Effect of *Beauveria bassiana* (Hypocreales: Clavicipitaceae) and Fungicide Applications on *Megacopta cribraria* (Hemiptera: Plataspidae) in Soybean

Ian A. Knight, Phillip M. Roberts, Wayne A. Gardner, Kerry M. Oliver, Alana Jacobson, and Michael D. Toews*

**Abstract**
Declining populations of kudzu bug, *Megacopta cribraria* (F.), in the southeastern United States have been observed since 2013 and are generally attributed to increased prevalence of natural enemies. *Beauveria bassiana* (Bals.-Criv.) Vuill. infects kudzu bugs in North America, but the level of pest suppression has not been reported. *Beauveria bassiana* is sensitive to classes of fungicides used to manage foliar pathogens in soybean. Here, the degree to which *B. bassiana* suppressed kudzu bugs in soybean and changes in pest abundance as a result of routine fungicide applications were assessed in soybean plots located in Alabama and Georgia. In Alabama, seed and foliar treatments of *B. bassiana* spores and treatment with fungicides were tested. In Georgia, conservation tillage and fungicide applications were tested for their effect on kudzu bug populations and *B. bassiana* related mortality. Kudzu bug suppression due to *Beauveria* differed between sites, with 20 to 75% cadavers to total bugs observed in Alabama and 1 to 6% observed in Georgia. Tillage had no effect on kudzu bug numbers or suppression, though fungicide applications decreased suppression compared with the non-treated control on one sample date. *Beauveria bassiana* seed and foliar treatments did not affect kudzu bug suppression. Effects of fungicides on ratios of cadavers to total bugs were variable, though less *Beauveria* was observed in plots receiving a fungicide tank mix compared with non-treated controls. Fungicides had no consistent effect on kudzu bug populations at either site.

*Megacopta cribraria* (F.) (Hemiptera: Plataspidae), kudzu bug, is an economically damaging pest of soybean. Across the native and introduced range, infestations may result in greater than 50% yield losses (Wang et al., 1996; Seiter et al., 2013). Kudzu bug is susceptible to a range of insecticides (Seiter et al., 2013) and can be effectively managed with a single appropriately timed insecticide application (Seiter et al., 2015). Kudzu bug populations have decreased in the southeastern U.S. since 2013, likely as a result of increasing natural enemy activity (Gardner and Olson 2016).
The primary natural enemies associated with the observed kudzu bug decline include the egg parasitoid Paratelenomus saccharalis and the entomopathogenic fungus Beauveria bassiana (Gardner and Olson 2016). Prior observation of B. bassiana infecting kudzu bug in North America is relatively scarce (Ruberson et al., 2013), but infection of kudzu bug by B. bassiana has been reported from their native range (Borah and Dutta, 2002). Borah and Sarma (2009) reported infection rates that exceeded 60% for adults and nymphs. Pathogenicity of B. bassiana on North American populations was confirmed with PCR (polymerase chain reaction) by Seiter et al. (2014). Kudzu bugs were later demonstrated to be susceptible to native and commercial strains of B. bassiana (Portilla et al., 2016).

Beauveria bassiana is a cosmopolitan entomopathogen that infects more than 700 arthropod species, including many of agricultural significance (Inglis et al., 2001; Rehner et al., 2005; Meyling and Eilenberg 2007). Conidia persist in the soil and can be dispersed by wind, rain splash, or infected hosts (Inglis et al., 2001; Ulevičius et al., 2004; Meyling and Eilenberg, 2007). Endophytic relationships between B. bassiana and several crop plants, including soybean, are reported (Russo et al., 2015; Vidal and Jaber, 2015).

Fungal soybean pathogens in the Southeast are managed with foliar application of triazole (demethylation inhibitors) or strobilurin (quinone outside inhibitors) fungicides (Whitaker et al., 2015). Both fungicide classes demonstrate reduced germination and growth of B. bassiana under laboratory conditions (Shapiro-Ilan et al., 2011; Gatarayiha et al., 2010). Soils treated with fungicides reduce mortality of sentinel Galleria mellonella to B. bassiana (Mietkiewski et al., 1997). Koch et al. (2010) observed lower infection of soybean aphid (Aphis glycines) (Aphididae: Hemiptera) to fungal pathogens in fungicide-treated soybean plots compared with the non-treated control. To date, no studies report risk of secondary kudzu bug outbreaks in response to fungicidal applications in soybean.

Cultural practices may influence communities of entomopathogens. Greater densities of B. bassiana conidia are reported from fields under conservation tillage compared with conventional tillage (Sosa-Gomez and Moscardi, 1994; Hummel et al., 2002; Meyling and Eilenberg, 2007). Klingen and Haukeland (2006) observed more favorable microclimates for arthropods and entomopathogens with conservation tillage but more antagonistic microorganisms as well. Del Pozo-Valdivia et al. (2017) observed fewer kudzu bugs in reduced-tillage treatments compared with conventional tillage. However, the relationship between conservation tillage and infection of kudzu bugs by B. bassiana has yet to be investigated.

This study was conducted at field sites in Alabama and Georgia. The objective of the Alabama study was to assess the effects of fungicides and foliar- and seed-applied B. bassiana treatments on kudzu bug populations. The objective of the Georgia study was to investigate the effects of tillage and fungicide treatments on kudzu bug infestation and suppression due to naturally occurring B. bassiana.

**Alabama: Experimental Design, Stand Establishment, Sampling, and Data Analysis**

Experimental plots were established during 2015 at Prattville, AL to assess the effects of fungicides and foliar and seed-applied B. bassiana treatments on kudzu bug populations. Experiments were conducted at the Prattville Agricultural Research Unit (32.4260° N, 86.4457° W) on an irrigated field of Lucedale fine sandy loam (fine-loamy, siliceous, subactive, thermic Rhodic Paleudults). The experiment consisted of eight treatments arranged in a randomized complete block. Treatments included a non-treated control, foliar applications of B. bassiana spores, powder formulation of B. bassiana spores applied to seeds at planting, foliar B. bassiana plus strobilurin fungicide, foliar B. bassiana plus triazole fungicide, foliar B. bassiana plus a tank mix of both strobilurin and triazole fungicide treatments, B. bassiana seed treatment plus foliar application of the strobilurin and triazole tank mix, and a pyrethroid insecticide (Table 1).

Plots were planted on 20 May 2015 with a Maturity Group V soybean (variety 95Y70, Pioneer, DuPont, Wilmington, DE) provided with base fungicide seed treatments (metalaxyl, prothioconazole, and penflufen). Plots were four rows (12 ft) wide by 30 ft long and were planted on a 3-ft row spacing. Pyrethroid treatments were applied on 8 July 2015 after nymphs were detected in plots. Foliar Beauveria applications were made on 17 July 2015, whereas all fungicide treatments were applied on 3 Aug. 2015. Kudzu bug populations and suppression by Beauveria were assessed prior to Beauveria treatments and pesticide applications on 7 July 2015 and following treatments on 27 Aug. 2015. Sampling was conducted by enumerating kudzu bug adults, nymphs, and Beauveria-infected cadavers by whole-plant visual inspection of 3 ft of row. No nymphs or cadavers were recovered from pre-treatment samples. Yield estimates were obtained by mechanically harvesting the middle two rows of each plot with a plot combine on 30 Oct. 2015 and adjusted to a 13% common moisture content.

Response variables were modeled with generalized linear mixed models using the GLIMMIX procedure in SAS (SAS Institute, 2008). Adult and nymph kudzu bug counts were modeled with a negative binomial distribution. No nymphs were recovered after pyrethroid application, and this treatment was therefore removed from the statistical analyses and considered statistically different. The ratio of nymph cadavers to total nymph counts and the ratio of adult bug cadavers to adult counts were modeled with a binomial distribution. Bifenthrin-treated plots were dropped from the analysis of Beauveria-induced suppression to improve model fit, and the remaining treatments were compared. When differences among treatments were detected (α = 0.05), treatments were separated following the LSMEANS procedure. All results in text and figures are reported using back-transformed means and standard errors.
Georgia: Experimental Design, Stand Establishment, Sampling, and Data Analysis

To test the effects of tillage and fungicide treatments on kudzu bug infestation and suppression by naturally occurring *B. bassiana*, experimental plots were established at the Coastal Plain Experiment Station, Tift County, Georgia (31.5242° N, 83.5483° W) on an irrigated field of Tifton loamy sand (fine loamy, kaolinitic, thermic Plinthic Kandiudults). Treatment structure was a two-way factorial arranged in a split-plot design. Tillage (conventional vs. strip tilled in rye) was replicated four times at the main plot level while foliar overspray was replicated in the subplots. Foliar-applied treatments consisted of a non-treated control, bifenthrin insecticide, tebuconazole fungicide, and azoxystrobin fungicide (Table 1).

Strip-tillage plots were planted in rye (*Secale cereal* L.) cv. Wrens Abruzzi on 1 Dec. 2015 with a Tye Pasture Pleaser no-till grain drill (AGCO Corporation, Duluth, GA) at the recommended rates of 90 lb seed/acre with 7-inch spacing. The rye cover was rolled and chemically terminated with 32 oz/acre glyphosate (Roundup WeatherMax; Monsanto, St. Louis, MO) on 18 and 19 Apr. 2016, respectively. Strip tillage plots were tilled with a two-row strip till rig (Rip/Strip Generation II; Kelly Manufacturing Co., Tifton, GA) equipped with an in-row subsoiler adjusted to a depth of 16 inches on 5 May 2016. Conventional tillage plots were cultivated (Field Cultivator-Four Bar; Kelly Manufacturing Co., Tifton, GA), followed by a rip and bed pass (Rip & Bed-Generation II; Kelly Manufacturing Co., Tifton, GA) with the subsoiler adjusted to a depth of 16 inches on 5 May 2016.

Strip and conventional tillage plots were planted on 23 May 2016 with a Maturity Group V soybean (AG 5935, ASGROW, Monsanto Co., St. Louis, MO) provided with base fungicide seed treatments (pyraclostrobin, metalaxyl, and fluytaxopyrad). Plots were 24 ft wide by 40 ft long and consisted of eight rows with 3-ft spacing. Insect and pathogen samples were taken from Rows 2, 3, 6, and 7 while yield estimates were obtained from Rows 4 and 5. Pesticide applications began when soybeans reached the early reproductive growth stage (R2), 58 d after planting, per recommendations by the University of Georgia Cooperative Extension (UGCE) for management of fungal pathogens. Two additional applications occurred at 72 and 86 d after planting, such that each plot received the same treatment three times during the growing season. Supplemental overhead irrigation was provided as needed and all plots were managed following UGCE recommendations for soybean (Whitaker et al., 2016). All plots received a single application of chlorantraniliprole (Prevathon; DuPont, Wilmington, DE) at 20 oz/acre (0.06 lb a.i.) on 17 Aug. 2016 to mitigate potentially confounding lepidopteran pests.

Kudzu bug infestation and *B. bassiana* infected cadavers were assed at 64, 80, 93, and 108 d after planting, beginning the week following the first pesticide application. Kudzu bug adult and nymph infestations were estimated from 20 sweeps in a single row using a 15-inch-diameter sweep net. Additionally, two beat sheet infestations per plot were obtained by vigorously shaking soybean plants from two rows over a 3-ft beat sheet. Counts from the two samples were pooled. Kudzu bug cadavers were recorded from beat sheet samples from the first sample date while the total number of live bugs and cadavers were recorded for each subsequent sample date. Dead kudzu bugs were only noted as cadavers if conidia were present outside the body cavity. Yield estimates were obtained by mechanically harvesting the two center rows on 6 Oct. 2016; harvest weights were adjusted to 13% moisture.

Response variables were modeled independently by sample date with generalized linear mixed models using the GLIMMIX procedure in SAS (SAS Institute, 2008). Sweep net counts of adult kudzu bugs were modeled with a Poisson distribution. The responses for sweep net nymph counts and live counts from beat sheets were heavily overdispersed, so using a negative binomial distribution greatly improved model fit. The ratio of *Beauveria*-infected cadavers to total kudzu bug counts was modeled with a binomial distribution. Following application of bifenthrin, all responses in those plots were zero or very close to zero, and these data resulted in poor model fit; therefore, this treatment was manually removed from the analyses, and we assumed that this treatment was statistically different from the remaining foliar-applied treatments. In the analyses of *Beauveria* rates only, inclusion of tillage as a treatment variable resulted in poor fit and had to be dropped from the model. When differences among treatments were detected (α = 0.05), treatments were separated following the LSMEANS procedure. All results in text and figures are reported using back-transformed means and standard errors.
Alabama: Kudzu Bug Population, Suppression, and Soybean Yield Response to Pesticide Treatments

Prior to applications of foliar treatments, no significant differences in adult counts were detected among treatments ($F = 1.23; df = 7, 20; p = 0.330$). Counts of adult bugs per 3 ft. of row were significantly lower in bifenthrin-treated plots compared with all other treatments at 3 wk after foliar applications of fungicides and the pyrethroid insecticide ($F = 3.49; df = 7, 21; p = 0.012$) (Fig. 1). No nymphs were recovered from bifenthrin-treated plots, and a mean (±SE) of 171.9 ± 21.4 nymphs was recovered from all other treatments, which were not significantly different from each other ($F = 1.15; df = 6, 18; p = 0.377$).

The ratio of infected cadavers to the total number of kudzu bugs recovered from 3 ft of row was generally higher in Alabama relative to the Georgia study. Treatment effect varied with life stage. Generally speaking, there were fewer kudzu bug cadavers in plots treated with a tank mix of fungicides compared with single-product treatments. This was true for adults ($F = 7.26; df = 6, 18; p < 0.001$) and nymphs ($F = 21.74; df = 6, 18; p < 0.001$). Treatment with a fungicide never increased cadavers above the level observed in the non-treated plots (Fig. 2). Mean (±SE) yield was 2552.2 ± 36.9 lb/acre and did not differ among all treatments ($F = 0.47; df = 7, 21; p = 0.844$).

Georgia: Kudzu Bug Population, Beauveria, and Soybean Yield Response to Pesticide Treatments

Treatment effects were observed for adult counts from sweep net samples across weeks. A significant tillage × pesticide treatment interaction was observed on the third sample date ($F = 11.59; df = 3, 21; p < 0.001$) but no other sample dates ($F = 1.35–2.55; df = 3, 21; p = 0.083–0.287$). When examining the differences between tillage types, no significant differences were detected, regardless of sample week ($F = 0.1–1.0; df = 1, 21; p = 0.328–0.750$). However, there were significant differences among pesticide treatments on each individual sample date ($F = 3.76–33.33; df = 3, 21; p < 0.001–0.026$). Bifenthrin-treated plots had the fewest adult kudzu bugs on each sample date while differences between fungicide-treated and non-treated plots differed by week (Fig. 3). No nymphs were recovered from bifenthrin-treated plots on 26 July 2016, 24 Aug. 2016, or 8 Sept. 2016, and very few nymphs (0.1 ± 0.1) per sample were observed on 11 Aug. 2016. Mean nymph counts from sweep net samples from the remaining plots were 0.4 ± 0.2, 8.1 ± 2.3, 12.7 ± 3.4, and 0.3 ± 0.2 for 26 July, 11 August, 24 August, and 8 September, respectively. No significant differences in nymph counts were observed among the remaining fungicide treatments or non-treated plots ($F < 0.01–2.29; df = 2, 15; p = 0.136–0.999$), between tillage types ($F < 0.01–2; df = 1, 15; p = 0.178–0.993$), or interactions between these treatment levels ($F < 0.01–0.94; df = 2, 15; p = 0.414–0.987$).

Live kudzu bug counts from beat sheet samples were highly variable. Mean ± SE total live kudzu bug counts from bifenthrin-treated plots were 1.0 ± 0.4 and 0.1 ± 0.1 for 11 August.

Fig. 1. Mean *M. cribraria* adults per 3 ft. row on 7 July 2015 at Prattville, AL by pesticide treatment. Means that share letters are not significantly different. LSMEANS test ($p < 0.05$). Tank-mix treatments are combinations of pyraclostrobin and flutriafol at labeled rates for each product.
and 8 September, respectively. No bugs were recovered from bifenthrin-treated plots on 24 August. Differences among the remaining treatments were only detected on the second week of sampling ($F = 3.68; df = 2, 15; p = 0.049$), with $49.5 \pm 15.2$, $22.4 \pm 7.0$, and $22.1 \pm 7.0$ bugs from the non-treated, azoxystrobin-, and tebuconazole-treated plots, respectively. No significant differences were observed among treatments on the remaining two sample dates ($F = 2.92–3.49; df = 2, 15; p = 0.057–0.086$). Mean beat sheet samples from the remaining treatments for the last two dates were $42.1 \pm 9.6$ and $56.5 \pm 15.9$. Tillage did

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**Fig. 2.** Mean ratio of *B. bassiana* infected *M. cribraria* cadavers to total *M. cribraria* recovered at Prattville, AL on 27 Aug. 2015, 3 wk after pesticide applications. Means that share letters within life stage are not significantly different. LSMEANS test ($p < 0.05$). Tank-mix treatments are combinations of pyraclostrobin and flutriafol at labeled rates for each product.

![Graph](image1)

**Fig. 3.** Mean *M. cribraria* adults per 20 sweeps from 26 July 2016 to 8 Sept. 2016 at Tifton, GA by pesticide treatment. Means that share letters within each sample date are not significantly different. LSMEANS test ($p < 0.05$). On 26 July 2016, only mean adult counts from non-treated plots were significantly greater than bifenthrin-treated plots. Arrows indicate timing of treatment applications.

![Graph](image2)
not have a significant effect on kudzu bug counts for any sample date \((F = 0.66–2.16, \text{df} = 1, 15; p = 0.162–0.431)\), nor were any interactions observed \((F = 1.07–2.01; \text{df} = 2, 15; p = 0.168–0.368)\).

Kudzu bug suppression, measured as the ratio of cadavers to total bugs recovered from beat sheet samples, was very low across all weeks of sampling. No cadavers were recovered from any plot on the first week of sampling; further, no cadavers were recovered from bifenthrin-treated plots. No significant differences among pesticide treatments were observed on the second and fourth sample dates \((F < 0.01–2.45; \text{df} = 2, 21; p = 0.111–0.999)\). However, on the third week of sampling, ratio of cadavers to total bugs was significantly greater in non-treated plots compared with either fungicide treatment \((F = 7.83; \text{df} = 2, 20; p = 0.003)\) (Fig. 4). Mean yield ± SE was 2570.1 ± 69.6 lb/ac, and there was no evidence of differences among pesticide treatments \((F = 2.38; \text{df} = 3, 21; p = 0.098)\), tillage type \((F = 3.42; \text{df} = 1, 21; p = 0.786)\), or an interaction \((F = 1.24; \text{df} = 3, 21; p = 0.320)\).

Managing Kudzu Bug with Foliar- and Seed-applied *Beauveria bassiana*

Suppression of kudzu bug by *B. bassiana* has been reported from eastern and western hemispheres (Borah and Dutta et al., 2002; Seiter et al., 2014). Portilla et al. (2016) investigated the *B. bassiana* pathogenicity by strain (including a Mississippi Delta native strain, the commercially available GHA strain, and a strain isolated from kudzu bugs under laboratory conditions) and found that kudzu bugs were susceptible to all three isolates. The lack of observed differences in live adult counts and ratio of cadavers to total bugs attributed to seed-treated or foliar-applied *B. bassiana* suggests that kudzu bugs were either not susceptible to this strain or the rates were suboptimal. Alternatively, the naturally occurring *Beauveria* strain may have already been present in the field. An endophytic relationship between *B. bassiana* and soybean following seed inoculation was reported by Russo et al. (2015); however, the endophyte diminished over time. Here, the extended time between planting and sampling during bloom would have likely mitigated any beneficial effects of *Beauveria* seed treatments.

Kudzu bug pressure at the Alabama study site greatly exceeded the Georgia study site. Reasons for increased populations at the Alabama study site are unclear; however, the study was replicated at three other sites in Alabama that were ultimately abandoned due to a complete lack kudzu bug pressure. Further, the Alabama study was conducted 1 yr prior to the Georgia study, and kudzu bug populations have declined throughout the southeastern U.S. since 2013 (Gardner and Olson, 2016).

**Implications for Fungicide Applications on Natural Control of Kudzu Bug by *Beauveria bassiana***

The primary objective of the Georgia study was to assess kudzu bug populations and *B. bassiana* infected cadavers after applying fungicides. The commercially labeled fungicides used in this study can inhibit the germination and growth of *B. bassiana* (Shapiro-Ilan et al., 2011) and reduce *Beauveria* mortality in the field (Mietkiewski et al., 1997; Hummel et al., 2002; Kouassi et al., 2003; Gatarayiha et al., 2010). Fungicide application significantly decreased the ratio of *Beauveria*-infected cadavers on 24 August. Additionally, significantly greater counts of adult kudzu bugs were observed in tebuconazole-treated plots on the same date. Although differences were not evident on the other sample dates, these observations could be explained by noting that germination of *B. bassiana* spores only occur under optimal

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**Fig. 4.** Mean ratio of *B. bassiana* infected *M. cribraria* cadavers to total *M. cribraria* recovered at Tifton, GA from 11 Aug. 2016 to 8 Sept. 2016. LSMEANS test \((p < 0.05)\). Arrows indicate timing of treatment applications.
temperature and humidity. Even with abundant spores, suppression generally occurs under favorable climatic conditions. Differences on any date should be concerning to growers as this suggests that conventional fungicide applications may decrease natural control of a serious agricultural pest. Gatarayiha et al. (2010) found B. bassiana to be less susceptible to azoxystrobin and suggested it may be more compatible with biological control. Here, there was a trend on the last sampling date for increased cadavers in the azoxystrobin-treated plots compared with the tebuconazole-treated plots. However, the ratios of cadavers to total bugs in this study were lower than the 19.3 to 31.5% mortality observed by Borah and Dutta (2002) from their native range.

Timing of suppression often occurs late in the growing season, but comparatively low populations of kudzu bugs and low levels of Beauveria may have suppressed observable differences. A study of B. bassiana pathogenicity on Perillus bioculatus (Hemiptera: Pentatomidae) found that lethal times (LT₅₀) for different isolates were variable, ranging from less than 3 d to more than 3 wk (Todorova et al., 2002). Mean lethal times observed by Lecuona et al. (2001) of different B. bassiana strains on Triatoma infestans (Hemiptera: Reduviidae) were generally under a week under ideal conditions. High spore concentrations of B. bassiana can cause mortality of kudzu bug in as little as 1 to 2 d (Portilla et al., 2016). Since no cadavers were observed on the first sample date, and extremely low rates were observed 2 wk later, these data suggest that natural levels of B. bassiana were low or that environmental conditions were poor for an epizootic to take place.

The primary reason for the inclusion of the pyrethroid insecticide treatment was to test for differences in kudzu bug suppression due to Beauveria in plots treated with an insecticide. Increased susceptibility to the entomopathogen Metarhizium anisopliae has been reported for stink bugs treated with sublethal doses of insecticides (Quintela et al., 2013). Synergistic interactions between entomopathogens or symbionts and insecticides have been reported for other insects as well (Paula et al., 2011; Kontsedalov et al., 2008; Koppenhöfer and Kaya, 1998). Here, bifenthrin reduced kudzu bug populations so effectively that it was not possible to analyze the impact of Beauveria in those plots. Current action thresholds for kudzu bugs in soybean are one nymph per sweep (Whitaker et al., 2016). Though the threshold was not met for this study, the extent to which bifenthrin affected kudzu bugs makes mortality due to Beauveria irrelevant from a management context.

Similar to the inclusion of bifenthrin treatments, the inclusion of conservation versus conventional tillage was intended to observe any differences in Beauveria-induced suppression. Reports from the literature are mixed on the effects of tillage on fungal entomopathogen communities (Sosa-Gomez and Moscardi, 1994; Klingen and Haukeland, 2006; Meyling and Eilenberg, 2007). Del Pozo-Valdivia et al. (2017) reported significantly greater numbers of kudzu bug adults and egg masses from conventional-till plots compared with reduced tillage. Tillage and whole-field effects were confounded in that study; however, Tillman et al. (2016) report similar differences in kudzu bug egg mass counts from conservation versus conventional tillage. While egg masses were not enumerated as part of this study, the lack of significant differences attributed to tillage suggests that effects of tillage on kudzu bug populations are site specific or only apparent under greater kudzu bug pressure. Similarly, the results of this study suggest that tillage has no effect on Beauveria in kudzu bugs; however, whether this holds true under higher kudzu bug populations and infection rates remains to be studied.

Applications of fungicides were made at labeled rates, with application timings dictated by the University of Georgia Soybean Production Guide (Whitaker et al., 2016) and intended to mitigate typical disease pressure. Timely applications of fungicides in response to foliar plant pathogens will protect soybean yield (Mueller et al., 2009) though treatment effects are not always consistent (Dorrance et al., 2010). While foliar fungal pathogens were not actively monitored prior to bloom, no symptoms were present post bloom. Henry et al. (2011) discussed how below-threshold applications of fungicides in soybean can significantly improve yield. Here, the fact that no differences in yield were observed, in spite of an aggressive treatment regimen, strongly suggests low disease pressure during the study. The lack of soybean yield differences between tillage types is consistent with other studies conducted in the Southeastern Coastal Plain (Campbell et al., 1984).

Future kudzu bug researchers should note differences in susceptibility by life stage and fungicide application. Increased B. bassiana infection rates in nymphs compared with adults corroborate observations by Borah and Sarma (2009). Due to differences in mobility, nymphs are a better target for assessing infection as a result of treatment differences. Adults could contact the conidia in one plot and fly to an unrelated plot before succumbing to the pathogen; nymphs tend to stay on the same host plant and therefore reflect conditions in that specific plot. A general trend for lower infection rates in fungicide-treated plots suggests that fungicide applications may interfere with natural and artificially applied B. bassiana. Of particular note, the two tank-mixed fungicide treatments produced the minimum observed infection rates in the study. Whether the combined activity of these two modes of action was additive or synergistic on Beauveria is unclear.

References


