option other than replanting which can quickly become costly. It is important to recognize when slugs are in the fields so that preventative measures can be taken before damage becomes severe. Scouting for slugs should be done by farmers and crop advisors.

There are several methods to manage slugs. As a biological control in Europe, nematodes are being used to control mollusks. However, this approach has not been used in the United States yet. Carabid or ground beetles are known to be predacious of slugs. This was tested this summer at the Research and Education Center in Princeton, KY. Several species of ground beetles were collected over the summer (Figure 1). A typical method for controlling slugs in vegetables or produce of high value is through applying molluscicides. The molluscicide baits suppress the slug population by drawing slugs to the area of application and then killing them after the molluscicide has been ingested. Since slugs are becoming more of a problem in field crops, some farmers have started using molluscicides in their fields. In Hardin County, a farmer

has applied molluscicides to his field at costs averaging $20/acre to avoid having to replant due to damage from slugs. It is commonly believed that potash is effective in repelling or reducing slugs. Some farmers use this approach, but there is not much evidence that supports this claim. Potash is an alkaline potassium compound, or a salt. It is believed that it could burn or suffocate slugs. Finding a cost-effective way to prevent slug damage is proving to be a challenge for agriculturists because there is not reliable science-based information on treatments for the management of slugs in field crops. In this research, both field and laboratory studies were conducted, using molluscicides (pesticides for slug control) and analyzing the predatory behavior of ground beetles.

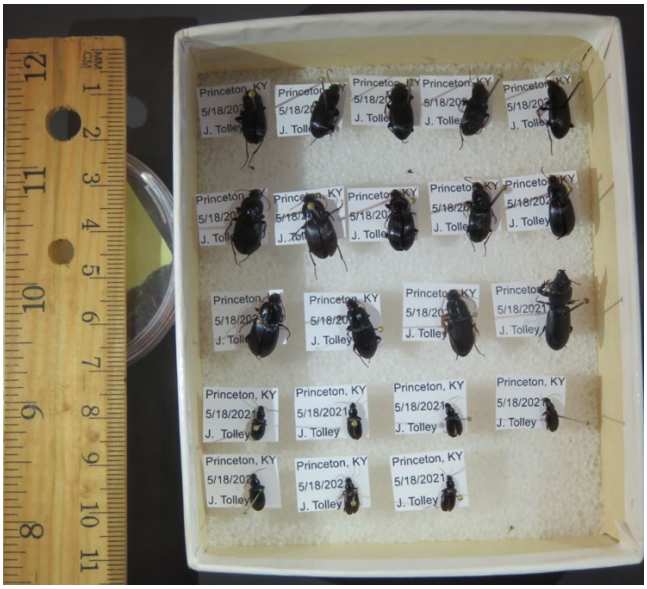

Figure 1. Different species of carabid beetles captured during summer 2021. Measurements in ruler are shown in inches and centimeters. Photo: Josey Tolley

Objectives

There were several objectives analyzed in this project. They included:

- To study the population phenology of slugs in a soybean field.
- To study the populations of ground beetles in a soybean field, identify potential ground beetle predators of slugs, and evaluate their capability of preying on different developmental stages of slugs (eggs, immatures, and adults) in laboratory bioassays

- To determine the effects of two molluscicides applied at two rates on slug populations in a soybean field.

Materials and Methods

Phenology of Slugs and Ground Beetles

Tallies on the population of slugs and carabid beetles were carried in a soybean field at the UKREC in Princeton, KY and comprehended a six-week period from 4 June to 23 July 2021. These tallies were conducted by searching for slugs and ground beetles on the surface in 4-ft row lengths and replicated 6 times on different randomized sites. Inspections consisted of uncovering organic debris left from the previous season and counting all slugs and carabids found there. The organic matter observed in this field was corn.

Field Study Using Molluscicides

This study was conducted in an experimental field at the UKREC. Research plots consisted of 4 soybean rows at 20ft length. Molluscicides were applied along the 2 central rows and were applied through sprinkling by hand on May 18, 2021. This study had 4 replications in RCBD. The study lasted for 14 days, and data was collected 6 times over the course of the 14 days. Each of the 2 molluscicides were applied at the rate recommended by the manufacturer as well as a lesser rate. In addition to this, there was an untreated control plot.

Table 1. Molluscicides used and rates. Rates in bold are doses recommended by the manufacturer.

TREATMENT	RATE (Lbs/A)
Iron phosphate	20
Iron phosphate	**44**
Metaldehyde	5
Metaldehyde	**10**
Control	-

Predation of Slugs on Ground Beetles

All the studies conducted for this study were completed in the laboratory using 3cm in diameter Petri dishes. In the bottom of the Petri dish, a piece of filter paper was applied and moistened with 0.025ml of water. This was done to prevent the different developmental stages of slugs from drying out during the experiment. Slug eggs that were oviposited in the laboratory from a slug colony were used in the study. Also, recently emerged immature slugs, and adult slugs were all used in this project. Ground beetles in this project were starved for 24 hours prior to the experiments. Starvation was conducted by placing individual ground beetles in a Petri dish then placing them in a plastic container that was in a cooler containing ice. All set up procedures were conducted the same way for each developmental study. After the filter paper was applied to the Petri dish, whichever life stage of the slug being studied was applied next. For the slug eggs, 10 eggs were placed in 1 Petri dish. For immature slugs, 7 immatures were in 1 Petri dish. Finally, there was 1 adult slug per Petri dish. One ground beetle per Petri dish was the standard for all 3 of these studies. Figure 2 shows the complete set up of the ground beetle and slug egg study. An identification number was applied to each ground beetle so that data could be collected and added to their predation history and for posterior identification of the carabid species.

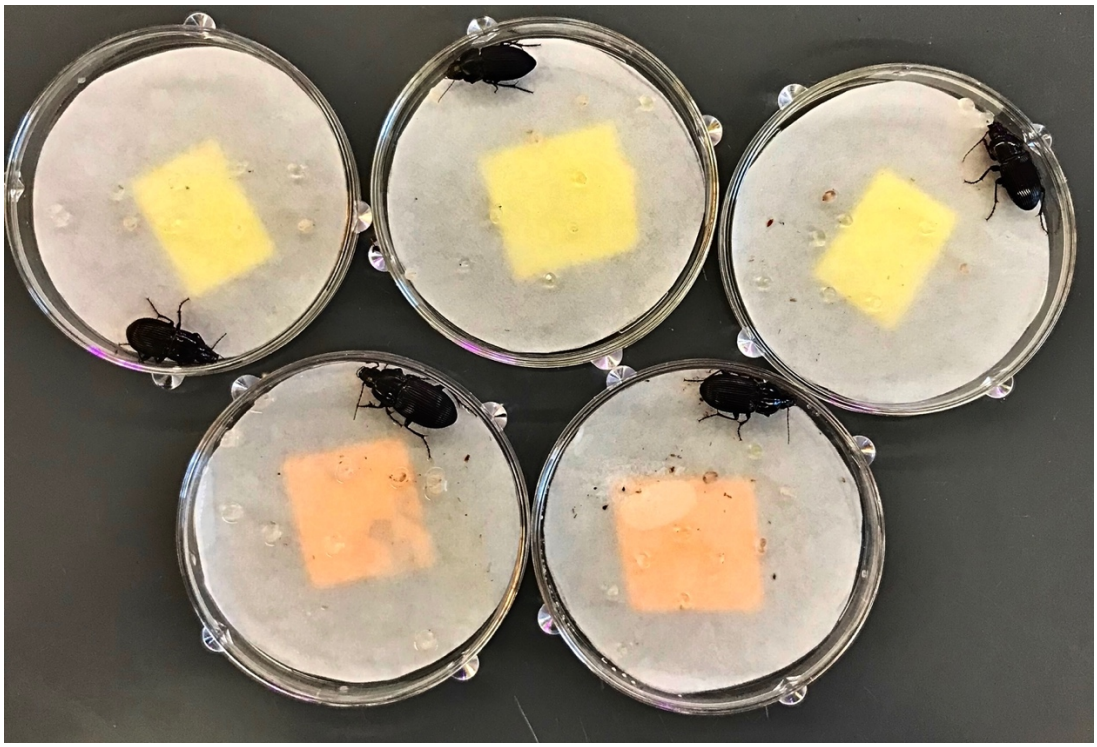

Figure 2. Overview of the ground beetle and slug egg study after completing all the set-up procedures. Eggs are a clear pearl shape.

Results and Discussion

Population of Slugs and Ground Beetles

Results on populations of slugs and ground beetles are shown in Figures 3 and 4, respectively. Both populations decline drastically around the same time. The slug population was not able to get above 1 slug per 4ft average for the rest of the study (Figure 3). Environmental conditions may have affected these trends, high temperatures and absence of rains are important for slug to move away from the soil surface looking for more moist conditions. Ground beetle species populations got back to its highest point around mid-July. Carabid beetles are polyphagous predatory species and when slugs are gone, they may be searching for other arthropod preys that increase during the summer months. (Figure 4)

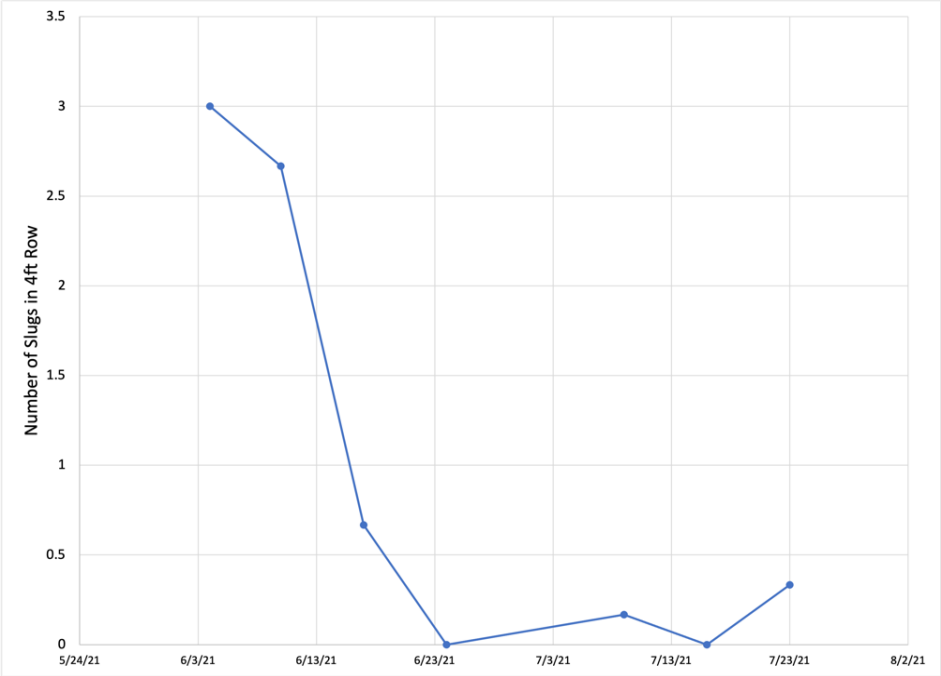

Figure 3. Average number of slugs in a 4ft row in a soybean field over 6 weeks in summer 2021.

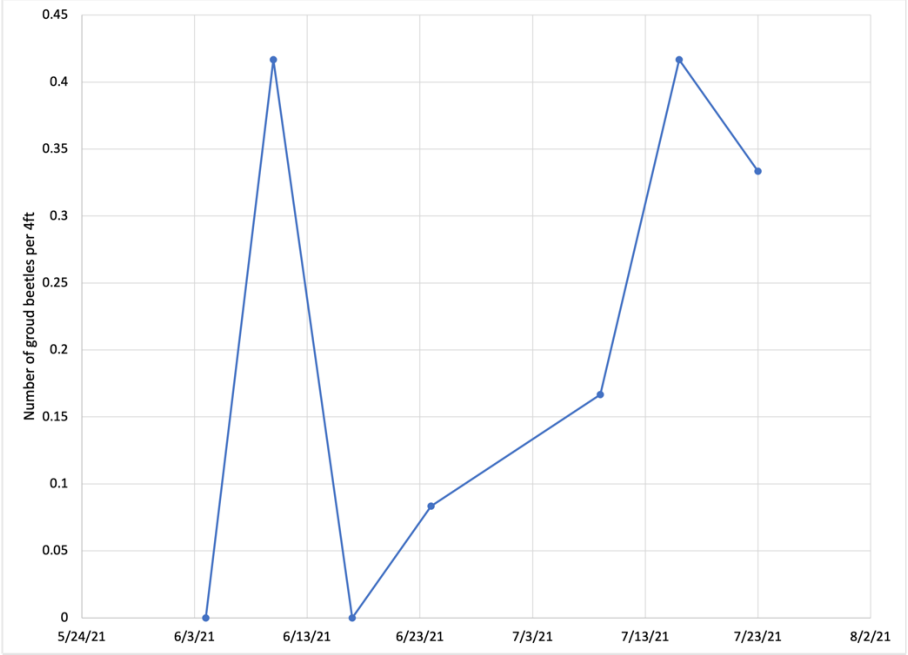

Figure 4. Average number of ground beetles in a 4 ft row in a soybean field over 6 weeks in summer 2021.

Field Study Using Molluscicides

Results of field application of molluscicides showed that the recommended rate of iron phosphate (44 lbs) was the most effective in decreasing the slug population (Figure 5). This treatment had the highest number of slugs in the plot after the molluscicide application, but then the number of slugs declined and by the end of the study, slugs were not found in any of these treated plots. The high number of slugs in the plot immediately after the molluscicide application could be due to attraction of the molluscicide baits. Baits might had attracted slugs to the application area and then did their job by killing the slugs after the molluscicide was ingested. The control might have a lower number of slugs at the beginning of the study because the slugs were attracted to baits and moved from these plots. However, by the end of the study the control had the greatest number of slugs. This also showed that molluscicide baits were effective because the slug populations in treated plots were lower than the control at the end of the experiment in all molluscicide treatments.

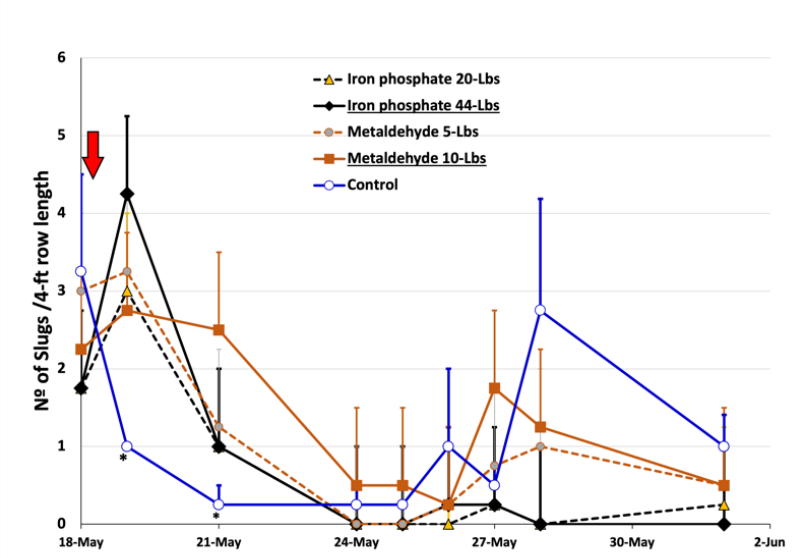

Figure 5. Mean (±SEM) slug numbers/4ft row lengths after molluscicide application (arrow indicates the time of the molluscicide application).

Predatory Study of Ground Beetles

Slug egg predation: the experiment with the ground beetles and slug eggs was replicated 5 times. Data were collected on the number of eggs consumed by carabid beetles at 24, 48, and 72 hours (Figure 6). By the end of 72 hours, all the beetles except for one specimen had fed on almost all the eggs allotted to them (Figure 6). The species of the ground beetles is currently still undetermined. However, one carabid beetle species that did not feed on slug eggs had a different aspect compared with the rest of the beetle species used in this study, and most likely this is a species of ground beetles that is not a predator of slugs. The rest of the ground beetles look very similar in size and structure, so they may be one or multiple species, Beetles will be send to an ID specialist for identification. All these predatory carabids prey upon different growth stages of slugs.

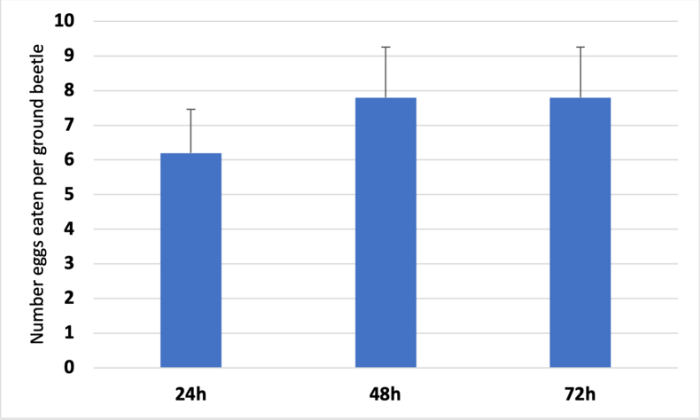

Figure 6. Mean (±SEM) number of eggs preyed on by ground beetles (*n* =5). at 24, 48, and 72 hours. (10 eggs per Petri dish)

Immature slug predation: the study with ground beetles and immature slugs was replicated 10 times. The beetles were allotted 7 immature slugs each. Data were collected at 2, 18, and 24 h after carabid release on Petri dishes (Figure 7). By the end of this study, almost every beetle had fed on all the immatures given to them. Figure 8 shows one of the ground beetle species used in the study preying upon an immature slug. All beetles in these studies were starved for 24 hours prior to the start of the study, so they preyed on more than half the immatures given to them in a 2 h window.

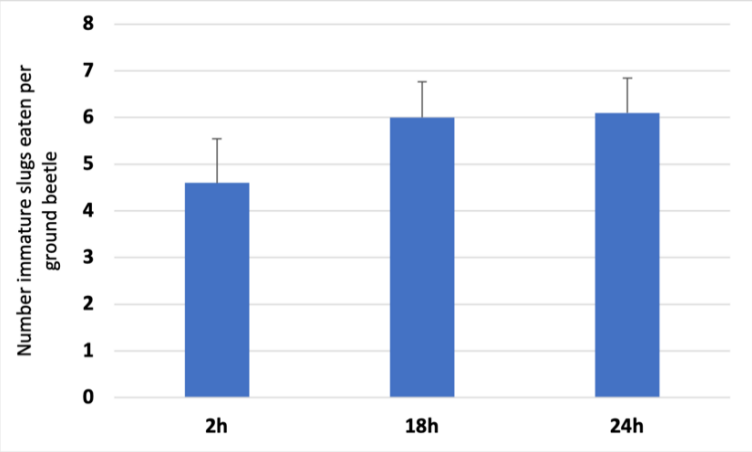

Figure 7. Numbers of immature slugs (±MSE) at 2, 18 and 24 h after the carabid beetle (*n* =10). was released (7 immature slugs per Petri dish).

Figure 8. Ground beetle feeding on immature slug. Photo: Josey Tolley

Adult slug predation: the study involving ground beetles and adult slugs was replicated 10 times. There was one adult slug given to each ground beetle. Data were collected at 24, 36, and 48 hours (Figure 8). Adult slugs and ground beetles are relatively the same size, so it is remarkable that the ground beetles can consume almost entirely an adult slug. At the end of the study, nearly all the beetles had eaten the 1 adult slug given to them.

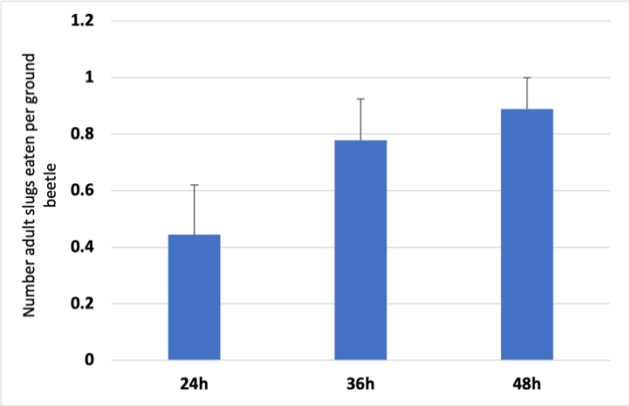

Figure 9. Mean (±SEM) of adult slugs preyed on by ground beetles (*n* =10). (1 adult slug per Petri dish)

Most of the beetles used in these 3 studies demonstrated predatory behaviors on slugs. As mentioned above, the exact species of these beetles have not yet been determined, but there are at least one or more species of ground beetles that are predators of all developmental stages of slugs. In addition, bioassays conducted using two or more carabid beetles per Petri dish and slugs resulted in predatory behavior of carabid species on their congeners.

Conclusion

Finding an effective and practical way to manage slug outbreaks in crop fields is still proving to be a challenge. These two studies have given us a baseline of what works and what does not work, but there is still more research to be done. Regarding the field study using molluscicides, the iron phosphate treatment seems to be more effective although significant differences between the applications were not observed. At 9-10 days after application, the number of slugs in the molluscicide plots were lower than the control plots. This means the

molluscicides were effective in reducing slugs, but eventually another application may be needed to be more effective than a single application. Regarding the predatory behavior of ground beetles, the beetles used in this study are being sent to Pennsylvania to determine their species. Some species of the ground beetles portrayed cannibalistic behaviors in the laboratory colony, so that is why only 1 beetle was in each Petri dish. A couple of questions that arise from the ground beetle study are: how can we increase the population of predatory ground beetles in fields, would higher populations of ground beetles be enough to lower the population of slugs? And how insecticides affect these carabid beetles.