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Impact of Management Practices on Population Dynamics of *Atherigona reversura* in Georgia Bermudagrass

Abstract

There is currently no published information regarding any difference in damage caused by the bermudagrass stem maggot (BSM; *Atherigona reversura* Villeneuve) in bermudagrass [*Cynodon dactylon* (L.) Pers.] harvested as hay compared to being grazed in a pasture. The objective of this study was to determine whether harvesting forage impacted the development of adult BSM or resulting BSM damage when compared to grazing the forage. Six plots were used in a 12-week trial of stem sampling. Three pastures and three hay fields were surveyed weekly by gathering 10 grass samples and 10 insect sweep net samples to determine the average percent damage and number of adult flies, respectively. These weekly averages were tracked over the course of the study to build a damage curve to compare fields and pastures. Sites were separated into pairs for comparison of treatment versus no treatment. Overall there was a significant difference in the damage observed due to management (hay vs. grazing) (P=2.937e-06) and location (Eatonton vs. Lexington) (P=2.2e-16). Overall there is a significant correlation between damage and population (r_s=.3303). We also found a significant difference between management types (p= .0085). This suggests that harvesting has a significant effect on BSM populations, therefore reducing overall damage.

Introduction

The bermudagrass stem maggot (BSM) is an invasive species of Muscidae from Southeast Asia. It was first discovered in the United States in Hawaii in the 1970s (Hardy, 1976) and California in 2009 (Holderbaum, 2009). The first report in Georgia was not documented until 2010 from Pierce, Tift, and Jeff Davis counties (Hancock, 2012). The fly is now readily found throughout the Southeast US, from Texas to Kentucky, although there was a recent report in Canada (Savage, 2016). *Atherigona reversura* attacks bermudagrass and stargrass *(Cynodon* spp.) here in the United States with a variety of host plants reported elsewhere in the world (Pont, 1995).

The adult fly is a highly mobile, yet low flying insect that generally stays within the crop canopy. Mature adults lay their eggs on the terminal leaves of bermudagrass, favoring finer stem cultivars such as Alicia, Coastal, or Russell. When these eggs hatch, the maggots migrate down the leaf blade inwards to the terminal node and create a bacterial "soup" of the internal tissue by macerating the pseudostem with their mouth hooks. After 2-3 weeks of feeding in the stems, the maggot emerges and moves to the ground to pupate just beneath the soil surface.

The BSM damage halts the growth of affected tillers and reduces the yield potential of the forage. Studies have documented up to an 80% yield reduction in heavily infested harvests. The current recommendations for spraying are to wait 7-10 days after cutting, followed by a second spray 7-10 days after the first application (Hudson, 2019). This timing is based on the phenology of the bermudagrass, which will initiate regrowth within a few days following a harvest or intense grazing event. The adult flies will seek refuge in the perimeters and neighboring fields and pastures when the forage is harvested, only to return to lay more eggs as the grass regrows. The flies will quickly re-infest the field once new tillers appear.

Materials and Methods

Treatment locations

A total of 6 sampling locations were selected from two counties in Georgia. No hay production field or pasture received any insecticide treatment throughout the entire trial period. One hay field and one grazed pasture were selected on the Lovin Family Farm in Lexington, Georgia. Two hay fields and two pastures were also selected at the University of Georgia Beef Cattle Research Farm in Eatonton Georgia.

Sample collection

Grass samples were collected on a weekly basis to monitor the amount of damage throughout the peak season (Jul 1-Aug 31 in 2019, Jun 8-Aug 25 in 2020). In 2019, 5 samples per field were collected on each sample date. In 2020 this was increased to 10 samples per field per sample date. On each sample date in 2020, 10 sets of 10 sweeps of a sweep net were used for the purpose of collecting adult BSM. At the end of each set the contents of the nets were placed in a mesh cage (12” Rearing and Observation Cube, BioQuip Products Inc.) for counting. In cases where more than ~20 adults were present, cages were returned to the lab, frozen overnight, and adults counted afterwards. Adults were released after each set and the same cubes would be utilized again. To ensure adequate representation, sweep samples were collected randomly throughout each field or pasture. Samples were collected at least 20 meters apart.

BSM damage is characterized by the “bronzing” of the top two leaves and also by the easy removal of the top two leaves from the pseudostem. A sample collection consisted of one handful of stems, cut at the base of the grass. These samples consisted of 16-154 (avg. = 64.9) stems. Soil samples were also collected in 2019 at each sample date. These consisted of 5 samples, each 1 ft^2 by ~2” depth, which were returned to the lab and examined by careful sifting for pupae. This was changed to 10 samples, collected one week after harvest for each field and pasture pair for the 2020 study.

Statistical analyses

Data were analyzed using R Studio (Ver. 1.3.1093, Boston, Ma). Aggregated Logistic regression models (Binomial Regression) were built to investigate the field damage data since the response is the damage percentage (count of damage/total count). Weeks were handled as continuous variable while Location and Event were categorical variables. All the variables were handled as fixed effects. A likelihood ratio test was performed to determine if reduced model was significantly different from full model.

Since the response variable is the count of adult sweeps from sample hay, Poisson regression was initially used to study the adult sweep data. The full model suggested a severe over dispersion problem, indicating that the data violate the assumption of Poisson Regression (this is likely due to the occurrence of a considerable amount of ‘0’ counts in the data). Therefore, we chose the negative binomial model to analyze the adult sweep data. Finally, field damage and counts of adult sweeps were analyzed as paired data and the Spearman rank correlation test was conducted to investigate the relationship between count of adult sweeps and field percent damage.

Results and Discussion

Preliminary data

In 2019 the same fields and pastures were sampled for stem damage and also pupae population (Figure 1). Five soil and five stem samples were each collected each week over a period of seven weeks. The same methods of sweeping and soil collection were maintained in the 2020 collection period. This preliminary research laid the foundation which our main study would use and gave insight to what results we could receive. Using the lessons learned here, it was decided that more samples for damage were required to build a better picture of overall damage. Weekly soil samples were limited to 10 samples 1 week after harvest, for the hay field and its accompanying pasture.

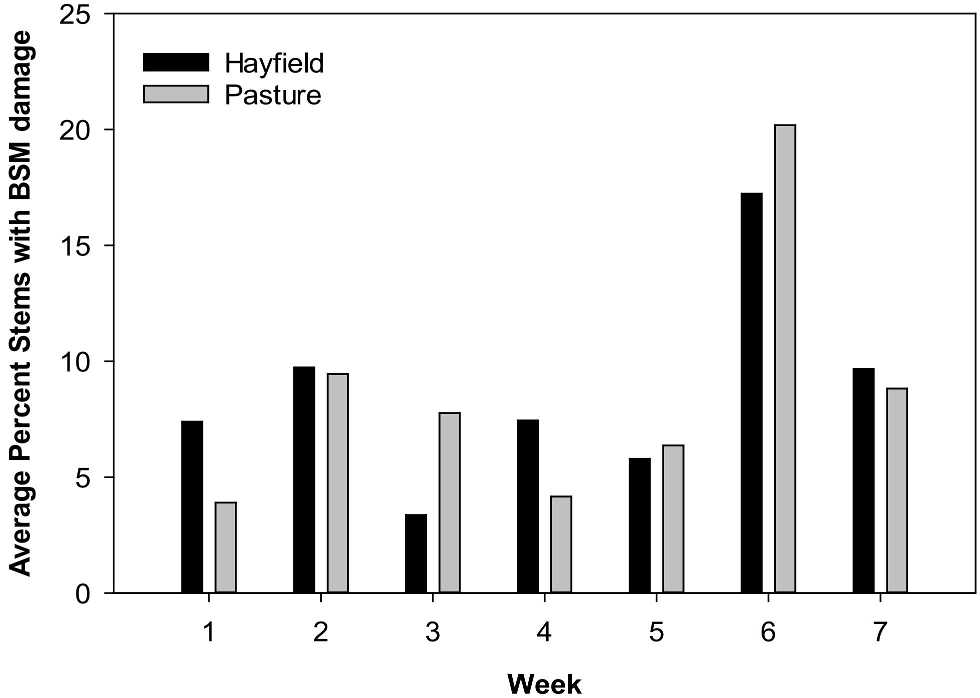

Figure 1. Preliminary data showing average damage among all hay fields and pastures over 7 weeks.

Stem damage

There is sufficient statistical evidence suggesting both management type (*P* = 2.937e-06) and location (*P*= < 2.2e-16) are significant. We can conclude there are differences between management types/locations over time for both damage and number of adults present (Table 1). Hay harvest events were significant (*P* = 0.00026) as well, which indicates that the action of harvesting hay would make a difference in field damage proportion and adult numbers. The harvesting did knock damage and adult populations to zero, but these levels rebounded quickly. The data shows us that although rebounding does occur, the damage levels never catch up to pastures (Figure 2).

Table 1. Analysis of deviance table (Type 3 Test) for damage

LR	CHISQ	DF	Pr(>CHISQ)
Event	13.32	1	0.0002***
Loc	219.71	2	<2.2e-16***
Type	21.86	1	2.937e-06***
Week:Event	21.74	1	3.128e-06***
Week:Loc	184.59	2	<2.2e-16***
Loc:Type	14.68	2	0.0006***
Event:Loc	48.64	2	2.748e-11***

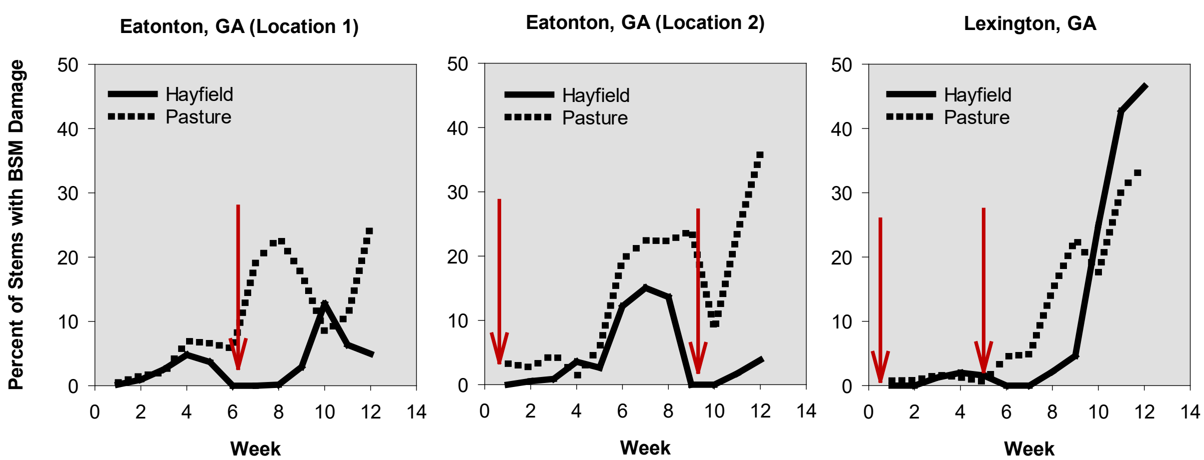

Figure 2. BSM damage seen in each test plot over a 12-week trial. Arrows indicate harvest.

- Eatonton Location = EP1/EF1
- Eatonton Location 2= EP2/EF2
- Lexington = LP/LF

During the 12 weeks of this study, EF1 was harvested only one time for hay (Figure 2) and otherwise was allowed to overgrow. Similarly, EP1 was only grazed for the first few weeks of the study and essentially allowed to go fallow. Lack of weed control and absence of grazing resulted in the proportion of bermudagrass in the stand being reduced to approximately 50% over the field with the rest consisting of other, non-forage grasses and broadleaf weeds. This under management contributed to the significance in differences between locations in the study.

The second pair of test plots from Eatonton was labeled as EP2 vs EF2. The story in these plots was somewhat similar to the first set of test plots. Cattle were removed from the pasture after the first 3 or 4 weeks and the plot was allowed to overgrow. EF2 was harvested twice (Figure 2) during our study, however the timing between cuts (9 weeks) still allowed for seed heads to form and was not an efficient form of management. As with EF1/EP1, this underutilization and infrequent harvest increased the variability between locations.

Lexington produced the most relevant set of data from the entire study. The management here was excellent and consisted of timely harvest, fertilization and herbicide applications to maintain weeds. Cattle and horses were allowed to graze the pasture freely for the entire length of the study. This grazing allowed for new growth and new resources for BSM throughout the study. Lexington Field (LF) was harvested twice (Figure 2) during the study, however in a more timely fashion than EF2 at a four week interval. This better overall management helped identify the interaction between harvest and overall damage (Table 1). Rains kept the producers from harvesting a third time during our study and there is a sharp increase in damage because of this. The field was a prime cultivar, freshly weeded with herbicides, and when left uncut, the BSM showed a sharp increase in damage and population.

Adult populations

From the output of our final model, we can conclude there are significant differences between management types *($P = 0.008549$)*/locations *($P = 6.645e06$)* in adult sweep habitation preference, suggesting that harvesting has an impact on adult population (Table 1). The Spearman's Rank Analysis shows a correlation between field damage and adult population levels of r_s=. 3303. A number closer to one signifies higher correlation between two inputs. This aligns with the hypothesis that higher adult populations lead to higher damage levels.

Over the course of 12 weeks the BSM adult population did grow in all fields and pastures. In the Eatonton plots (EF1/EF2/EP1/EP2), forage was underutilized resulting in an over mature stand with lower forage quality and severe weed invasion. Only when the fields were harvested and allowed to regrow were large numbers of adults found again (Figure 3). Pastures were allowed to grow and go to seed with no intervention, showing a similar adult build up as the hay fields. Due to Covid-19, funds were not available for staffing and production on the Eatonton Beef Cattle Research farm, resulting in greatly reduced management.

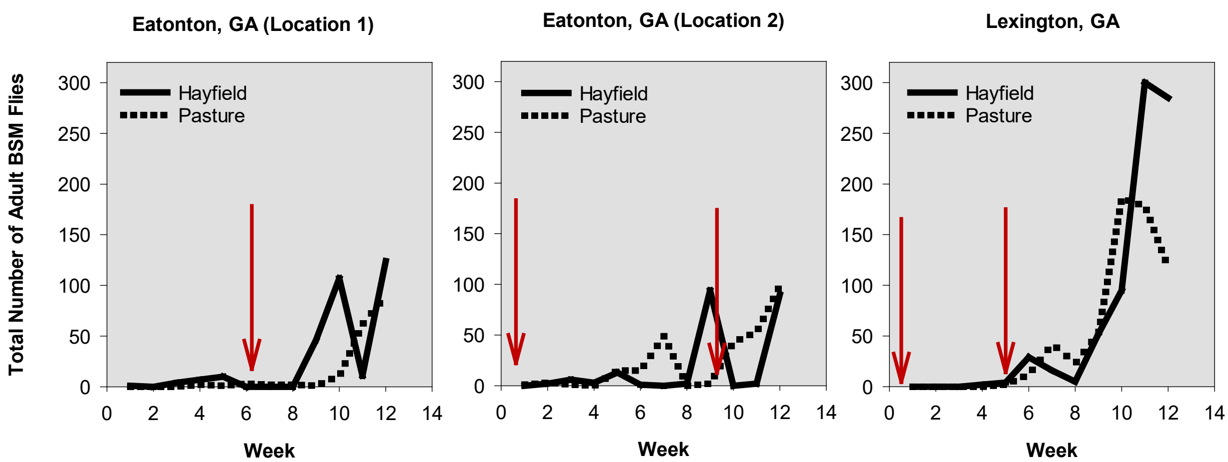

Figure 3. BSM adult population counts from each test plot over 12 weeks. Arrows indicate harvest.
Eatonton Location 1=EP1/EF1.
Eatonton Location 2=EP2/EF2.
Lexington = LP/LF

The Lexington plots were maintained properly throughout the study and gave a more realistic outlook on adult population build up (Figure 3). Here we observed proper grazing and harvesting that would be comparable to other commercial hay production operations. Overall, we determined a significant difference in adult populations between locations (*P*=2.685e-07, Table 2) and we can potentially attribute it to that maintenance (Table 3).

Table 2. Analysis of deviance table for adult sweep counts

LR	CHISQ	DF	Pr(>CHISQ)
Event	16.97	1	3.794e-05***
Loc	30.26	2	2.685e-07***
Type	6.91	1	0.008**
Week:Loc	23.71	2	7.101e-06***
Loc:Type	5.18	2	0.074*
Loc:Event	40.08	2	1.972e-09***

Table 3. Comparison of management between locations

	HERBICIDES	WEEKS GRAZED	# OF HARVEST
EP1	NO	3	0
EP2	NO	3	0
LP	YES	12	0
EF1	NO	0	1
EF2	NO	0	2
LF	YES	0	2

Pupal population observations

Finding mature pupae has been a difficult process under field conditions. Using a soil sifter and timing the collection properly has led to in-field discoveries at depths of <3 inches. So few pupae were found that the research team decided that the effort (more than 1 hour per sample, 30 samples per week) was not productive. In 2020, soil samples were collected only after harvest when numbers of pupae should have been highest. Those maggots that were present at the time of harvest left the stems all at once as the cut grass dried. Even then, numbers were so low that the data were not useful. It is possible we are missing important information on the pupal stage of BSM. It seems that the adult populations and damage we see in fields is not represented by pupae in the soil. Perhaps BSM has naturally low pupation rates or pupates deeper in the soil. Further research is needed to answer these important biological questions.

Conclusions

We demonstrated that higher adult populations lead to higher damage in bermudagrass hay fields. Harvesting the hay lowers the overall adult populations and damage when compared to pastures. When healthy fields are left untreated, BSM has a great ability to rebound and damage the hay severely. Proper management and timely harvest are key to controlling BSM and damage levels.

Conflict of Interest

The authors declare that there is no conflict of interest.

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