WHAT WE HAVE LEARNED ABOUT THE BERMUDAGRASS STEM MAGGOT[1]

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Abstract

Since first being discovered in southern Georgia in July 2010, the bermudagrass stem maggot (BSM; *Atherigona reversura* Villeneuve) has infested and damaged forage bermudagrass (*Cynodon dactylon*) throughout the southeastern United States. Our objectives for this presentation were to summarize the available literature on this new, invasive species and provide additional insight from what is currently known about other *Atherigona* spp. The BSM, along with other *Atherigona* spp*.,* are small, muscid flies native to Central and Southeast Asia. The adult fly of the BSM lays its eggs on bermudagrass leaves. Upon hatching, the BSM larva slips into the sheath, down the tiller, and penetrates the pseudostem at the first node. The BSM larva then feeds on the vascular tissue, sap, and (potentially) the subsequent decaying plant material before exiting the tiller, pupating in the soil, and emerging as a fly. As a result of the larval feeding, bermudagrass exhibits senescence and necrosis of the terminal leaves on the affected shoots. The affected leaves are easily pulled out of the sheath and show obvious damage near the affected node. In severe infestations, over 80% of the tillers in a given area may be affected. There is a paucity of information about the lifecycle of *A. reversura* and how it can be managed or controlled, but some information is available on basic larva behavior, fly physiology, and the potential differences in resistance among some bermudagrass varieties. Additional research is underway to better understand the lifecycle of this species, confirm and quantify the degree of preference *A. reversura* has for the different bermudagrass varieties, and quantify the severity of damage in yield, quality, and aesthetics.

Introduction: In the summer of 2010, bermudagrass hay producers in Jeff Davis, Irwin, Pierce, and Tift Counties in Georgia began noticing a “bronzing” of their hay fields, generating damage similar to that of severe drought or frost damaged bermudagrass (Hancock, 2012; Fig. 1A). The bronzing was the result of chlorosis and necrosis in the top two to three leaves of the plant (Fig. 1B). The damaged leaves could easily be pulled from the sheath and the end inside the sheath either showed evidence of insect damage or obvious decay (Fig. 1C). This damage was clearly not that of abiotic stress but rather a consequence of larval feeding. Under controlled conditions, collected larvae were grown out and allowed to pupate and mature. The resulting adults were subsequently identified as *Atherigona reversura* Villeneuve, now commonly known as the bermudagrass stem maggot (BSM).

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The BSM is believed to be native to SE Asia, which is where Villeneuve first discovered it (1936). First reports of the BSM in the US followed diagnosis of BSM damage in turfgrass in Hawaii (Hardy, 1976). The first report of the BSM in North America was in 2009 when it was found in Los Angeles, CA (Holderbaum, 2009). Since the 2010 discovery in southern Georgia, the BSM has spread throughout the southeast, damaging bermudagrass turfgrass, hayfields, and pastures as far north as North Carolina and Tennessee and as far west as Texas.

Figure 1. "Bronzing" of bermudagrass hay fields as a result of bermudagrass stem maggot damage (A). The bronzing is the result of damage done at the uppermost node that results in senescence of the top two to three leaves of the plant (B). The damaged leaves can easily be pulled from the sheath and the end inside the sheath shows evidence of insect damage or obvious decay (C). Photo credits: A: Will Hudson, University of Georgia Entomology Dept.; B and C: Lisa Baxter, University of Georgia Crop and Soil Sciences Dept.

<u>Identifying the BSM:</u> The BSM fly is easier to find and identify than the larva or pupae because it occurs outside of the pseudostem and has distinct coloration (Fig. 2). The males and females have transparent wings, a gray thorax, and a yellow abdomen with at least one pair of black spots (Fig. 2A and 2B). Adult BSMs range between 3.0 and 3.5 mm in length, and the females are typically larger than the males. The female abdomen is longer and more pointed, while the male's abdomen is shorter and more rounded. A thorough and detailed anatomical description of the male and female flies has been recorded by Pont and Magpayo (1995). The larvae are white,

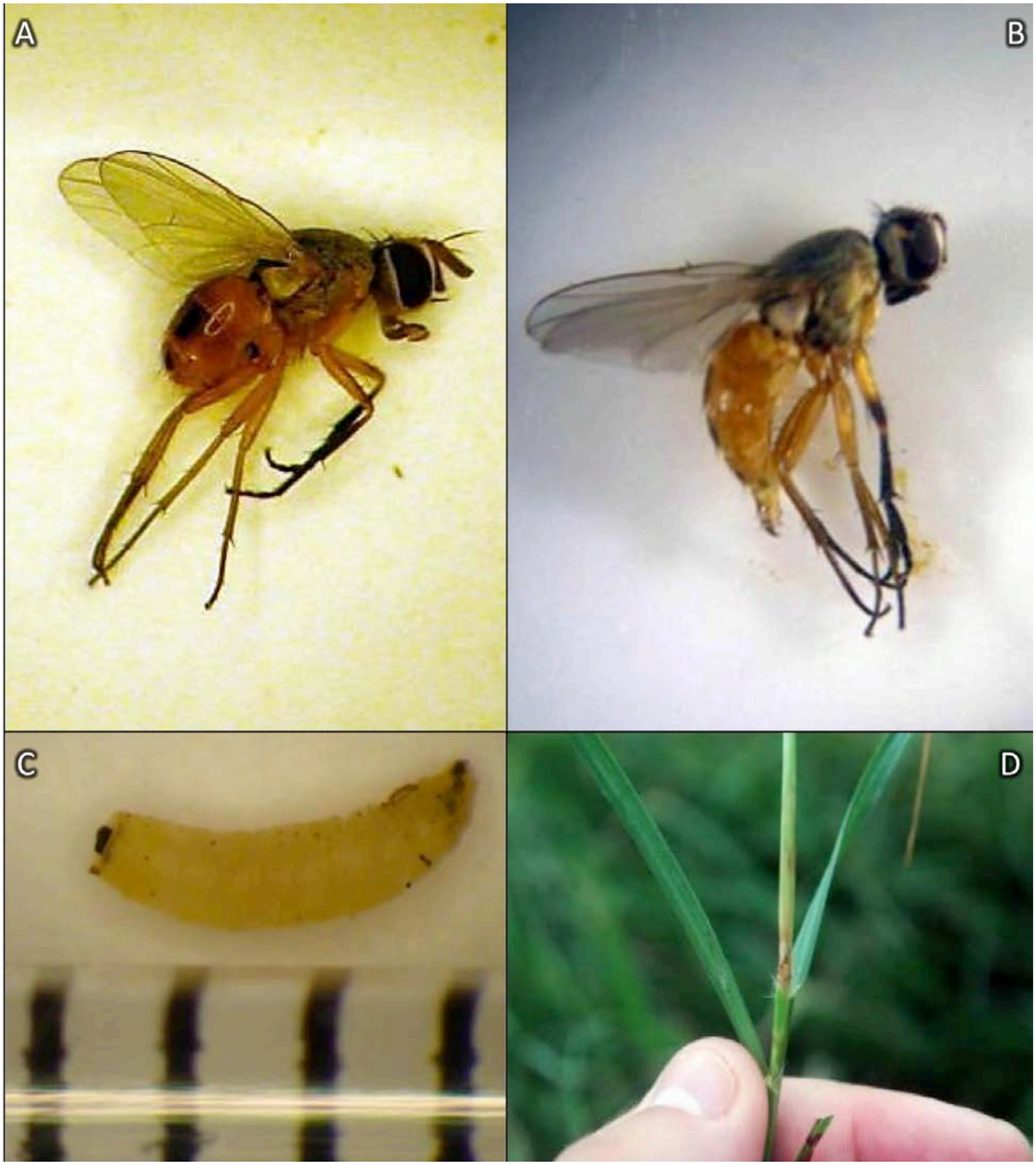

Figure 2. The adult male (A) and female (B) bermudagrass stem maggot fly, larvae (C), and exit hole made by the larva as it emerges from the pseudostem (D). Photo credits: Lisa Baxter, University of Georgia Crop and Soil Sciences Dept.

cylindrical and about 3 mm in length (Fig. 2C). As they mature, the color gradually darkens. The larvae also have mouth-hooks that are barely visible to the naked eye. It is presumed that these mouth-hooks enable the BSM to macerate the walls of the pseudostem. The puparium is orange to dark red and barrel shaped, which is simi lar to that of other *Atherigona* species (Gryzwacz et al., 2013). A precise description of the fly's egg has not been made.

Life Cycle and Means of Damage: The life cycle and biology of the BSM has not been substantially documented in the literature. Therefore, much of what is presented here are suppositions based on our previous work (Gryzwacz et al., 2013); observations in the field, greenhouse, and laboratory in the months since; as well as assumed similarities to a closely related and more studied *Atherigona* species, the sorghum shoot fly (*A. soccata*; Talati and Upadhyay, 1978; Hardy, 1981; Raina, 1981; Pont, 1981; and Raina, 1982).

Phases in the life cycle include hatching, maturing inside the stem, pupating within moist soil, and emerging as a fly. We presume that the BSM fly lays an egg on the underside of the bermudagrass leaf in a manner similar to *A. soccata* and the larva emerges approximately 2.5 days post-oviposition. Upon emerging, the larva slips or bores into the central whorl of the pseudostem, feeding on the sap at the first node encountered. Signs of damage are observed between 1-3 days later. Between the time when chlorosis is first observed and the top 2-3 leaves are completely chlorotic or necrotic, the larva exits the stem (Fig. 2D) and moves to the soil for pupation. After pupating for 7-10 days, the adult fly emerges. Adult flies that we have reared, provided sugar water, and kept in enclosures have lived for approximately 18-20 days. Based on these observations, we believe the life cycle of the BSM to be four to five weeks long with multiple offspring being produced by the fly during its adulthood.

The degree to which the BSM overwinters in the SE USA remains unclear. We have observed that populations increase progressively from south to north, with high populations developing as early as mid-June in Central Florida, early July in South Georgia, mid-July in Central Georgia, and late July in North Georgia and points further north. This would lead one to believe that overwintering success is, at a minimum, much more successful in more southern climes. Nonetheless, we have collected flies as early as mid-May in areas near Athens, GA, so we presume they have at least some ability to overwinter at this latitude.

Host Range: *Atherigona* are found on a wide range of hosts but are primarily a pest of the Poaceae family (Pont and Magpayo, 1995). In general, each *Atherigona* species has its own preferred host. Though the BSM has been found on other grass species, damage by the BSM has only been observed in bermudagrass plants. Clearly, the larvae feed on the bermudagrass sap and/or vascular tissue. However, it is not clear what the flies feed upon. We hypothesize that the flies may feed on sugar exudates in guttation that occurs overnight and early in the morning.

Collecting Flies and Larvae: Sweep net collections and identification of the BSM fly within the field can be made relatively easily. However, they tend to stay down in the forage canopy and rarely fly higher than 18 inches (0.5 m) above the canopy. Consequently, sweeping may not result in an accurate estimate of fly population. Nonetheless, the population of flies per square foot can be high. Using a sweep net, we have observed fly populations as high as 50 flies per 10 sweeps.

Finding the larva is more challenging and requires dissecting pseudostems that show the first signs of chlorosis in response to BSM damage. If the pseudostem shows extensive damage, then it is likely the larva has already left the pseudostem to pupate. Pseudostems may be carefully dissected using a sharp knife or razor blade, then splitting the stem until the center of the shoot is revealed. Because of the small size of the larva, it is best to work over a solid, dark colored surface so that the larva is not lost during the procedure. As of yet, no protocols have been developed to search for the pupae in a damaged field's soil.

Mitigation Strategies: In general, *Atherigona* populations cannot be fully controlled through mechanical and/or chemical means, and it is likely impossible to fully control or eradicate BSM, as well. The use of mechanical and/or chemical controls may, however, suppress the population to achieve an acceptable level of economic damage.

To date, we have not been able to successfully establish economic thresholds for when action is warranted. The population built so quickly in the 2012 and 2013 seasons that there was no range in the population data (i.e., it was bimodal, going from very low population levels of 0-2 flies per 10 sweeps to very high population levels of 30+ flies per 10 sweeps in a matter of less than 10 days). We are also examining the potential to correlate the number of damaged tillers per square foot (or meter) in a given growth cycle to a likelihood of potential damage in the subsequent growth cycle. However, this method is fraught with challenges because cultivars vary in tiller density and other environmental factors may influence the precision of these estimates.

If signs of BSM damage occur near the end of a regrowth cycle (within 2.5-3 weeks after cutting or grazing), the producer should harvest or graze the field as soon as conditions become favorable. Damage seen earlier in the growth cycle will very likely reduce agronomic performance of the crop substantially. Once a stand that is 6 inches (15 cm) or taller has been damaged by BSM feeding, the only option is to cut and/or graze the stand to a height of 3-4 inches (7.5-10 cm) and encourage regrowth to occur because the bermudagrass crop is unlikely to further develop. It is better to cut the field extremely early and accept the loss than to have a low-yielding, severely damaged crop that harbors a large fly population and leads to a further buildup. Ideally, the infected material would be removed from the field to prevent shading of any regrowth. The larvae do not appear to remain in cut stems. Within hours of cutting, larvae will exit damaged stems and travel to the soil. Those larvae that are mature enough to progress will pupate and emerge from the soil approximately 10 days later. Flies in fields that have been harvested escape to field margins and neighboring bermudagrass fields.

Chemical control of the BSM larva is challenging because it is inside the pseudostem. Consequently, an insecticide with systemic activity would be needed to prevent larval feeding. However, systemic insecticides are not approved for use in pastures or hay crops.

Suppression of the BSM fly is also challenging because the flies are mobile, and it is unclear to what degree the flies travel from one field to another or escapes from a treated area. In our experience, the flies do not fly far (no more than 10 feet) in any single instance of flight, even after being disturbed. Further, properly timing the control tactic requires some knowledge of how the effort will overlap with the life cycle, which remains vaguely developed at best in the case of the BSM. In addition, one must consider the limits of a chemical application in canopy penetration. In our experience, the BSM flies tend to remain deep in the canopy except to move from one location to another or in response to a disturbance.

According to Delobel (1982), sorghum shoot fly infestations are most easily reduced when the crop is in the lag and early exponential growth phases. Potentially, this could be true for BSM suppression, as well. During these phases, canopy penetration should be substantial. Moreover, suppressing flies at this time could serve to protect the crop until the bermudagrass gets tall enough and/or produces adequate tillers to reduce the effects of the damage on yield.

The current recommended chemical suppression technique is to apply a recommended rate of an inexpensive pyrethroid insecticide after the bermudagrass has begun to regrow (7-10 days after cutting) following an affected harvest. A second application should be made 7-10 days later to suppress any flies that have emerged or arrived since the last application. Chemical actions should be taken if there is a known history of BSM damage to the bermudagrass and the expense of the two applications (usually less than $15/acre for both applications) is justified by the forage yield saved. Based on our current observations, BSM populations are not high enough to warrant chemical suppression prior to the first bermudagrass hay cutting (or equivalent timing if the crop is to be grazed) and population buildup may not occur until late into the regrowth cycle for the second cutting for the central latitudes of the SE US or third cutting for more northern areas where bermudagrass is grown.

<u>Susceptibility Variation Between Cultivars:</u> Ikeda et al. (1991) noted that the proportion of tillers damaged by the BSM was positively correlated to shoot density and negatively correlated to tiller diameter, length of internode, and width of leaf blade. The connection to more damage in fields with a higher number of shoots has also been observed throughout Georgia and confirmed in recent greenhouse trials (Baxter et al., 2013; 2014). In general, stargrass (*Cynodon nlemfuensis*) and hybrids of bermudagrass and stargrass (cv. 'Tifton 85', 'Coastcross-I', and 'Coastcross-II') have fewer tillers but proportionately fewer of those tillers are damaged. Cultivars with a higher number of shoots also tend to have a smaller shoot diameter, narrower leaves, and lighter green color. These plant characteristics create a denser forage canopy, which seems to attract the BSM (Fig. 3).

<u>Future Research:</u> Much remains unanswered about the BSM; its lifecycle; its effects on the severity of BSM damage on bermudagrass yield, quality, and aesthetics; and how it can be managed or controlled. Our work to date has merely begun to grapple with these issues, but it has laid the groundwork for future research efforts. We have learned enough to provide producers basic suppression techniques, but much more research is needed to assist producers in making informed decisions about options for BSM management.

Figure 3. Hybrids of bermudagrass with stargrass (left), such as cv. 'Tifton 85', 'Coastcross-I', and 'Coastcross-II', result in fewer tillers per unit area, larger tillers, and less canopy thickness compared to bermudagrass cultivars (right). Photo credits: Lisa Baxter, University of Georgia Crop and Soil Sciences Dept.

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