SPATIAL VARIABILITY OF SLUG POPULATIONS IN PERENNIAL RYEGRASS STAND ESTABLISHMENT: SECOND-YEAR RESULTS

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Introduction

Slugs are widely viewed as serious pests of many Willamette Valley crops, including grasses grown for seed, especially during the establishment of new fall plantings. Objectives of this project were to monitor the timing of slug emergence and evaluate the feasibility of identifying areas within fields with highest populations of slugs to help focus control efforts on situations with the greatest risk of crop damage. Fall 2015 was the second year of ongoing research, and this report focuses on results from that year, along with comparisons between 2014 and 2015.

Materials and Methods

Tests were conducted in the grass seedling establishment phase of four major crop rotations (Table 1): turnip grown for seed followed by fall planting of new perennial ryegrass (PR) stands, (2) red or white clover followed by fall planting of PR, (3) winter wheat follow by fall planting of PR, and (4) green manure cover crops or fallow followed by fall planting of PR.

Traditional small research plots were used at the Hyslop Crop Science Field Lab in Benton County, despite the possibility that slugs could migrate between adjacent treatments. At the Polk and Linn County sites, slug blankets were placed in grid patterns spaced at approximately 1 acre per blanket, with a minimum of 30 locations per field. Ground chicken mash was applied beneath each water-soaked blanket on one day, and slugs, worms, and beetles were counted the next day. Plywood squares (16 inches x 16 inches) were used to cover the slug blankets to prevent disturbance by wind or water and to help maintain good levels of moisture within the blankets.

Slug baits were applied by growers based on their own experience and on information we provided to them concerning weekly slug counts. In the two Benton County studies, we applied metaldehyde baits, along with several experimental treatments, but only results for currently registered treatments are reported here.

Weekly counting of slugs, predatory beetles, and earthworms began before crop emergence and continued until stands were well established by mid- to late winter. Slugs were counted over a period of 19 weeks from the third week of October through late February, although not all sites were counted every week. Slugs were counted at sites 1, 2, 3, 4, 5A, and 5B a total of 9, 10, 10, 8, 8, and 8 times, respectively, including one or more cases of counts made at the conventionally tilled sites in mid- to late October before any slugs were present at the soil surface (Table 1). Timing of slug counts in this report refers to the number of weeks

Table 1. Test site conditions, fall 2015.

Site no.	County	Previous crop	Seedbed preparation	Planting date	Number of slug counts	Slug bait application dates
1	Polk	Red clover	Conventional tillage	Oct. 21	9	Nov. 10 Nov. 25
2	Linn	White clover	No-till	Oct. 20	10	Oct. 21 Nov. 3 Nov. 25 Dec. 16 Jan. 15
3	Linn	Turnip for seed	No-till	Sep. 7	10	Nov. 12
4	Polk	Wheat	Conventional tillage	Oct. 21	8	Not applied
5A	Benton	Green manure	Conventional tillage	Oct. 16	8	Oct. 22 Dec. 17
5B	Benton	Fallow	Conventional tillage	Oct. 9	8	Oct. 22 Dec. 17

since mid-October, with week 1 being the period from October 18 to October 24, 2015. Experiments were terminated once crops were well established and final counts of crop stands and slug densities had been taken in February. Soil moisture was measured gravimetrically using surface 2-inch-deep soil samples taken each time slugs were counted.

Crop stands were evaluated by counting the number of missing 1-inch-long sections of row in a total of 3,120 inches of row at each plot in a rectangle around the target flag, skipping the center 10 feet x 9 feet because of soil sampling disturbance and crop damage under the plywood squares and slug blankets.

Access to fields (for us to count slugs and for farmers to apply slug bait) was more often a problem in the five conventionally tilled fields than in the one no-till field. In general, growers had fewer problems getting on their fields to apply slug bait in 2015 than in 2014, until the heavy rains in December.

Methods explored to quantify the spatial distribution of slugs and crop damage included inverse distance weighting (IDW) maps, Kriging, Getis-Ord Gi-star hot spot analysis, and both normal and geographically weighted regression. The Gi-star hot spot analysis technique provided more useful information on statistical significance than IDW or Kriging and therefore was chosen for mapping slug populations within fields over time.

Results and Discussion

Soil moisture content at the conventionally tilled sites ranged from 10 to 15% in late October, delaying crop or weed seedling emergence until early November, when several light rains finally raised soil moisture above 25%. Growers who planted crops early in the fall reported some instances of spotty perennial ryegrass germination in September followed by seedling death, as soils dried out to below the wilting point.

The unusually hot, dry summer also adversely affected slugs. Comparing fall 2014 (Mueller-Warrant et al., 2015) with fall 2015 (Table 2), slugs first appeared on the soil surface about 3 weeks later in 2015 and at densities of less than half those in the previous year. There was also a dearth of larger individuals in 2015, implying that the slugs that did appear likely did not over-summer as adults, but rather hatched from eggs buried fairly deep in the soil profile. In contrast, in 2014 the slugs that emerged were of varying sizes on most dates, suggesting that multiple “safe havens” existed that year within the soil for adults, juveniles, and eggs.

Predatory beetle populations were highest in the first 2 weeks of counting and declined approximately 10-fold as weather cooled in later fall. Numbers of predatory beetles were lower overall in 2015 (Table 2) than in 2014. Earthworm counts were very low initially and peaked in the third week of November at most sites. Peak earthworm counts were lower than in 2014.

Similar to 2014, slugs were not uniformly distributed across any of the sites on any single date, and counts varied from a minimum of 0 to a maximum of 34 slugs per blanket. The hot spots for slugs in 2015 tended to be situated at lower elevation locations within each field. This was true both on the nearly level ground of Linn County and on the rolling hills of Polk County. The number of slugs present in spatial hot spots varied from a low of 2.5 per blanket at Site 4, to medium values of 7.3 and 8.3 per blanket at Sites 3 and 1, and to a high

Table 2. Test site results, fall 2015.

		Highest weekly ------ average slug counts ------		Slug counts from period most closely related ------- to crop loss -------		Average counts --------- of other organisms ---------	
Site no.	Average weekly slug count, entire fall season	Week[1]	Average number	Weeks included[1]	Average number	Predatory beetles (weeks 1–6)	Earthworms (weeks 1–9)
1	0.8	5	1.4	—	—	0.26	0.4
2	4.0	5	6.4	1–6, 8, 9	4.0	0.22	0.7
3	1.3	4	3.7	3–6	1.5	0.21	10.2
4	0.2	4	0.4	—	—	0.27	2.5
5A	0.8	2	1.5	—	—	0.04	0.7
5B	4.7	9	7.7	2–6, 9	4.7	0.44	3.0

[1]Week 1 of fall establishment season is defined as October 18 to October 24, 2015.

of 19 per blanket at Site 2. Modest numbers of slugs appeared at nearly all locations (other than the hot spots) within each field site.

There were fewer differences over time in 2015 than was the case in 2014. In other words, the higher slug counts tended to occur in the same plots on all dates rather than fluctuating across space as the season progressed. Statistically significant spatial hot spots for slugs remained generally stable in the fall of 2015, in contrast to 2014, when there was a mix of stable hot spots and locations with fluctuating counts—high in some weeks and near zero in other weeks. This may be a result of the limited set of conditions in which slugs were able to survive the summer drought, likely mainly as deeply buried eggs.

Bait applications typically reduced slug counts by approximately two-fold (e.g., six slugs per blanket before treatment and three slugs after treatment). Bait performance was poorer than in 2014, when five-fold reductions were common.

Cutworms were found in the third week of November 2015 at several sites, especially no-till PR into white clover (Site 2). However, their numbers were low and our ability to find them was very limited due to the substantial canopy of surviving clover plants.

There are many ways to analyze and display slug count and crop stand data, and not all results can be presented in this report. We tested multiple relationships between crop stand gaps and slug counts at each site and have shown the best models for each site in Figures 1–4. In general, sites with the highest numbers of slugs had the widest ranges in crop stand loss, while sites with fewest slugs had the least variation in crop stands.

At Site 2, stand loss (missing PR seedlings relative to perfect stands) increased from 20% in plots with no slugs to around 60% in plots with averages of 15 slugs/blanket (Figure 1). However, plots of stand loss versus slug counts revealed the presence of three outliers with severe stand loss but low numbers of slugs (Figure 1). The worst two cases were near one of the spots where cutworms had been detected, suggesting that it was reasonable to assume that the most severe crop damage was from cutworms rather than slugs. The regression in Figure 1 omitted the three points with greatest injury, although relationships between slug counts and stand loss remained significant even when the instances of probable cutworm damage were included in the logistic regressions.

At Site 5B, stand loss increased from 10% in plots with less than two slugs/blanket to around 60% in plots with averages of nine slugs/blanket (Figure 2).

Stands at the other four sites were less affected by slugs, mainly because slug counts were much lower (Table 2). At Site 3, prolonged exposure of PR seed after planting to extremely dry conditions resulted in stand loss of nearly 50%, even in plots averaging less than one slug/blanket, with an additional 20% stand loss at maximum slug populations of three or four slugs/blanket (Figure 3). Site 4 (following winter wheat)

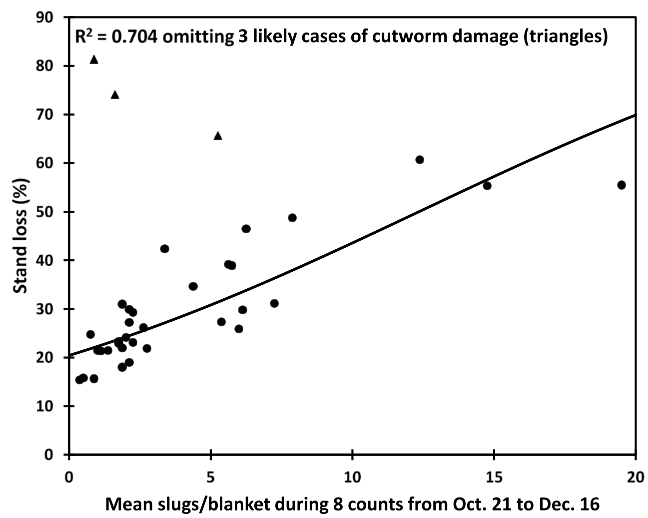

Figure 1. Stand loss from slugs at Site 2.

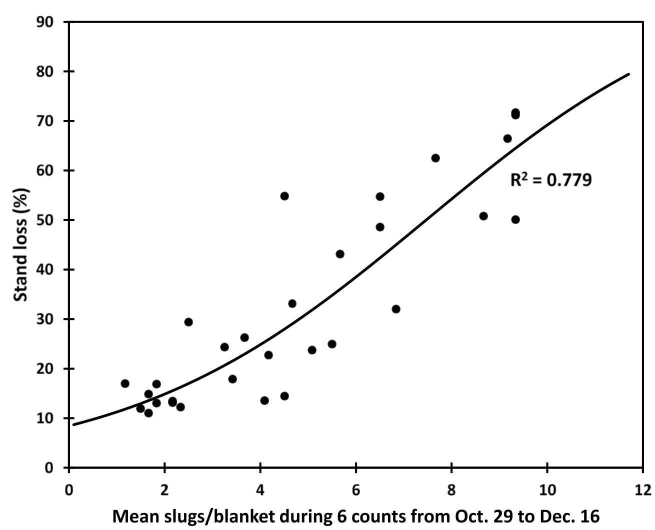

Figure 2. Stand loss from slugs at Site 5B.

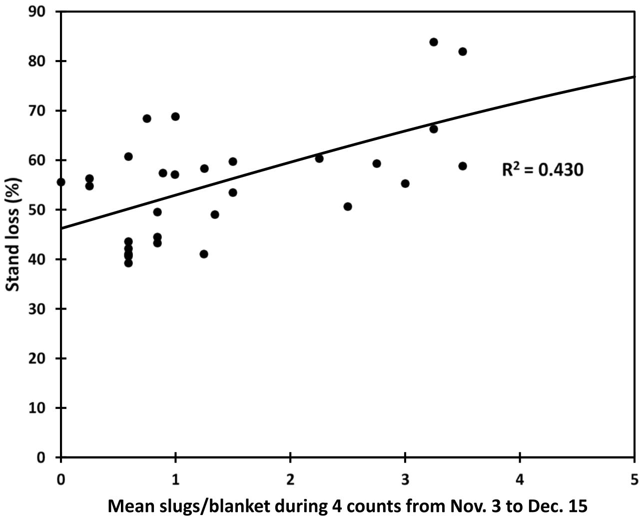

Figure 3. Stand loss from slugs at Site 3.

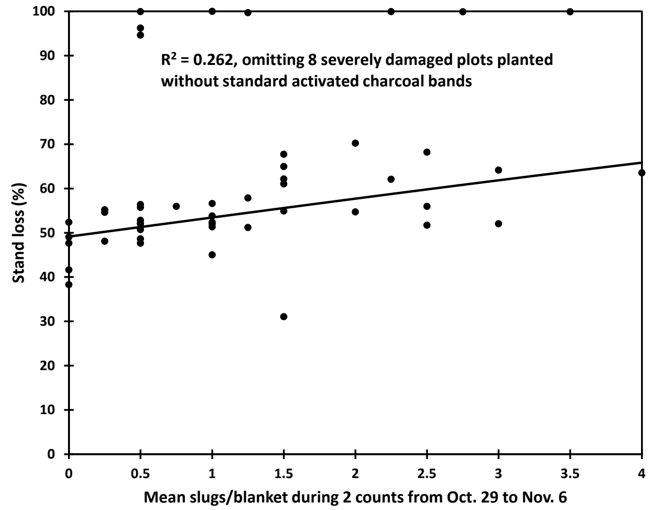

Figure 4. Stand loss from slugs at Site 5A.

had excellent PR stands, very low numbers of slugs, and no significant relationship between stand loss and slug counts (data not shown). Site 5A (following green manure cover crop) had mediocre PR stands, moderate numbers of slugs, and only 17% greater stand loss as slug counts increased from zero to four (Figure 4). PR stands at Site 1 were apparently damaged by both cutworms and herbicide injury, and there was no detectable relationship between slug counts and stand loss (data not shown). Stand loss averages of 73% at Site 1 actually understated the problem, as at least half of the ryegrass plants counted were weedy annual ryegrass rather than true PR. In many cases, it was difficult to locate the position of the crop rows due to the low numbers of PR seedlings and the greater relative abundance of annual ryegrass.

The critical period for crop damage caused by slugs (from emergence to appearance of the first tiller) began later in the fall of 2015 than in 2014 because both PR germination and slug emergence were delayed by the prolonged dry weather.

Conclusions

These findings have several important implications for management of slugs by grass seed growers. First, the absence of cold spots means that entire fields ought to be treated at least once during the peak emergence of slugs after fall rains begin; there were no truly safe locations free of all slug danger. Second, the presence of a few stable hot spots at each of the sites means that some areas will need repeated applications of slug bait. One way to identify those areas is to mark locations where high numbers of slugs have already been found. Third, the stable correlation between lower elevations and higher slug counts within fields suggests that it may be possible to predict where slug numbers will be highest within fields, at least when tillage and moisture stress combine to limit slug survival to the most favorable positions within the soil profile. Fourth, no-till establishment of PR into existing clover crops can succeed if growers are diligent in their scouting for slugs and other pests such as cutworms and are willing to apply slug bait multiple times over the fall (i.e., whenever more slugs appear at the soil surface ready to eat crop plants). Fifth, the economic threshold for damage to PR seedlings remains a very low number, likely somewhere from two to four slugs/blanket for measurements made during active slug baiting. The threshold would presumably be even lower if no slug bait was ever applied.

We have not yet been able to identify all of the specific factors that would be needed to develop a good predictive model for slug emergence and density. The tendency of lower elevation positions within fields to have higher slug counts failed to correlate with surface soil moisture content throughout the fall, although it remains possible that spatial variation in soil moisture at depths below the tillage zone was important to slug survival over the summer.

Gradients in slug counts from the outer edge to the inside of tilled areas at Benton County Site 5B indicated a need for use of wider borders and larger plots in future research. Further analysis of results from 2015 should refine the experimental treatments worth repeating down to a very small number, allowing use of much larger plot sizes in future experiments.

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