The Stink Bug Complex in Alabama Field Crops with a Focus on the Brown Marmorated Stink Bug

by

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Abstract

The brown marmorated stink bug, *Halyomorpha halys* (Stål), was first confirmed in the state of Alabama in 2010. Population spread was observed by researchers, prompting further studies in 2014-2017. There are now 29 counties confirmed to have *H. halys*. Preliminary data from field corn ear samples in 2013 indicated an increase in stink bug damage in commercial field corn of north Alabama. Field corn samples during the summers of 2014-2016 showed ear injury from stink bugs and sap beetles in most corn fields of north Alabama. Though not every field in the study showed high stink bug feeding injury, the fields with high stink bug injury justify the increasing importance of scouting methods in corn fields in north Alabama. *Halyomorpha halys* is a new addition to the stink bug complex that feed on corn. The starburst symptom caused by infection of *Fusarium verticilloides* was also common. In 2014, corn collected on 11 August showed significantly less stink bug and sap beetle injury than corn collected ten days later. In 2015 and 2016 corn from the edge of the field showed significantly more stink bug injured kernels than samples taken from the middle of the field. *Halyomorpha halys* is spreading throughout the state of Alabama. Stink bug injury to field corn in North Alabama has increased significantly.

A study of the stink bug complex including *H. halys* was designed to evaluate treatment thresholds in cotton in 2016-2017. The untreated cotton plots had significantly more boll injury than plots that were treated with bifenthrin on threshold or those treated with a weekly application to provide maximum protection. There was no significant difference between maximum and threshold spray regimes in terms of internal boll injury. Cotton yield was significantly reduced in untreated compared to treated plots in 2017, but not in 2016. The data suggest that thresholds can be used to reduce the number of insecticide application, even in the presence of *H. halys*. Impact of *H. halys* was evaluated in field corn by caging two adult stink bugs for five days at different growth stages of corn from VT to R6. Feeding by adult *H. halys* caused significantly more kernel injury than the uninfested controls at pretassel, silk, dough, and dent stages. Stink bug injury from two feeding adult *H. halys* in five days averaged 16 kernels per ear in Prattville, AL and 12 kernels per ear in Shorter, AL. Ear deformation was significantly higher in the infested compared with uninfested corn at pretassel stage (V10-VT).

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DD..Degree Days

l ....liter

ha...hectare

m ....meters

cm^2 ....centimeters squared

lb ....pounds

Literature Review

1. History & Biology of *Halyomorpha halys*

The brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera:Pentatomidae), is a fairly new invasive pest in the United States. Originally from Japan, Korea, China and Taiwan, *H. halys* has been slowly spreading to countries outside of Asia, including Canada, Switzerland, Germany, France, Italy, Greece, Hungary, Romania, Spain, Georgia, Abkhazia, Russia, and Chile (Leskey and Nielsen 2017). It is believed to have first entered the U.S. in the mid-1990s, when it was discovered near Allentown, PA (Hoebeke and Carter 2003). In the U.S., it has been detected in 46 states (Leskey and Nielsen 2017). According to DNA analysis, the specific populations currently in the U.S. came directly from China (Xu et al. 2014). The rate of spread of this pest does not seem to be slowing down, due to the high volumes of global trade and travel. As a result this insect continues to draw attention, prompt research efforts, and raise concerns.

Halyomorpha halys is a polyphagous insect which causes significant damage on agricultural row crops like corn, cotton, and soybeans, ornamentals, and fruits (Wallner et al. 2014). Studies in mid-Atlantic fruit orchards found that it damages tree fruits and that peach trees serve as an excellent host for *H. halys* (Leskey 2012a). It causes significant injury to the tissue of a variety of vegetables such as: beans, tomatoes, peppers, asparagus, cucurbits, and brassicas (Rice et al. 2014). Large numbers of feeding *H. halys* on fruiting vegetables were observed to cause fruit rot and abortion (Kuhar et al. 2012). Aside from the large economic threat it poses for farmers, *H. halys* doubles as a domestic nuisance pest because overwinters in man-made structures like barns, sheds, recreational vehicles, and homes (Lee et al. 2014).

Halyomorpha halys, like other species in the family Pentatomidae, undergoes hemimetabolous metamorphosis. There are slight differences in coloration with each molt until eclosing to an adult. Characteristic white bands on antennae and legs separate this insect by appearance from many of the native stink bugs in the U.S., in addition to more banding on the edge of the abdomen. Another distinguishing characteristic is a grouping of pits that reflect a metallic green color from areas on the prosternum, mesosternum, metasternum, and gena of the insect (Charles Ray, Auburn University, personal communication). The male brown marmorated stink bug can be differentiated from the female by the claspers on the last ventral abdominal segment (Rice et al. 2014).

The adult brown marmorated stinkbug can live from six to eight months. As temperatures rise above 10˚C, adults are triggered to leave overwintering sites in mid-March to April (Lee et al. 2013) but, reproductive diapause continues until the photoperiod is 13.5 to 14 hours (Yanagi and Hagihara 1980, Wantanabe 1979). The adult female *H. halys* emerges from diapause in a pre-vitellogenic stage, not yet reproductively mature and becomes vitellogenic with an additional 148 DD (Nielsen et al. 2016, Nielsen et al. 2008). After emerging from its overwintering site, the adult feeds on various available host plants until reaching reproductive maturity, at which time the adult disperses.

The polyandrous female will lay a cluster of approximately 28 eggs on the underside of a leaf (Kawada and Kitamura 1983, Nielsen et al. 2008). Researchers in North Carolina and Virginia have found that the first eggs appear during the last week of

May through to the first week of June (Bakken et al. 2015). Egg masses are laid roughly a week apart, and one female is capable of laying up to 400 eggs (Gyeltshen et al. 2005). These egg masses appear a light green color when first deposited, but turn white and then darken close to hatching. The individual egg is barrel-shaped.

There are five nymphal instars. Neonates have black heads, red eyes, and burnt orange/red markings (Rice et al. 2014). First instar nymphs feed on their own eggshells and may obtain endosymbionts this way (Taylor et al. 2014). Research conducted by Nielsen et al. (2008) found that developmental rates along with percent survival were most ideal when reared at 25°C. The following estimated developing days are based on the optimal 25°C. Six days after oviposition the 1st instar molts into the second instar nymphs and begin to feed on host plants. Second instar nymphs still have some orange coloring, and their body is without sharp edges. They have more black markings than first instar nymphs and have distinguishable black and white banding on the antenna. Nymphs reach the third instar 22 days after egg hatch at 25°C (Nielsen et al. 2008). Third instar nymphs display more dark markings than the previous nymphal stages. Fourth instar nymphs emerge around 29 days and the fifth instar nymphs around 45 days after hatching. Fourth and fifth instar nymphs appear browner in color than the third instar and have the black and white banding on both antennae and their legs. The full development from egg to adult requires 538 degree days (DD) with a minimum and maximum developmental threshold of 17°C and 33°C (Nielsen et al. 2008).

In parts of southern China, *H. halys* is multivoltine and capable of having anywhere from four to six generations in a year (Hoffmann 1931). In the mid-Atlantic area of the United States, where *H. halys* has been present the longest, it has up to two generations per year (Neilsen et al. 2008). The number of potential generations of *H. halys* in the southern U.S. has not been determined, as the pest still continues to spread and adapt to the new climate. It has been said that we can expect the same or similar patterns to China's five generations as *H. halys* settles in the south (Hoebeke and Carter 2003, Hoffmann 1931). However, a model that incorporates day length and other environmental factors to estimate the pest's full potential for population size and growth suggests that the two generations being seen in the Southeast now is likely the maximum we will see (Nielsen et al. 2016). Nielsen et al. (2016) speculated the possibility for *H. halys* to evolve a differential response to photoperiod as observed in the mosquito *A. albopictus* (Diptera: Culicide). Such evolution would result in a change in *H. halys'* estimated range and pest potential, but has not been observed so far (Nielsen et al. 2016).

2. Row Crops of Alabama

Farming in the south is an important part of the agricultural industry in the U.S. and in world trade. In 2011, farming brought in over 5 billion dollars in revenue in the state of Alabama (USDA 2011). Many of these top commodities are host plants of *H. halys*, including; corn, soybeans, cotton, and sorghum. The USDA reports that 430,000 acres of cotton, 235,000 acres of corn, and 350,000 acres of soybeans were harvested in Alabama in 2017, with a combined value exceeding 570 million dollars (https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=ALABAMA).

Corn (*Zea mays (*L.) (Poales: Poaceae)); soybeans (*Glycine max* (L.) (Fabales: Fabaceae)); and cotton (*Gossypium hirsutum* (L.) (Malvales: Malvaceae)) are some of the primary crop hosts for *H. halys* in the Southeast. *Halyomorpha halys* in Alabama is joining a preexisting native stink bug complex that is already well established throughout Alabama. The common stink bug pests (Hemiptera: Pentatomidae) include three main species: brown stink bug, *Euschistus servus* (Say); green stink bug, *Acrosternum hilare* (Say); and the southern green stink bug, *Nezara viridula* (L.) (Pilkay 2013). The southern green and brown stink bugs have been reported to cause feeding injury to kernels of field corn in both late vegetative and reproductive stages (Negrón and Riley 1987, Ni et al. 2010). The green stink bug has been observed in Georgia corn, but not in high populations (Tillman 2010). Research conducted in Louisiana soybeans confirms that crop yield and quality are both significantly lowered when soybean pods exposed to feeding by these three native stink bugs (McPherson et al. 1979). Cotton bolls are also susceptible to stink bug feeding injury, with the most crop damage resulting from the green, southern green, and brown stink bugs (Herbert et al. 2009). Current recommendations to farmers for native stink bug control involves scouting and application of conventional insecticides dependent on the thresholds associated with the specific infesting insect (Herbert et al. 2009, Stewart 2018). Threshold recommendations for stink bugs in corn are: before tasseling, around the V8-10 growth stages, treat if 5 percent of plants have stink bugs; at kernel fill, treat if 10 percent of the plants have stink bugs. Continue to protect corn plants from stink bugs through the silking stage (Flanders et al. 2018). In a study on the brown stink bug it was reported that the highest stink bug activity is seen in the early mornings and in the evenings when compared to the mid-afternoon (Ni et al. 2016). Research has also found that native stink bugs of the southeastern U.S. display a pronounced edge effect in corn, cotton, and soybeans (Tillman et al. 2009, Tillman 2010, Olsen et al. 2011).

Surveys in Alabama find that *H. halys* begins to heavily colonize corn fields when the ears are developing in July in the R3/milk and R4/dough stages (Duke, personal observation). When feeding on corn kernels, the damage created by a stink bug results in under-developed or discolored kernels (Ni et al. 2011). In a study of *H. halys* in sweet corn, Cissel et al. (2015b) observed that the yield losses were greatest when feeding took place during early developmental stages. The greatest loss of quality by stink bug feeding was in later stages of ear development. They also found that *H. halys* has the ability to cause significant damage to sweet corn in a short amount of time even at small numbers of infesting stink bugs. A study similar to this sweet corn research not been conducted with *H. halys* in field corn in the stages before the silking or during the dent stage. In North Alabama native stink bug populations in field corn are not perceived to cause sufficient damage to warrant control tactics. The increase in *H. halys* in North Alabama may mean that farmers will need to scout and manage corn for stink bugs (Kathy Flanders, personal communication). A survey of stink bug injury to field corn in North Alabama is needed to accurately determine management needs.

In eastern Pennsylvania, close to the New Jersey state line, populations were observed moving to soybeans once the crop had entered the reproductive stages of development in August and September (Nielsen et al. 2011). This same behavior has also been observed in Alabama (Duke, personal observation). Soybeans in Alabama are generally entered by *H. halys* when the nearby corn crops are drying up (Duke, personal observation). Venugopal et al. (2015) also observed this movement in Maryland, from corn into soybean in adjacent fields. Populations of *H. halys* infesting corn of R4/dough stage moved into soybeans at the beginning of the R5/seed development stage. This movement continued through R6 which is a fully developed bean (Venugopal et al. 2015). Cissel et al. (2015a) suggests thresholds for soybean fields with high *H. halys* adult and large nymph densities as follows: visual (3-5 stink bugs in a 2 minute count), sweep net (3-5 stink bugs in 15 sweeps), and beat cloth (0.5 stink bugs per row foot). Soybeans in the R3 and R4 stages of development are at the highest risk for economic loss from stink bug feeding (Nielsen et al. 2011). These are the stages when the seeds are developing in the pods. Stink bug feeding damage to soybeans can cause pods to be underdeveloped or even aborted. As the soybean continues to develop the result of this damage is a shriveled or deformed seed (Owens et al. 2013). Further complications are caused by stink bug damage when the plant attempts to compensate for the damage/lost pods and exhibits "stay-green" syndrome, which is essentially a delayed senescence of the soybean plant (Rice et al. 2014). When "stay-green" syndrome occurs, it may cause costly mechanical damage to harvesting equipment in addition to the yield loss associated with the heavily damaged crop (Cissel et al. 2015a).

Cotton crops in Alabama are commonly planted in the month of April and May (Birdsong 2016). The cotton crops are harvested around the month of November. During the late summer in September and October, cotton becomes one of the most ideal stink bug host crops that are still in the field. Other crops such as corn and some soybeans have already peaked in maturity and become less desirable for stink bug feeding. In Alabama, native stink bugs require the most control due to heavy feeding on vulnerable medium sized bolls. Suggested economic thresholds in southeastern cotton are as follows: 50%

internal boll damage (week 1 of bloom); 30% internal boll damage (week 2); 10% internal boll damage (weeks 3-5); 30 % internal boll damage (week 6-7); and 50% internal boll damage (week 8) (Herbert et al. 2009). Feeding injury to cotton caused by stink bugs causes wart-like growths on inner carpel walls, stained lint, and shriveled seeds that can result in economic loss to growers (Bundy and McPherson 2000, Emfinger et al. 2004, Wene and Sheets 1964). Cotton bolls are considered to be the most at risk to stink bug feeding at medium size, around 2.4 centimeters in diameter, so this is the recommended stage for scouting (Greene and Herzog 1999). Researchers at the University of Georgia found that, unlike the native stink bugs, as boll size increased, so does the *H. halys* feeding injury (Kamminga 2014). This means that *H. halys* is feeding in cotton fields on older bolls than native stink bugs and could cause boll injury and potentially losses that were not a concern to farmers before this new species arrived.

3. Potential Control and Integrated Pest Management of *Halyomorpha halys*

Insecticides are the most commonly used control method for stink bugs. In the mid-Atlantic area among the tree-fruit growing operations the more successful available insecticides for stink bugs are broad-spectrum pyrethroids, and this poses a problem on natural enemies and other beneficial insects in the area treated (Leskey et al. 2012a). In row crops, such as soybeans and cotton, *H. halys* is an edge feeding pest, so it has been recommended to growers to use field edge-only sprays and this technique has proven to be effective in managing early populations in soybean (Rice et al. 2014). Researchers in Maryland conducted a study evaluating *H. halys'* edge effect at the USDA Beltsville

Agricultural Research Center and other fields around Maryland. This research found strong evidence that *H. halys* has a clear edge effect in corn and soybeans, with the highest densities within the first 3 meters of the field and gradually lesser densities from the edge as far as 15 meters, and the numbers decrease moving inward (Venugopal et al. 2014, Rice et al. 2014). It is known that fields with edges in close proximity to wooded areas or other suitable overwintering sites are more susceptible to invasion than those that are not in proximity (Aigner et al. 2017).

There are several known natural enemies of *H. halys* in its region of origin. *Ophiocordyceps nutans* (Hypocreales: Ophiocordycipitaceae) is a naturally occurring fungus found in Japan. It shows promise for possible future biological controls (Northeastern IPM Center 2017). In Asia there are arthropod predators, Dipteran parasitoids, and Hymenopteran egg parasitoids (Qui 2007, Qui et al. 2007, Leskey et al. 2012b, Leskey et al. 2013). One wasp species native to Asia, *Trissolcus japonicus* (Ashmead) (Hymenoptera: Scelionidae), that is known to attack *H. halys* was discovered in the United States in Beltsville, Maryland in 2014 (Talamas et al. 2015). It is speculated that *T. japonicus* was accidentally introduced to the U.S. through trade (Neal 2016). The existing native natural enemies in the U.S. include parasitoid wasps that lay their eggs inside of *H. halys* eggs, but these wasps are generalist and attack several stink bug species. There are many documented cases of predation on *H. halys* in America by generalist predators. The presence of natural enemies has not seemed to slow the spread or decrease on *H. halys* populations as they infest new areas of the United States.

The brown marmorated stink bug releases a two-component aggregation pheromone that was recently identified as (3*S*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol and

(3*S*,6*S*,7*R*,10*R*)-10,11-epoxy-1-bisabolen-3-ol (Khrimian et al. 2014, U.S. patentWO2013090703 A1). This aggregate pheromone attracts all life stages of the insect (Rice, et. al 2014). Identifying this pheromone made it possible to create pheromone traps for an alternate way of detecting *H. halys*. *Halyomorpha halys* also responds to kairomone 2,4,6, E,E,Z methyl decatrienoate, the aggregation pheromone of *Plautia stali* Scott (Heteroptera: Pentatomidae), but is less attractive to *H. halys* than the two component aggregation pheromone (Aldrich et al. 2009, Nielsen et al. 2011, Leskey et al. 2012a). The 2,4,6, E,E,Z methyl decatrienoate pheromone was found to be a good synergist to pair with the aggregation pheromone found in *H. halys*. Currently, a combination of the two aggregation pheromones is used in traps for detecting *H. halys* (Weber et al. 2014).

4. Other Corn Pests

Sap beetles (Coleoptera: Nitidulidae) are recognized as an economic pest of sweet corn (Knowlton and Houck 1948, Harrison 1962, Nuessly et al. 2010). Sap beetles will feed on field corn (Myers 2004) but are not considered an economic pest of field corn (Knodel 2013). The corn sap beetle, *Carpophilus dimidiatus*, (Coleoptera: Nitidulidae) (Fabricius), was the most commonly found sap beetle in corn samples taken in Tallassee, Alabama in 2013 (Charles Ray, Auburn University, personal communication). Sap beetles feed on corn pollen, silks, and caterpillar frass (Sanford and Luckmann 1963) and are attracted to fermentation (Bartelt et al. 1995).

Sap beetle damage in corn is related to how much of the ear tip is exposed by bird, caterpillar, or other physiological stressors (Connell 1956, Nuessly et al.2010). Sap beetles were observed during this trial in field corn samples from north and central Alabama. Sap beetles have been found to spread bacterial and fungal pathogens like *Aspergillus flavus* and *Fusarium verticilloides* (Dowd 2000, Bartelt et al. 1995, Lussenhop and Wicklow 1990, Nuessly et al. 2010). They also are likely to come into contact with mycotoxins due to their feeding habits (Myers 2004).

Fusarium ear rot, commonly known as “starburst,” is caused by the fungal pathogen *Fusarium verticilloides* (Sacc.) (Hypocreales: Nectriaceae) (Nirenberg and O’Donnell 1998). This disease is important because it presents a mycotoxin issue (Austin Hagan, personal communication). *Fusarium verticilloides* produces a group of mycotoxins called fumonisins. Mycotoxins affect the consumption of the grain, cause complications including but not limited to: illness, difficulty in reproduction, loss of appetite, or even death in livestock that consume grain containing the pathogen (Jacobsen et al. 1993). Temperature, drought stress, insect damage, other fungal disease, and the genotype of the maize all influence the success of the *Fusarium* and the production of fumonisins (Miller 2001). *Fusarium verticilloides* is passed through generations of corn by way of seedborn infection (Wilke et al. 2007).

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Chapter 1: Introduction

Distribution of *Halyomorpha halys* (Stål) in Alabama and Prevalence of Stink Bug Injury in North Alabama Field Corn

Abstract

The brown marmorated stink bug, *Halyomorpha halys* (Stål), was first confirmed in the state of Alabama in 2010. Population spread was observed by researchers, prompting further studies in 2014-2017. There are now 29 counties confirmed to have *H. halys*. Preliminary data from field corn ear samples in 2013 indicated an increase in stink bug damage in commercial field corn of north Alabama. Field corn samples during the summers of 2014-2016 showed ear injury from stink bugs and sap beetles in most corn fields of north Alabama. Though not every field in the study showed high stink bug feeding injury, the fields with high stink bug injury justify the increasing importance of scouting methods in corn fields in north Alabama. *Halyomorpha halys* is a new addition to the stink bug complex that feed on corn. The starburst symptom caused by infection of *Fusarium verticilloides* was also common. In 2014, corn collected on 11 August showed significantly less stink bug and sap beetle injury than corn collected ten days later. In 2015 and 2016 corn from the edge of the field showed significantly more stink bug injured kernels than samples taken from the middle of the field. *Halyomorpha halys* is spreading throughout the state of Alabama. Stink bug injury to field corn in North Alabama has increased significantly.

Introduction

Farming in the south is an important part of the agricultural industry in the United States and in world trade. Corn (*Zea mays (*L.) (Poales: Poaceae) is one of the primary crops grown in the Southeast. Pests of corn that are control considerations include the early season insect complex, corn earworms, fall army worms, and diseases such as southern rust (Flanders et al. 2018). While field corn in south Alabama is routinely sprayed to protect ears from the three main native Pentatomid pests (brown stink bug, *Euschistus servus* (Say); green stink bug, *Acrosternum hilare* (Say); and the southern green stink bug, *Nezara viridula* (Linnaeus) (Pilkay 2013), stink bugs have not been considered an economic pest on north Alabama field corn.

The brown marmorated stink bug, *Halyomorpha halys* (Stål), (Hemiptera: Pentatomidae) is an invasive species from Asia brought to the United States by trade and is believed to have been accidentally introduced through Allentown, Pennsylvania in the 1990s (Neilsen and Hamilton 2009). Populations of *H. halys* continue to spread through the United States. This pest is extremely phytophagous and is a known pest of many field crops produced by American farmers throughout the country. The first *H. halys* confirmed in the state of Alabama was found in Jefferson County in 2010 (Charles Ray, Auburn University, personal communication). Preliminary data collected from corn fields in north Alabama in 2013 showed higher stink bug injured kernel counts than previous years (Kathy Flanders, personal communication). The discovery of higher stink bug injury along with the introduction of the new pest *H. halys* prompted further investigation into stink bug activity in north Alabama field corn.

Sap beetles (Coleoptera: Nitidulidae) are recognized as an economic pest of sweet corn (Knowlton and Houck 1948, Harrison 1962, Nuessly et al. 2010). Various species of sap beetles will feed on field corn (Myers 2004) but they are not considered an economic pest of field corn (Knodel 2013). The corn sap beetle, *Carpophilus dimidiatus*

(Fabricius), was the most commonly found sap beetle in field corn samples taken in Tallassee, Alabama in 2013 (Charles Ray, Auburn University, personal communication). Sap beetles feed on corn pollen, silks, and caterpillar frass (Sanford and Luckman 1963). Sap beetles are attracted to fermentation (Bartelt et al. 1995) and their damage in corn is related to how much of the ear tip is exposed by bird, caterpillar, or other physiological stressors (Connell 1956, Nuessly et al. 2010). Sap beetles have been found to spread bacterial and fungal pathogens like *Aspergillus flavus* and *Fusarium verticilloides* (Dowd 2000, Bartelt et al. 1995, Lussenhop and Wicklow 1990, Nuessly et al. 2010). They also are likely to come into contact with mycotoxins due to their feeding habits (Myers 2004).

Fusarium ear rot is caused by the fungal pathogen *Fusarium verticilloides* (Sacc.) (Nirenberg and O'Donnell 1998). Starburst corn kernels are an easily recognized symptom of the disease in which maturing corn kernels are marked with fine white lines. The pathogen produces mycotoxins called fumonisins (Stack and Carlson 2003). Mycotoxins cause complications including but not limited to: illness, difficulty in reproduction, loss of appetite, or even death in livestock that consume grain containing the micotoxin (Jacobsen et al. 1993). Temperature, drought stress, insect damage, other fungal disease, and the genotype of the maize all influence the success of the pathogen and the production of fumonisins (Miller 2001). *Fusarium verticilloides* is passed through generations of corn by way of seed-borne infection (Wilke et al. 2007).

The objectives of this study were to determine where *H. halys* occurs in Alabama and to assess the amount of kernel injury in north Alabama field corn with emphasis on stink bug injury.

Materials and Methods

Stink Bug Detection Survey. A field study was conducted in 2015-2016 to establish the current distribution of *H. halys*. Sweep net sampling of soybean fields was used to assess the distribution of *H. halys* populations in Alabama. Soybeans are a known host for *H. halys* and are ideal for sweep netting methods, allowing for a large sample of the stink bugs present in the field (Bakken et al. 2015). Fields were sampled along east-west transects in northern, central, and southern Alabama. This methodology is modeled after a previous study that was effective in establishing *H. halys* distribution (Bakken et al. 2015). Thirty sets of 20 sweeps with a standard 38-cm diameter sweep net were collected in each field. Because this pest is known as an edge pest (Venugopal et al. 2014), sweep samples were taken five to ten feet from the edge of the field, running along the border of the field. Sides with hedgerows or other host crops nearest to them were the preferred sample site if available. Some supplemental visual scouting was used when field conditions were not ideal for a sweep net. This visual scouting method involved walking along the edge of the field or down a row slowly and looking for the insects in the top portion of the soybean plants. Sample fields were visited 1-3 times during sampling trips to north Alabama in an attempt to confirm the presence of *H. halys* and to also monitor established populations. Sampling visits were made while the soybeans were in the reproductive stages of development (stages R-5 to R-7). A total of 50 counties were visited in 2015-2016 (Figure 1.1). Data is reported at the county level, although the geographical coordinates of each site were recorded (Appendix Tables A5, A6).

To determine which species were present in field corn in North Alabama that could potentially injure reproductive stage corn, visual scouting was conducted in 2016 during the reproductive stages R3 to R6. Identification was done in the field. After having little success while scouting at other times of the day, a corn field was scouted in the evening. This methodology was suggested because Ni et al. (2016) observed increased stink bug activity in the evening. Field edges of a large commercial corn field in Madison County were observed and species present were recorded. Approximately 350 yards of edge row corn was observed before dark.

Social media and emails to Regional Home Grounds Agents, Gardens, and Home Pests Extension Agents with Alabama Cooperative Extension System were used to bring in additional information for areas lacking agricultural land for sweep net scouting method. All contributions to the states' county records were added to the list of confirmed counties after proper identification made by Dr. Charles Ray, Research Fellow IV, at Auburn University. This data was then added to a working map of county confirmations that is accessible to the public through the Early Detection and Distribution Mapping System, a service of the University of Georgia Center for Invasive Species and Ecosystem Health (https://www.eddmaps.org/distribution/uscounty.cfm?sub=9328).

Corn Injury Survey. Ears were sampled from 20-25 corn fields in 2014-2016, primarily in north Alabama (Appendix Tables A1- A4). Two or more fields in each county were sampled, depending on availability and permission. Ears were sampled once they had begun to dry down, starting in early to mid-August, as the corn was in late dent (R5) or black layer stage (R6). Fields were sampled at 10-14 day intervals until harvest. On the first sampling date for each field 20 ears were collected from the outer edge within the first five feet (two rows) of the field and 20 ears were collected from the middle, approximately 250 feet from the edge of the field. Ears were collected from the edge during subsequent sample dates. In 2014 only the edges were sampled. The corn samples were brought back to the lab in Auburn and assessed for ear damage. Number of kernels per ear with injury from stink bugs was recorded, and identification of this injury was made using published examples (Michel et. al 2015). Stink bug kernel injury appears as a brown puncture hole or as a light colored cloudy area. The number of kernels per ear with injury from sap beetles was recorded and identification of this injury was made using published examples (Kaster 1999). Sap beetle injured kernels appear as brown, often hallowed out kernels. The number of kernels showing the starburst symptom were recorded. Identification of starburst symptoms were made using published examples from (Payne 1999). Starburst symptoms appear as fine white lines running from the center of the top of the kernel down.

Injury from corn earworm and other Lepidopteran caterpillar pests was recorded (Thomison et al. 2018, Reisig 2016, Hooks 2011) (Appendix Tables A7-A10). Ears were rated as quickly as possible to avoid deterioration of the samples during the evaluation process. Mean kernel injury per ear was calculated for each field on each sample date. Two-tailed unpaired *t*-tests using field as the unit of observation were used to explore whether kernel injury changed from the first to the second sample date each year. The *P* values for these unpaired *t*-tests were determined using a generator created by http://www.socscistatistics.com.

In 2015 and 2016 no significant differences were found between the first and second samples, so data was averaged across dates (Table 1.1). One-tailed *t*-tests were used in 2015 and 2016 to determine if injury was greater on the edge compared to the middle of each field.

Results

Stink Bug Detection Survey. The field survey of soybean fields in 2015-2016 resulted in new positive *H. halys* county records for Madison, Talladega, DeKalb, Macon and Morgan counties (Figure 1.2). . Outreach and networking with the public brought in positive *H. halys* county records for Clay, Elmore, Montgomery, Cleburne, Blount, Franklin, and Colbert counties. During this time and in 2017, additional specimens were also turned in: Dr. Ron Smith (Escambia, Henry, and Lawrence Counties), Dr. Rao Balusu (Chilton County), Dr. Tim Reed (Franklin County), Alabama Cooperative Extension System Client (Montgomery County), and Dr. Kassie Conner (Tallapoosa County). Counties with previous confirmations were sampled to confirm that populations were still established and to assess the relative density of brown marmorated stink bugs and other stink bugs in soybean fields. In 2015, 29 soybean fields in 19 Alabama counties were sampled, (Appendix Table A5) and 7 fields in seven counties were confirmed to have *H. halys*. Finding any *H. halys* was still uncommon in most soybean fields of Alabama. However, a Madison County sample site had high numbers of *H. halys* and was therefore monitored throughout the rest of the season. By August of 2015, the numbers of *H. halys* greatly exceeded economic thresholds for both visual counts and sweep net counts (sweep net: more than 5 insects per 15 sweeps, visual: 3-5 insects in 2 minute count) (Cissel et al. 2015a).

On 11 August 2015 a *H. halys* nymph was found in soybeans by Dr. Ron Smith, Auburn University Professor Emeritus, in Escambia County, in southern Alabama. This raised interest in the insect possibly inhabiting an area that was formerly believed to be unsuitable. Surveying efforts in summer of 2016 were concentrated in the southern counties to try to confirm establishment in southern Alabama. In the summer of 2016, 25 fields in 11 counties were sampled, and 9 of those were southern counties (Appendix Table A6). None of the southern counties swept in this survey were confirmed to have any *H. halys* in the soybean fields sampled. In north Alabama, all 3 counties sampled were reconfirmed to have *H. halys*.

Approximately 10-15 corn fields were scouted in the daytime during R3 to R6 corn developmental stages in 2016. Some native stink bugs were observed but *H. halys* was not observed in the daytime hours. However, 1 *H. halys* was observed shortly before sunset (7:00 PM) in field corn in Madison County, Alabama, along with 49 *Euschistus servus* (Say). At 7:30 PM in the same field, more scouting observed 16 *E. servus;* 1 *Chinavia halaris* (Say); and 1 *Oebalus pugnax* (Fabricius). An additional scouting trip in 2017 found 1 *H. halys* nymph in the edge of a corn field just before sunset in Madison County on 6 July 2017.

Corn Injury Survey. Significantly more stink bug injured kernels were found on 21 August 2014 (Sampling Round 2) versus 11 August 2014 (Sampling Round 1) (Table 1.1) There was no significant difference between the first and second samplings (mid-

August and late August) in 2015 and 2016 so samples from each field were averaged from these two dates (Table 1.1). Sample size was limited in rounds later than the second round, so no statistical tests were performed.

Mean number of stink bug injured kernels varied from field to field in north Alabama each year (Figure 1.3). Median (minimum-maximum) stink bug injured kernels per ear was 7.1 (0.75-16.3) on 11 Aug 2014, 11.8 (2.2-26.15) on 21 Aug 2014, 8.8 (0.4-30.5) in August 2015, and 6.6 (0-36.9) in August 2016.

Edges and middle samples were collected upon the first visit to a field in 2015 and 16. Stink bug injury was more prevalent in edges than in the middle of the field (Table 1.2). In 2015 there was a significant difference in stink bug injured kernels between edge and middle (t= 1.88; df = 23; P<0.05). In 2016 a significant difference between edge and middle was seen again (t= 2.25; df = 28; P<0.05).

Sap beetle injury was significantly higher on 21 August (Round 2) compared with 11 August 2014 (Round 1) (Table 1.1). Median (minimum-maximum) sap beetle injured kernels per ear was 0.95 (0-4.85) on 11 Aug 2014, 4.1 (0-26.1) on 21 Aug 2014, 6.7 (0.25-27.4) in August 2015, and 2.2 (0-13.05) in August 2016 (Figure 1.4). There was not a significant difference in sap beetle damage found between the first and second sampling in 2015 or 2016 (Table 1.1). In 2015, significantly more sap beetle injury was found in the edge vs the middle of the field (t= 1.76; df = 23; P<0.05). There was not a significant difference in edge versus middle for sap beetle damage in 2016.

There were no significant differences in starburst symptoms between the first and second sampling in 2014, 2015 or 2016 (Table 1.1). There were no significant differences in starburst symptoms between edge and middle samples in 2014, 2015, or 2016 (Table

1.2). Median (minimum-maximum) kernels with starburst symptoms per ear was 1.3 (0-33.7) on 11 Aug 2014, 4.05 (0-19.7) on 21 Aug 2014, 1.65 (0-45.8) in August 2015, and 5.8 (0-109.7) in August 2016 (Figure 1.5).

Sitophilus zeamais (Motschulsky) (Coleoptera: Curculionidae) commonly known as maize weevil was observed in one field in Lawrence County in 2014. Weevil injury increased over time from early August through mid-September (Figure 1.6). Injury from corn earworms and other caterpillars is not presented because the use of above-ground Bt traits in all or parts of fields confounded the survey results.

Discussion

The current research shows that *H. halys* is establishing successfully in north and central Alabama. There are currently 29 counties confirmed to have *H. halys*. The results support the hypothesis that *H. halys* is spreading and becoming established in north and central Alabama. These results also support the model created by Nielsen et al. (2016) that predicted *H. halys* can occur in southern regions of the US. This model predicts that there would be two generations a year in Alabama.

In Henry County, Alabama on 29 September 2017, Dr. Ron Smith found an adult *H. halys* in soybeans, further indicating that there may be undetected populations of the insect in the southern counties of the state. It is possible that the insects being found on these research stations in the South are traveling in or on the vehicles with researchers that also visit areas with heavy population (For example: Alabama Agricultural Experiment Station Prattville Agricultural Research Unit). More surveying is needed to clearly establish whether the insects are established or are being transported accidentally.

In previous years stink bug pests have not been a focus in control methods for North Alabama farmers. The reported stink bug injured kernels per ear in north Alabama field corn are considered high in comparison to sampling from years previous to 2014 (Dr. Kathy Flanders personal communication). The presence of *H. halys* in north Alabama and the increase in stink bug injury being seen suggests the necessity of a heightened awareness and need for stink bug scouting in all commercially grown host crops. Though not every field in the study showed high stink bug feeding injury levels (as evidenced by the fact that the median was routinely lower than the mean) the fields with high stink bug injury justify the increasing importance of scouting methods in corn fields in north Alabama. The existing native stink bug complex in south Alabama is proven to cause crop damage when populations are unmanaged. The increase of stink bug injury in north Alabama could be an indication that stink bug activity is increasing in north Alabama. As yet *H. halys* is just one stink bug in the complex that occurs in Alabama. Stink bug injury in north Alabama is caused by stink bug species of the complex and further studies are needed to establish what species are causing the increase in damage seen in north Alabama. Reports of higher stink bug activity in field corn during evening time were not made until summer of 2016. Visual observations made at in the evening at sunset suggested that the highest populations in field corn are *E. servus* but that *H. halys* is also present. More research is needed to determine the composition of the stink bug complex in field corn, particularly in areas infested by *H. halys*.

H. halys is capable of high population growth and high feeding damage in a growing season. Research conducted in Maryland (Cissel et al. 2015b) found that *H. halys* infestation in sweet corn caused the greatest loss of quality during the last stages of ear development. It is likely that unmanaged populations could cause loss in both quality and yield in field corn.

The results support previous reports of the edge effect of *H. halys* as well as the existing stink bug complex in field corn (Tillman 2010, Ni et al. 2011, Venugopal et al. 2014, Rice et al. 2014). The corn samples in 2014 showed a significant increase in the kernel injury from 11 August and 21 August caused by both stink bugs and sap beetles. This supports current recommendation of timely harvest of field corn. Further studies are needed to identify if sap beetle injury is associated with stink bug injury. Stink bug injury that is present and detectable before beetle damage is no longer detectable once the kernel has been fed upon by sap beetles. The presence of sap beetles in corn samples may explain low stink bug injury counts in areas that are known to have high stink bug activity.

The most available time to scout corn is during the daytime hours yet stink bug activity is lower than that seen in the evening time. Integrated pest management programs should recognize the likelihood of low stink bug activity in the daytime hours versus the evening time feeding activity.

Symptoms of starburst show that corn in north Alabama is affected by *Fusarium verticilloides*. Only visual symptoms were recorded. It is possible that kernels with infection without symptoms went undetected in these counts. Mycotoxin levels were not tested. A report by Dively et al. (2014) found that mycotoxin levels, specifically fumonisin, are higher in *H. halys* injured corn and the amounts found were directly correlated to the amount of feeding damage.

The occurrence of *S. zeamais,* the maize weevil, is not uncommon in corn fields in the Southeast. The case of population growth from early August through mid-September in Lawrence County 2014 is directly correlated with the passage of time, which allows for more generations of the pest to occur. As the corn stays in the field and dries after maturity, it becomes increasingly vulnerable to numerous pests. This demonstrates what can happen to late harvested corn. Recommendations for timely harvest are an important factor in ensuring a quality yield with the lowest insect and fungal damage as possible.

Table 1.1 Mean number of injured kernels from edge samples, north Alabama corn survey, 2014-2016.

Year	Round	Date(s) Sampled	**Mean number of injured kernels per ear (±SE)** Stink Bug	Sap beetle	Starburst	Number of Fields
2014	1	11 Aug	7.8 ± 0.8	1.4 ±0.2	3.3 ±1.5	22
	2	21 Aug	10.9 ±1.2	5.4 ±1.1	5.3 ±1.0	23
	3	2 Sep	14.3 ±2.3	3.3 ±0.9	7.8 ±2.5	14
	4	16 Sep	10.7 ±1.5	4.3 ±1.6	4.5 ±1.5	7
2015						
	1	12-14 Aug	9.8 ±1.3	7.57 ±1.2	6.9 ±3.8	24
	2	21-22 Aug	13.4 ±2.3	11.8 ±1.8	6.1 ±1.7	14
2016						
	1	8-18 Aug	9.9 ±2.6	3.0 ±0.4	9.02 ±4.7	23
	2	24-30 Aug	9.7 ±1.7	3.6 ±0.7	12.36 ± 3.1	24
	3	9-12 Sep	11.4 ±4.2	3.6 ±0.6	20.3 ±6.6	7
Comparison of injury between Rounds 1 and 2						
2014 (df = 43)		*t*	2.015*	3.310*	1.111	
		P	0.0501	.0019	.2727	
2015 (df = 36)		*t*	1.542	7.964	0.1599	
		P	.1318	.0572	.8738	
2016 (df= 45)		*t*	0.0004	0.6805	0.5947	
		P	.9996	.4996	.5550	

Unpaired two tailed *t*-test.

Table 1.2 Comparison of mean kernel injury in edge and middle sections of corn fields, north Alabama, 2015-2016.

	Mean no. injured kernels per ear (±SE)			
	Stink bug	Sap Beetle	Starburst	df
2015				
Edge	9.84 ± 1.3	7.57 ± 1.2	6.93 ± 3.8	
Middle	6.94 ± 1.1	5.52 ± 0.8	2.95 ± 1.6	
Ave difference	2.90	2.06	3.98	
t	1.88	1.76	1.58	
P	$0.025<P<0.05$	$0.025<P<0.05$	$0.1<P<0.05$	23
2016				
Edge	9.65 ± 2.1	3.54 ± 0.5	12.18 ± 4.3	
Middle	5.72 ± 0.8	3.14 ± 0.4	19.06 ± 7.7	
Ave difference	3.93	0.399	-6.89	
t	2.25	0.60	-1.64	
P	$0.01<P<0.025$	*Ns*	*ns*	28

Paired One-Tailed *t*-Test

Figure Captions

1.1. Alabama counties in which soybeans (and other crops) were scouted for the presence of *H. halys* (2015-2016).

1.2. Map of Alabama County where *H. halys* was confirmed.

1.3. Mean number of kernels per ear showing stink bug feeding injury in samples collected from the edges of corn fields, north Alabama, 2014-2016.

1.4. Mean number of kernels per ear showing sap beetle feeding injury in samples collected from the edges of corn fields, north Alabama, 2014-2016.

1.5. Mean number of kernels per ear showing starburst symptoms in samples collected from the edges of corn fields, north Alabama, 2014-2016.

1.6. Mean number of maize weevil injured kernels per ear collected from the edges a corn field in Lawrence County in 2014.

Figure 1.1


Lauderdale
Limestone
Madison
Jackson
Colbert
Franklin
Lawrence
Morgan
Marshall
De Kalb
Marion
Winston
Cullman
Blount
Etowah
Cherokee
Lamar
Fayette
Walker
Jefferson
St. Clair
Calhoun
Cleburne
Pickens
Tuscaloosa
Shelby
Talladega
Clay
Randolph
Greene
Hale
Bibb
Chilton
Coosa
Tallapoosa
Chambers
Sumter
Perry
Autauga
Elmore
Lee
Marengo
Dallas
Macon
Russell
Choctaw
Wilcox
Lowndes
Montgomery
Bullock
Barbour
Clarke
Butler
Pike
Crenshaw
Monroe
Henry
Washington
Conecuh
Coffee
Dale
Covington
Escambia
Geneva
Houston
Mobile
Baldwin
Visited in 2015
Visited in 2016

Figure 1.2


Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Franklin
Morgan
Marshall
De Kalb
Marion
Winston
Cullman
Cherokee
Blount
Etowah
Lamar
Walker
St. Clair
Calhoun
Fayette
Jefferson
Cleburne
Tuscaloosa
Talladega
Pickens
Shelby
Clay
Randolph
Bibb
Chambers
Coosa
Greene
Chilton
Tallapoosa
Hale
Sumter
Perry
Lee
Autauga
Elmore
Macon
Dallas
Montgomery
Marengo
Russell
Lowndes
Bullock
Choctaw
Wilcox
Barbour
Pike
Butler
Crenshaw
Clarke
Monroe
Henry
Washington
Conecuh
Coffee
Dale
Covington
Escambia
Houston
Geneva
Mobile
Baldwin
2015-2017 Study confirmations
2015-2017 Other confirmations
Pre-2015 confirmations
Not confirmed

Figure 1.3

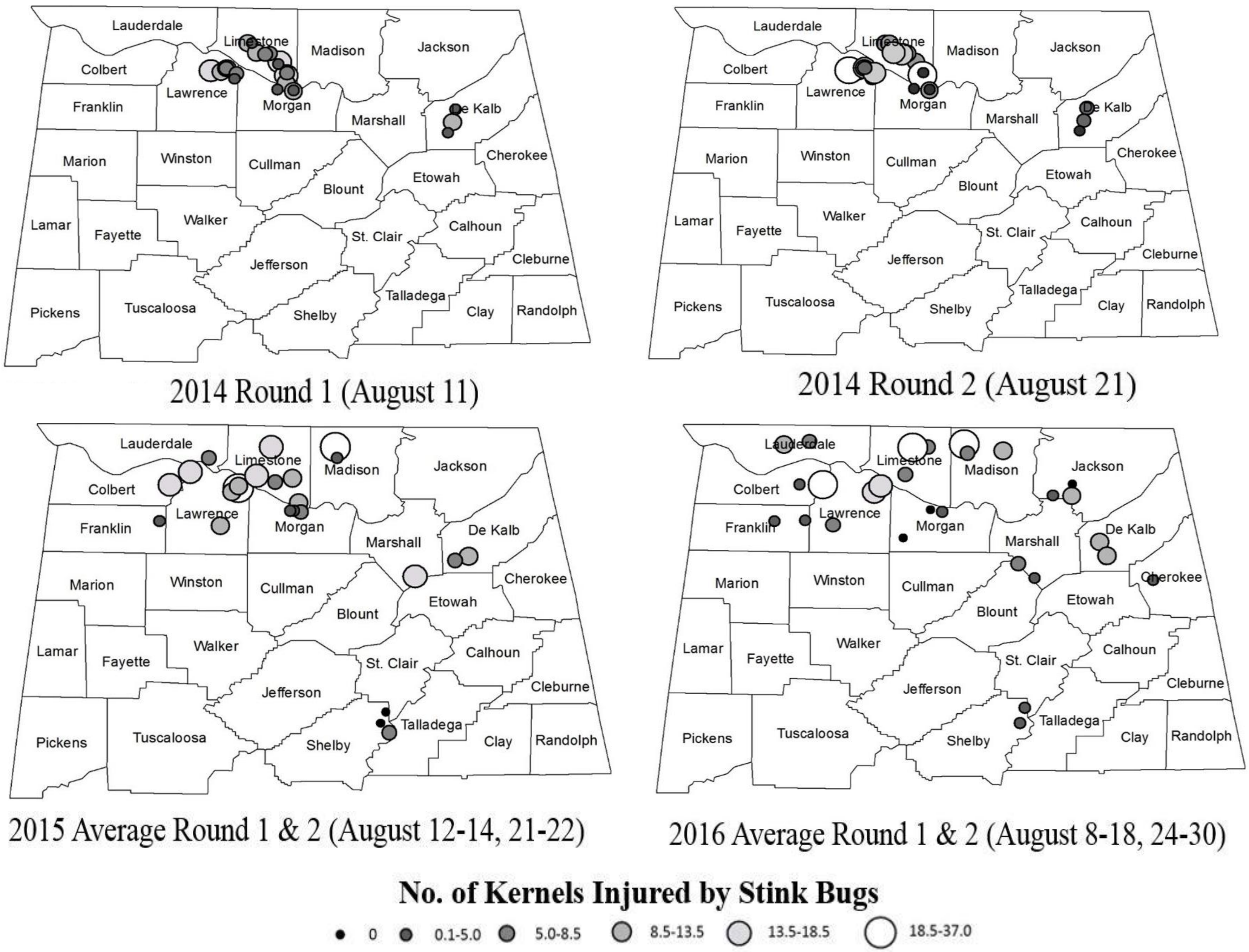

Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Morgan
Franklin
Marshall
De Kalb
Marion
Winston
Cullman
Cherokee
Etowah
Blount
Lamar
Fayette
Walker
St. Clair
Calhoun
Jefferson
Cleburne
Talladega
Pickens
Tuscaloosa
Shelby
Clay
Randolph
2014 Round 1 (August 11)
2014 Round 2 (August 21)
2015 Average Round 1 & 2 (August 12-14, 21-22)
2016 Average Round 1 & 2 (August 8-18, 24-30)
No. of Kernels Injured by Stink Bugs
0
0.1-5.0
5.0-8.5
8.5-13.5
13.5-18.5
18.5-37.0

Figure 1.4

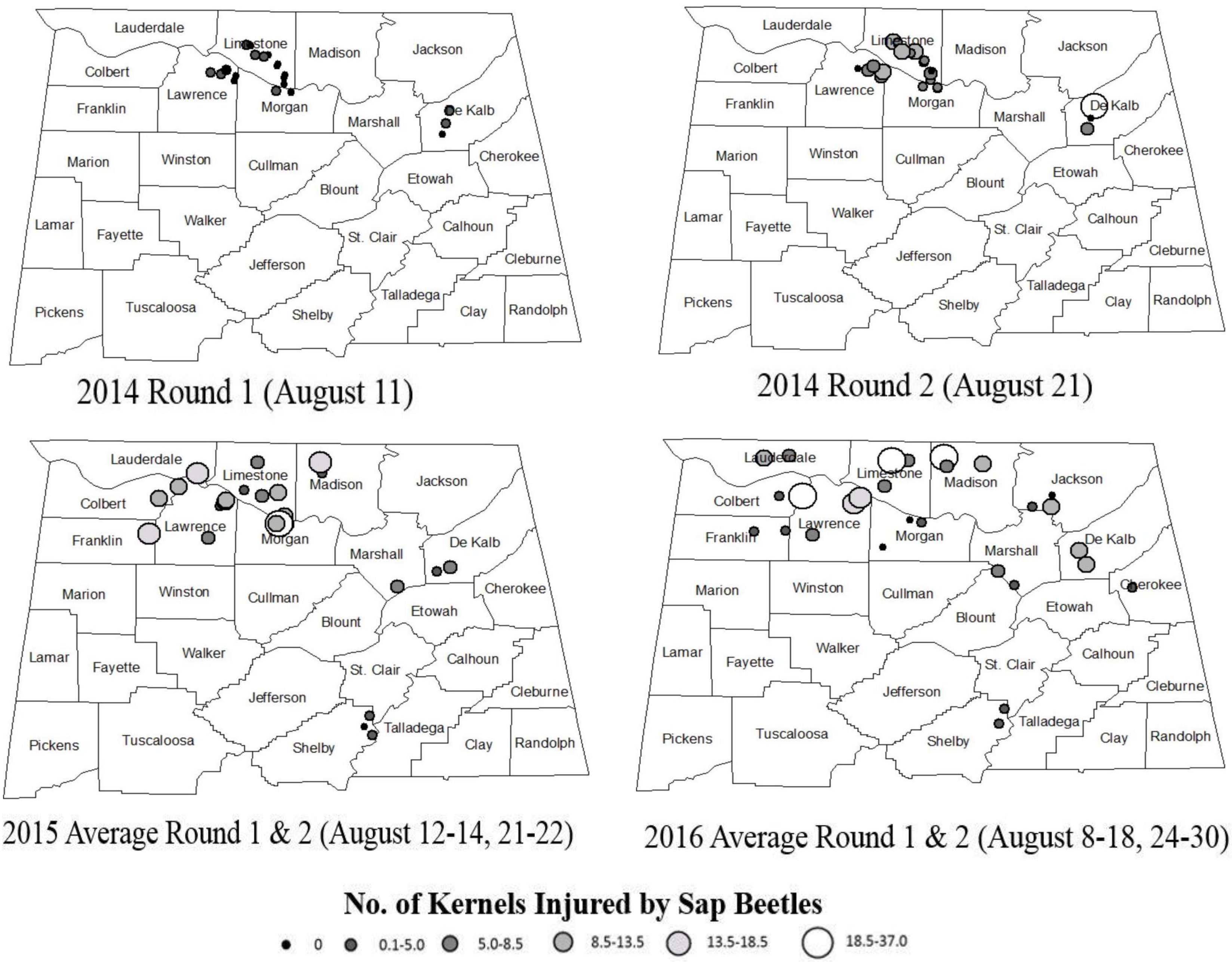

Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Morgan
Franklin
Marshall
De Kalb
Marion
Winston
Cullman
Cherokee
Etowah
Blount
Lamar
Fayette
Walker
Calhoun
St. Clair
Jefferson
Cleburne
Pickens
Tuscaloosa
Talladega
Shelby
Clay
Randolph
2014 Round 1 (August 11)
2014 Round 2 (August 21)
2015 Average Round 1 & 2 (August 12-14, 21-22)
2016 Average Round 1 & 2 (August 8-18, 24-30)
No. of Kernels Injured by Sap Beetles
0
0.1-5.0
5.0-8.5
8.5-13.5
13.5-18.5
18.5-37.0

Figure 1.5

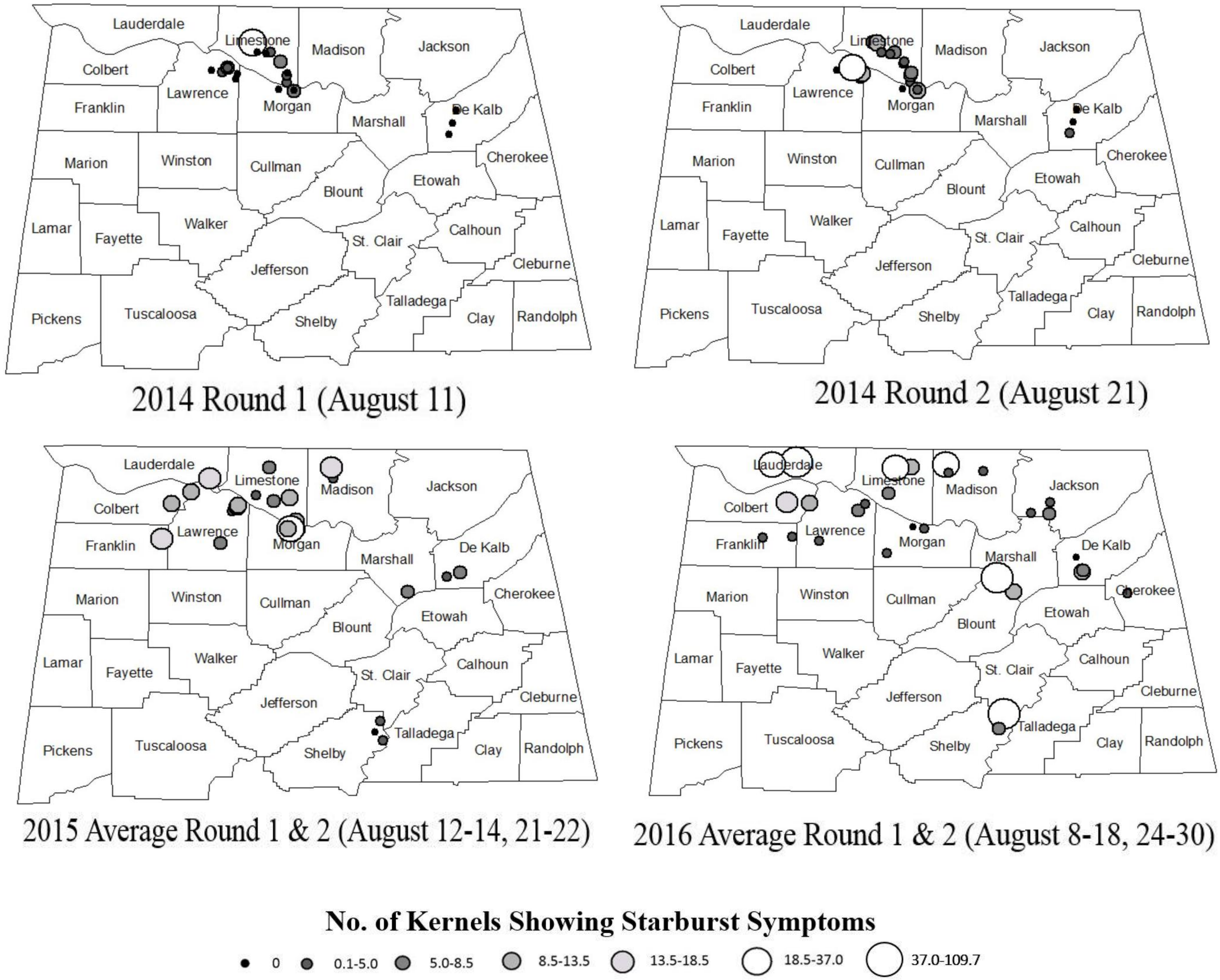
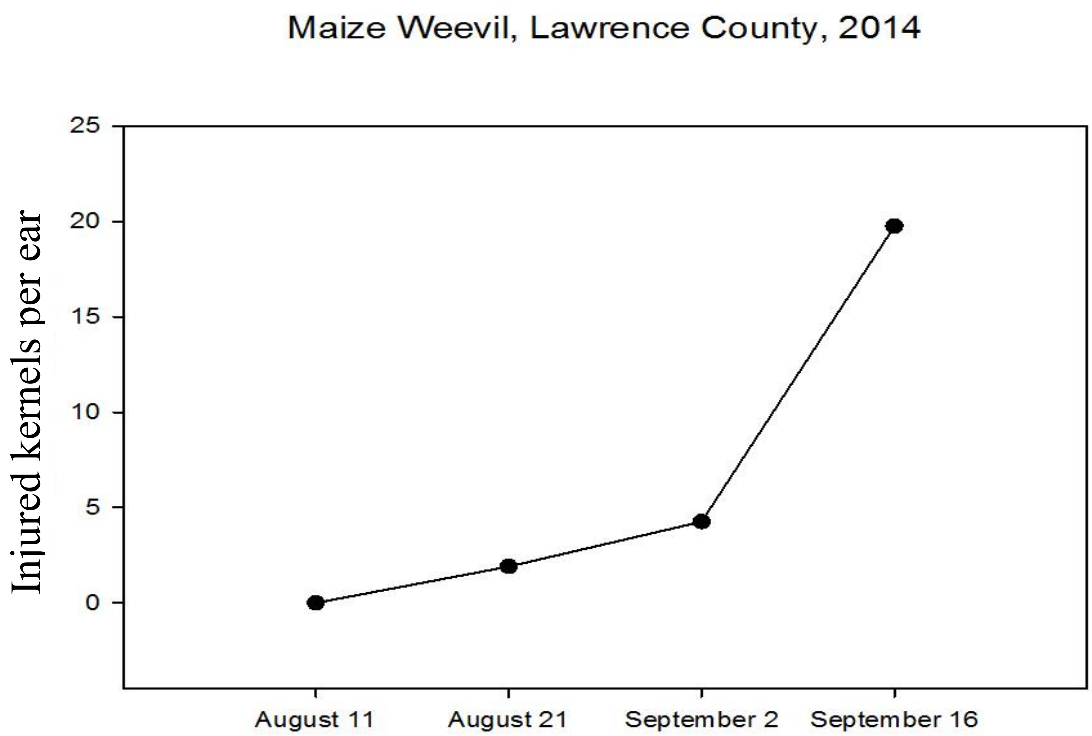

Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Morgan
Franklin
Marshall
De Kalb
Marion
Winston
Cullman
Cherokee
Blount
Etowah
Lamar
Fayette
Walker
St. Clair
Calhoun
Jefferson
Cleburne
Pickens
Tuscaloosa
Talladega
Shelby
Clay
Randolph
2014 Round 1 (August 11)
Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Morgan
Franklin
Marshall
De Kalb
Marion
Winston
Cullman
Cherokee
Blount
Etowah
Lamar
Fayette
Walker
St. Clair
Calhoun
Jefferson
Cleburne
Pickens
Tuscaloosa
Talladega
Shelby
Clay
Randolph
2014 Round 2 (August 21)
Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Morgan
Franklin
Marshall
De Kalb
Marion
Winston
Cullman
Cherokee
Blount
Etowah
Lamar
Fayette
Walker
St. Clair
Calhoun
Jefferson
Cleburne
Pickens
Tuscaloosa
Talladega
Shelby
Clay
Randolph
2015 Average Round 1 & 2 (August 12-14, 21-22)
Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Morgan
Franklin
Marshall
De Kalb
Marion
Winston
Cullman
Cherokee
Blount
Etowah
Lamar
Fayette
Walker
St. Clair
Calhoun
Jefferson
Cleburne
Pickens
Tuscaloosa
Talladega
Shelby
Clay
Randolph
2016 Average Round 1 & 2 (August 8-18, 24-30)
No. of Kernels Showing Starburst Symptoms
0
0.1-5.0
5.0-8.5
8.5-13.5
13.5-18.5
18.5-37.0
37.0-109.7

Figure 1.6


Maize Weevil, Lawrence County, 2014
Injured kernels per ear
25
20
15
10
5
0
August 11
August 21
September 2
September 16

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Chapter Two

Impact of *Halyomorpha halys* (Stål) in Alabama Field Corn and Cotton

Abstract *Halyomorpha halys* (Stål) was first confirmed in Alabama in 2010. A study of the stink bug complex including *H. halys* was designed to evaluate treatment thresholds in cotton in 2016-2017. The untreated cotton plots had significantly more boll injury than plots that were treated with bifenthrin on threshold or those treated with a weekly application to provide maximum protection. There was no significant difference between maximum and threshold spray regimes in terms of internal boll injury. Cotton yield was significantly reduced in untreated compared to treated plots in 2017, but not in 2016. The data suggest that thresholds can be used to reduce the number of insecticide application, even in the presence of *H. halys*. Impact of *H. halys* was evaluated in field corn by caging two adult stink bugs for five days at different growth stages of corn from VT to R6. Feeding by adult *H. halys* caused significantly more kernel injury than the uninfested controls at pretassel, silk, dough, and dent stages. Stink bug injury from two feeding adult *H. halys* in five days averaged 16 kernels per ear in Prattville, AL and 12 kernels per ear in Shorter, AL. Ear deformation was significantly higher in the infested compared with uninfested corn at pretassel stage (V10-VT).

Introduction

The brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), is an invasive species from Asia brought to the United States by trade and accidentally introduced through Allentown, Pennsylvania in the 1990s. Populations of *H. halys* continued to spread through the United States. This pest is extremely phytophagous and poses threat of feeding injury to over 100 host plants (Northeastern IPM Center 2017) including many crops produced by American farmers throughout the country. The first *H. halys* confirmed in the state of Alabama was found in Jefferson County in 2010 (Charles Ray, personal communication). By 2017 it had been confirmed in 27 counties (Duke, personal observation). The establishment of this new insect species warrants further investigation to understand its impact and behaviors that cause injury to the major agronomic crops of Alabama.

Corn, *Zea mays (*L.) (Poales: Poaceae) and cotton, *Gossypium hirsutum* (L.) (Malvales: Malvaceae) are some of the primary field crop hosts for *H. halys* in the Southeast. *Halyomorpha halys* is joining a preexisting stinkbug complex that is already well established throughout Alabama. The common stink bug pests (Hemiptera: Pentatomidae) of the Southeast include three main species: brown stink bug, *Euschistus servus* (Say); green stink bug, *Acrosternum hilare* (Say); and the southern green stink bug, *Nezara viridula* (L.) (Pilkay 2013). The southern green and brown stink bugs have been reported to cause damage to field corn in both early vegetative and late reproductive stages (Negrón and Riley 1987, Ni et al. 2010). The green stink bug has been observed in Georgia corn, but not in high populations (Tillman 2010). Cotton is also susceptible to stink bug injury, by these three main stink bug species (Herbert et al. 2009).

Surveys in Alabama find that *H. halys* begins to heavily colonize corn fields when the ears are developing in July in the R3/milk and R4/dough stages (Duke, personal observation). When feeding on corn kernels, the damage created by a stink bug results in underdeveloped or discolored kernels (Ni et al. 2011). In a study of *H. halys* in sweet corn, Cissel et al. (2015) observed that the yield losses were greatest when feeding took place on the ear of the plant during early developmental stages (R1); and the quality losses were the greatest when feeding on the ear occurred in later stages of ear development (R2-R3). This study found that *H. halys* has the ability to cause significant damage to sweet corn in a short amount of time even at small numbers of infesting stink bugs (Cissel et. al 2015). A study similar to this sweet corn research has not been conducted with *H. halys* in field corn. In South Alabama stink bug pests are a considered a threat to field corn and populations are monitored as well as managed according to current control recommendations. In North Alabama native stink bug populations in field corn are not perceived to cause sufficient damage to warrant scouting or control tactics. The increase in *H. halys* in North Alabama may mean that farmers will need to scout and treat field corn for stink bugs (Kathy Flanders, personal communication).

Cotton crops in Alabama are commonly planted in April or May (Birdsong 2016). The cotton crops are harvested around the month of November. During the late summer in September and October, cotton is an important stink bug host crop that is still in the field. Other crops such as corn and some soybeans have already peaked in maturity and become unsuitable host plants for stink bug. Cotton bolls are considered to be the most at risk to stink bug feeding at medium size, around 2.4 centimeters in diameter, so this is the recommended stage for scouting (Greene and Herzog 1999). Feeding injury to cotton caused by stink bugs causes wart-like growths on inner carpel walls, stained lint, and shriveled seeds that can result in economic loss to growers (Bundy and McPherson 2000; Emfinger et al. 2004; Wene and Sheets 1964). In the Southeast, native stink bugs are scouted by examining injury to medium sized bolls (Herbert et al. 2009). Current recommendations to farmers for stink bug control in cotton involve scouting and application of conventional insecticides dependent on the thresholds associated with the specific infesting insects (Herbert et al. 2009, Stewart and McClure 2018). Researchers at the University of Georgia found that, unlike the three main native stink bugs, as boll size increases, the *H. halys* feeding injury increases as well (Kamminga 2014). Because this stink bug feeds on older bolls, its introduction to the stink bug complex in cotton could change scouting recommendations. The objectives of this study are to evaluate the current stink bug threshold recommendations in cotton with the presence of *H. halys*; and to assess the kernel injury caused by adult *H. halys* feeding during four growth stages of field corn.

Materials and Methods

Evaluating stink bug thresholds on cotton. An evaluation of the stinkbug complex that includes *Halyomorpha halys,* and its impact on cotton was conducted at Alabama Agricultural Experiment Station Prattville Agricultural Research Unit in Prattville, Alabama in 2016-2017. This research unit in Prattville is ideal because it has high populations of *H. halys* and many of its host plants and overwintering sites occur on its 32 hectares. Overwintering sites include barns, sheds, wood piles, dead trees and a residential neighborhood along one edge of the farm. In 2016 cotton variety DP1555B2RF was planted on 4 May. In 2017 cotton variety DP 1555 was planted on 18 May. Cotton was planted in rows spaced 0.9 m apart at a planting density of 90,000 seeds per hectare. The cotton plots used in both years were grown according to standard commercial practice regarding weed control and fertilizer per the farm superintendent's judgement. In the summer of 2016 plots were 8 rows x 15.1 m of cotton. In the summer of 2017 the plots were 8 rows x 9.1 m, with an unplanted space in the middle of the test as a tractor turn row. Three treatments were used: Maximum, Threshold, and Untreated. Insecticide was applied weekly for 6 weeks in the maximum treatment regime. In the threshold treatment regime, insecticides were applied when cotton boll injury exceeded previously determined thresholds for stink bug feeding in cotton (Herbert et al. 2009): 50% internal boll damage (week 1 of bloom); 30% internal boll damage (week 2); 10% internal boll damage (weeks 3-5); 30% internal boll damage (week 6-7); and 50% internal boll damage (week 8). Percent internal stink bug injured bolls were recorded weekly for 6 weeks in the summer of 2016 and 2017. The insecticide used was Discipline® 2EC (bifenthrin, Amvac Chemical Corporation) @ 0.46 l/ha, both years. In 2016, 12 replications of these treatments were randomized in a complete block design, buffer rows were not incorporated into the plot design due to a lack of available space. Eight replications were randomized in a complete block design in 2017, and 4 buffer rows were added to the side of the field adjacent to a trial that would potentially have unwanted unmanaged stink bug populations. Bolls of a uniform size at 2.4 cm in diameter were sampled weekly, a total of 10 bolls per plot were collected haphazardly from separate plants within each plot each date. The bolls were dissected to determine if they had injury from stink bugs, based on the presence of internal symptoms associated with stinkbug feeding (Bundy et al. 2000).

Boll samples were collected early in the week allowing for evaluation (Monday-Tuesday) and determining the need for the application of a threshold spray toward the end of the week (Thursday-Friday depending on weather conditions). Threshold sprays in 2016 were applied on the following dates: 28 July, 2 August, 17 August, and 24 August. Threshold sprays in 2017 were applied on the following dates: 11 August, 29 August, 14

September, and 20 September. Maximum sprays in 2016 were applied on the following dates: 28 July, 2 August, 12 August, 17 August, and 24 August, 6 September. Maximum sprays in 2017 were applied on the following dates: 11 August, 23 August, 29 August, 6 September, 14 September, and 20 September. Data collected was analyzed using SAS 9.4 PROC GLIMMIX.

Evaluating impact of caged *H. halys* adults feeding on field corn. Two field corn experiments were conducted in the summer of 2017. A 15.1 m x 15.1 m block of field corn hybrid Dyna-Gro (D57VP75) was planted on 7 April at the Alabama Agricultural Experiment Station Prattville Agricultural Research Unit in Prattville, Alabama. A similar variety (DeKalb DKC68-03) was planted around the plot as a 7.6 m buffer from the rest of the farm to reduce interaction with other hosts and insects outside of the trial. Corn was planted in rows spaced 0.9 m apart at a planting density of 100,000 seeds per hectare. The experiment was repeated at the Alabama Agricultural Experiment Station E. V. Smith Research Center Field Crops Unit in Shorter, Alabama. In this test, Dyna-Gro (D57VP75) seeds were planted on 15 June. Stink bugs were added to caged ears when corn reached four developmental growth stages: pretassel (V10-VT), silk (R1), dough (R4), and dent (R5).

The methodology for these trials is modeled after a cage study conducted by researchers at the University of Delaware on sweet corn with *H. halys* (Cissel et al. 2015). Silk, dough and dent stages were isolated by full mesh bags covering and isolating the insects on the primary ear of the corn plant (Figure 2.3). The bags were 41 cm (length) x 20.3 cm (width), white monofilament 2 mm mesh bags purchased from

MIDCO Global Inc. At the pretassel stage (V10-VT), the same mesh bags with an open end with draw strings and added elastic were used to isolate two adult *Halyomorpha halys* on each ear. Caging the pretassel stage required the closed end of the bag to be cut open and the drawstring end of the bag was gently slid over the top of the corn plant down to the location of the primary ear (Figure 2.3). Once in place, the drawstrings were pulled at the bottom to ensure there were no holes and to enclose the bottom of the cage. White knit elastic, (0.6 cm width) purchased from Hobby Lobby, was cut into 7 inch pieces and used to secure the top of the cage above the site of the developing ear without restricting the growth of the plant during this rapid developmental stage. The leaf at the location of the developing ear was gently rolled and tucked into the bag. The bags used in silk (R1) through dent (R5) stages were left intact. To minimize injury caused by insects naturally present in the field, bags were attached to the corn plants at the beginning of the silk stage. Each bag was slipped over the gently curled leaf and emerging primary ear. The bag was secured at the base of the ear with the drawstring.

For the pretassel stage in both trials, the corn plants were chosen for developmental uniformity and then treatments (infested and noninfested) were randomly assigned. This method was used for the pretassel stage because it is a small window of time with rapid growth. At the Prattville Agricultural Research Unit the treatments (stage of corn growth as well as infested and not infested) were assigned randomly for the test of two stages (dough (R4) and dent (R5)). At the E.V. Smith Research Center Field Crops unit the plants were randomly assigned for the test of three stages (silk, dough, and dent).

Halyomorpha halys adults were collected from pheromone traps using Pherocon® stink bug lures made by Trécé Inc. Adult *H. halys* were also collected from other host plants around the farm. The insects were kept for up to a week at the Prattville Agricultural Research facility in a clear plastic ventilated insect container in a shed with ample ambient light and temperature. The insects were provided with fresh carrots and ears of corn, as well as a moistened cotton ball. Field collected insects were used to infest the mesh bags because they were hardier in field conditions compared to lab-reared colony insects. Two adults were placed in each bag for the infested treatment per their randomly assigned growth stages. The insects were left for five days, but were checked each day to be replaced if necessary. Replacements were made if an insect was absent, had died, or seemed to be of low fitness in any capacity. Insects used were released at the end of the five day treatment. Ears were collected at full developmental maturity (R6) and the amount of stink bug damage was evaluated to compare the injury from stink bug feeding at each stage. Number of kernels per ear with injury from stink bugs was recorded, and identification of this injury was made using published examples (Michel et. al 2015). Stink bug kernel injury appears as a brown puncture hole or as a light colored cloudy area. Ears were evaluated for area of damage (cm^2) caused by other insects (sap beetle and caterpillar). Injury from sap beetles was identified using published examples (Kaster 1999). Sap beetle injured kernels appear as brown, often hallowed out kernels. Starburst symptoms were recorded by percent of kernels showing symptoms, and the identification of symptoms were made using published examples from (Payne 1999). Starburst symptoms appear as fine white lines running from the center of the top of the kernel down. Ears were also evaluated for length, the degree of ear curling or deformation (measured by standard protractor), and percent of the ear filled with normally developed kernels.

Data for this trial were analyzed using SAS 9.4 PROC GLIMMIX in a 2 by 2 factorial (CRD) for the Prattville trial data, in addition to a separate unpaired *t*-test to analyze the pretassel stage. Data from the E. V. Smith trial were analyzed in a 3 by 2 factorial (CRD) in SAS 9.4 PROC GLIMMIX, and a separate unpaired *t*-test was used to analyze the pretassel stage.

Results

Evaluating stink bug thresholds on cotton. The stink bug species composition of the cotton field was scouted and recorded in each year (Table 2.1). In both 2016 and 2017 injury ratings averaged over the season were significantly higher in the untreated plots compared with either of the insecticide treatment regimes (Table 2.2). There were two dates in 2016 where percent boll injury in untreated plots were significantly higher than treated plots (threshold or maximum) (Figure 2.1, Table 2.3). In 2017 there was a significant difference in boll injury between the treated and untreated plots on all dates (Figure 2.2, Table 2.4). There is no significant difference between maximum treatments (6 sprays in 6 weeks) and threshold treatments (4 sprays in 6 weeks) in percent boll injury in either year. In 2016, there was no significant difference between the 3 treatments in the plot yields (Table 2.2), although there was a trend showing the lowest yield in untreated plots. In 2017 the untreated plots had significantly lower yields than the treated plots (maximum or threshold) (Table 2.2). There was no significant difference in yield between the maximum and threshold treatment regimes (Table 2.2).

Evaluating impact of caged *H. halys* adults feeding on field corn. The results of this study show that there is a significant difference in kernel injury between stink bug infested and uninfested ears of corn in silk, dough, and dent (Figure 2.4-2.5). An unpaired *t*-test also showed that there were significantly more stink bug injured kernels in the infested than uninfested treatments in the pretassel stage (Tables 2.4). In the Prattville trial, there was significantly more stink bug kernel injury in infested ears compared with uninfested ears at the silk and dent stages (Figure 2.4). There was no significant difference seen in ear deformation between infested and uninfested ears in pretassel (Tables 2.5).

There was a significant increase in starburst symptoms in uninfested ears when compared to infested ears seen in silk and dent stages (Table 2.5). There was no significant difference in ear length between infested and uninfested ears in any developmental stages. There was no significant difference seen in percent ear fill between infested and uninfested ears in any developmental stages. There was a significant difference in area damaged between infested and uninfested at the pretassel stage (Table 2.5). There was no significant difference seen in area damaged between infested and uninfested ears in silk or dent stages. There were significantly more stink bug injured kernels in the infested silk stage than in the infested dent stage (Figure 2.4). There were significantly higher symptoms of starburst seen in the uninfested dent stage than seen in both the uninfested and infested silk stages in Prattville (Tables 2.5).

In the Shorter trial, there were significantly more stink bug injured kernels in the infested compared with uninfested treatments at the silk, dough and dent stages (Figure 2.6). An unpaired *t*-test showed that there were significantly more stink bug injured kernels in the infested than uninfested treatments in the pretassel stage. There were significantly more deformed ears in the infested compared with uninfested at the pretassel stage (Table 2.6). There were significantly more deformed ears in the uninfested ears compared with infested ears at pretassel, silk, dough, and dent stages. There were significantly more starburst symptoms seen in the infested ears when compared to the uninfested ears in silk, dough, and dent stages (Table 2.6). There was no significant difference seen in ear length between infested and uninfested ears in any developmental stages in Shorter. There was a significant increase in area damaged seen in infested ears when compared to uninfested ears in the pretassel stage (Table 2.6). There was no significant difference seen in percent ear fill between infested and uninfested ears in any developmental stages. There were significantly more stink bug injured kernels in corn infested at the dent stage than in corn infested at the silk stage (Figure 2.5).

Discussion

The results show that stink bugs (*H. halys* in combination with the existing native stink bug complex) are capable of causing high levels of internal boll injury in untreated cotton fields in Alabama. Cotton yields in the threshold treatment regimen were not significantly different from the maximum insecticide treatment regimen even though fewer insecticide applications were made. Therefore, even in the presence of *H. halys*, scouting in combination with the use of a threshold spray regimen could save money for the farmer by limiting the use of insecticide. The potential reduction in pesticide use is also in the best interest of the environment and other beneficial insects inhabiting the crops.

The results of this study are further proof of the importance of proper scouting methods and thresholds for insect populations and boll injury in cotton crops. Current thresholds allow for more damage in the later weeks of bloom with the assumption that native stink bugs are less likely to feed on the large bolls in the field. However, the increase of injury seen in untreated plots throughout the season in 2017 suggests that stink bug activity is continuing late into the last weeks of bloom. This agrees with reports by researchers at the University of Georgia that *H. halys* has been observed feeding in cotton on older bolls, unlike the native stink bugs, and as boll size increased, so did the *H. halys* feeding injury (Kamminga et al. 2014). Therefore, current threshold recommendations may need to be adjusted to better manage late season populations of *H. halys* that can potentially cause injury to large bolls. With the presence of *H. halys*, there is a possibility for increased pressure on older bolls that were previously a lesser concern once they surpassed the medium size (2.4 cm in diameter) that is most commonly fed upon by native stink bugs.

It is important to note the there was a severe drought in Alabama in the summer of 2016. The portion of the 2016 trial that was aligned with a partial tree-line suffered stunting due to the moisture being absorbed from the ground by the tree roots in that general area. The stunting of some plants in this trial may have reduced the appeal of these host plants in comparison to plants under less stress on other areas of the farm. Buffer rows were not incorporated into the 2016 plots due to a lack of available space. The neighboring trial was an unmanaged plot of cotton and the insect population was able to move freely between this trial and the unmanaged trial. This may have affected the results in 2016 because of the potential for a quick reinvasion after treatments. The increasing amount of internal boll injury through the growing season in the untreated plots indicates that the buffer rows were effective in 2017.

The results of the caged field corn study show that stink bug feeding by adult *H. halys* causes significant injury with small numbers of infesting insects. Two adult *H. halys*, caged for 5 days caused significant stink bug feeding injury in pretassel, silk, dough and dent developmental stages at E.V. Smith and at pretassel, silk, and dent stages in Prattville. Stink bug injury to corn kernels looks the same regardless of the feeding stink bug species. A similar caged field corn study using southern green stink bug (*Nezara viridula*) by Negron and Riley (1987) found that an increased number of infesting insects resulted in an increase in the number of punctures from stink bug feeding. The Negron and Riley (1987) results are in agreement with another similar study conducted by Cissel et al. (2015) with *H. halys* in sweet corn that found the number of discolored kernels and damaged kernels significantly increased when there was an increase in the numbers of infesting insects. Because this study only used one level of infestation (2 insects per ear), direct comparison to those of Negron and Riley (1987) and Cissel (2015) is not possible. However, the study reported does agree with these trials in that even at low levels of infestation, kernel injury is possible. The results of the similar studies may suggest that when numbers of infesting *H. halys* increase above two insects during the pretassel and dent stages, the amount of stink bug injury will increase.

This study agrees with the Cissel et al. (2015) that great amounts of injury are caused when stink bugs feed on corn in the reproductive stages. Similarly high stink bug injury was seen in the pretassel stage in Prattville, but not in Shorter. This is contrary to our hypothesis that more stink bug injury would be observed in the pretassel stage than in the reproductive stages. Deformation ratings of ears infested at the pretassel stage in Shorter were slightly increased when compared to uninfested plants. However ears in the uninfested treatments at other growth stages in Shorter and at two stage in Prattville were slightly more deformed than the infested treatments. This injury could have been due to damage caused during the attachment of mesh bags, but more investigation is needed.

The research conducted by Cissel et al. (2015) studied *H. halys* on sweet corn and evaluated three stages: silking (R1), blister (R2), and milk (R3). The study reported here used field corn and is the only study to have analyzed *H. halys* on pretassel (V10-VT) and dent (R5) stages. Further studies are needed to fully understand the impacts of stink bug feeding damage on the pretassel stage as well as the later dent stage of development.

The symptoms of starburst were greater in the Prattville trial than in the Shorter trial. Significantly greater starburst symptoms were observed in the uninfested treatment at the dent stage at Prattville. The opposite was seen in Shorter, where significantly greater starburst symptoms were seen in the infested treatment than in the uninfested treatment at silk and dent stages. This may have been due to the difference in planting dates or to differences in both location and environment.

A consideration for variations between the trials in Prattville and Shorter are the planting dates. The 15 June planting date is considered a very late planting date in Alabama. Late planting increases the risk of injury from corn insect pests and pathogens. This late season planting may have affected the outcome of the Shorter corn planting data.

This study showed that *H. halys* is capable of injuring field corn. As this stink bug becomes established it will be even more important to scout field corn in Alabama for stink bugs in order to make appropriate management decisions.

Table 2.1 Stink bugs present in cotton, Prattville, AL 2016-2017.

	Percent of Total Insects		
	Brown Marmorated Stink Bug	Southern Green Stink Bug	Brown Stink bug
Visual Counts in 2016*			
July 19	5	53	42
August1	41	56	3
August 8	31	65	4
August 10	83	17	0
Sweep Net Scouting 2017*			
August1	83	11	6
August 8	50	38	12
August 16	47	52	0

*Scouting records courtesy of Dr. Ron Smith

Table 2.2 Cotton yield and mean season boll injury, Prattville, AL 2016-2017.

	Percent Boll Injury (mean ±SE)		Yield (kg seed cotton/ha mean ±SE)	
Treatment	2016	2017	2016	2017
Untreated	32 ± 3.2 a	56 ± 3.2 a	3802 ± 1.3 a	2099 ± 1.1 b
Threshold	19 ± 3.2 b	24.2 ± 3.2 b	4077 ± 1.3 a	2895 ± 1.1 a
Maximum	21 ± 3.2 b	19.8 ± 3.2 b	4142 ± 1.3 a	2766 ± 1.1 a

[1]Means within a column followed by the same letter are not significantly different.

Table 2.3 Mean cotton boll injury, Prattville, AL 2016

Treatment	25 July	1 August	8 August	15 August	22 August	6 September
Untreated	14 ± 0.4 a	40 ± 0.6 a	33 ± 0.6 a	54 ± 0.7 a	27 ± 0.7 a	21 ± 0.3 a
Threshold	8 ± 0.4 a	35 ± 0.6 a	8 ± 0.6 b	33 ± 0.7 b	17 ± 0.7 a	11 ± 0.3 ab
Maximum	1 5 ± 0.4 a	31 ± 0.6 a	13 ± 0.6 b	37 ± 0.7 ab	22 ± 0.7 a	7 ± 0.3 b
F	1.02	0.55	4.90	3.58	1.02	3.81
df	2,22	2,22	2,21	2,22	2,21	2,22
P	0.3772	0.5862	0.0179	0.0449	0.3783	0.0380

Table 2.4 Mean cotton boll injury, Prattville, AL 2017

Treatment	22 August	28 August	6 September	12 September	18 September	26 September
Untreated	30 ± 0.5 a	49 ± 0.6 a	43 ± 0.5 a	63 ± 0.5 a	74 ± 0.5 b	79 ± 0.5 a
Threshold	10 ± 0.5 ba	26 ± 0.6 b	16 ± 0.5 b	24 ± 0.5 b	36 ± 0.5 a	33 ± 0.5 b
Maximum	16 ± 0.5 b	16 ± 0.6 b	13 ± 0.5 b	21 ± 0.5 b	33 ± 0.5 a	20 ± 0.5 b
F	3.21	8.70	15.55	20.60	16.42	44.54
df	2,14	2,14	2,14	2,14	2,14	2,14
P	0.0714	0.0035	0.0003	<.0001	0.0002	<.0001

Table 2.5. Effect of caged adult *H. halys* stink bugs on ear injury in field corn, Prattville, AL 2017.

Treatment	Infest[3]	Stink Bug Injured Kernels (No. ± SE)	Ear Deformation[4] (◦ ± SE)	Ear Fill (% ± SE)	Area Damaged[5] (cm^2 ± SE)	Starburst[6] (% ± SE)	Ear Length (cm ± SE)
Silk[1]	Y	18.7 ± 1.2 a	1.24 ±1.2 b	85 ± 3.8 a	10.9 ± 5.0 b	23.5 ± 7.4 b	16.8 ±0.3 a
Silk[1]	N	0.6 ± 1.1 c	6.0 ± 1.2 a	81.5 ± 3.8 a	24.9 ± 5.0 b	25 ± 7.4 ba	17.0 ± 0.3 a
Dent[1]	Y	10.6 ± 0.8 b	0 ± 1.2 b	83.5 ± 3.8 a	25.09 ± 3.6 a	12.7 ± 7.4 b	17.4 ± 0.2 a
Dent[1]	N	0.6 ± 0.8 c	0 ± 1.2 b	83 ± 3.8 a	26.1 ± 3.6 a	42 ± 7.4 a	18.5 ± 0.2 a
Pretassel[2]	Y	19.1 ± 5.2	0.05 ± 0.1	87.9 ± 1.4	5.9 ± 1.8	42.1 ± 13.0	17.8 ± 0.1
Pretassel[2]	N	0 ± 0	2 ± 1.3	80.5± 4.0	19.5± 3.0	34.2 ± 6.5	16.8±0.3
t_{15}		4.38*	-1.2	1.46	-3.4*	0.59	0.92

[1]PROC GLIMMIX 2x2 Factorial CRD.
Means within a column followed by the same letter are not significantly different, ls means test, *P* =0.05
[2]Unpaired two tailed *t*-test with critical value = 2.131, for *P*=0.05, 15df
[3]Infested ears = Y, uninfested ears = N
[4]Measurment take with standard protractor
[5]Area damaged by non-stink bug insect feeding or unknown cause.
[6]Symptom of *Fusarium* infection.
* = significance at *P*=0.05

Table 2.6 Effect of caged adult *H. halys* stink bugs on ear injury in field corn, Shorter, AL 2017.

Treatment[1]	Infested[3]	Stink Bug Injured Kernels (No. ± SE)	Ear Deformation [4] (◦ ± SE)	Ear Fill (% ± SE)	Area Damaged[5] (cm^2 ± SE)	Starburst[6] (% ± SE)	Ear Length (cm ± SE)
Silk[1]	Y	10.9 ± 1.3 ab	1.7 ± 1.3 bc	89 ± 1.4 b	6.3 ± 1.8 a	10.7 ± 3.1 a	15.2 ± 0.1 b
Silk[1]	N	0.7 ± 1.3 c	8.0 ± 1.3 a	91.0 ± 1.4 ba	8.5 ± 3.4 a	0 ± 3.1 b	16.1 ± 0.1 ba
Dough[1]	Y	9.9 ± 1.3 b	0 ± 1.3 c	93.5 ± 1.4 a	0.1 ± 1.5 b	7.6 ± 3.1 ba	16.0 ± 0.1 ba
Dough[1]	N	0.4 ± 1.3 c	6.1 ± 1.3 a	91.0 ± 1.4 ba	6.6 ± 1.5 a	0 ± 3.1 b	16.1 ± 0.1 ba
Dent[1]	Y	14.4 ± 1.3 a	0 ± 1.3 c	89 ± 1.4 b	2.1 ± 1.5 ba	12.5 ± 3.1 a	15.9 ± 0.1 ba
Dent[1]	N	0 ± 1.3c	4.7 ± 1.3 ab	90.0 ± 1.4 ba	7.3 ± 1.5 ba	0 ± 3.1 b	16.9 ± 0.1 a
Pretassel[2]	Y	1.3 ± 0.4	7.2 ± 1.3	93.3 ± 0.8	5.3 ± 0.8	0 ± 0	16.0 ± 0.1
Pretassel[2]	N	0.3 ± 0.2	3.1 ± 1.0	92.5 ± 1.1	1.9 ± 0.9	0 ± 0	15.3 ± 0.1
t_{17}		2.31*	2.45*	0.6	2.6*	0	-1.2

[1]PROC GLIMMIX 3x2 Factorial CRD. Means within a column, excluding the pretassel stage followed by the same letter are not significantly different, ls means test.
P =0.05.
[2]Unpaired two tailed *t*-test with critical value = 2.11, for *P*=0.05, 17df
[3]Infested ears = Y, uninfested ears = N
[4]Measured using a protractor
[5]Area damaged by non-stink bug insect feeding (including caterpillars and sap beetles) or unknown cause.
[6]Symptom of *Fusarium* infection.
* = significance at *P*=0.05

Figure Captions

2.1 Stink bug injury to cotton bolls, 25 August to 6 September Prattville, AL 2016.

2.2 Stink bug injury to cotton bolls, 22 August to 26 September Prattville, AL 2017.

2.3 Stink bug cages used for pretassel stage and silk, dough, and dent stages.

2.4 Stink bug injured kernels from 2 *H. halys* caged for 5 days, Prattville, AL2017.

Pretassel was randomized and analyzed separately.

2.5 Stink bug injured kernels from 2 *H. halys* caged for 5 days, Shorter, AL 2017.

Pretassel was randomized and analyzed separately.

Figure 2.1

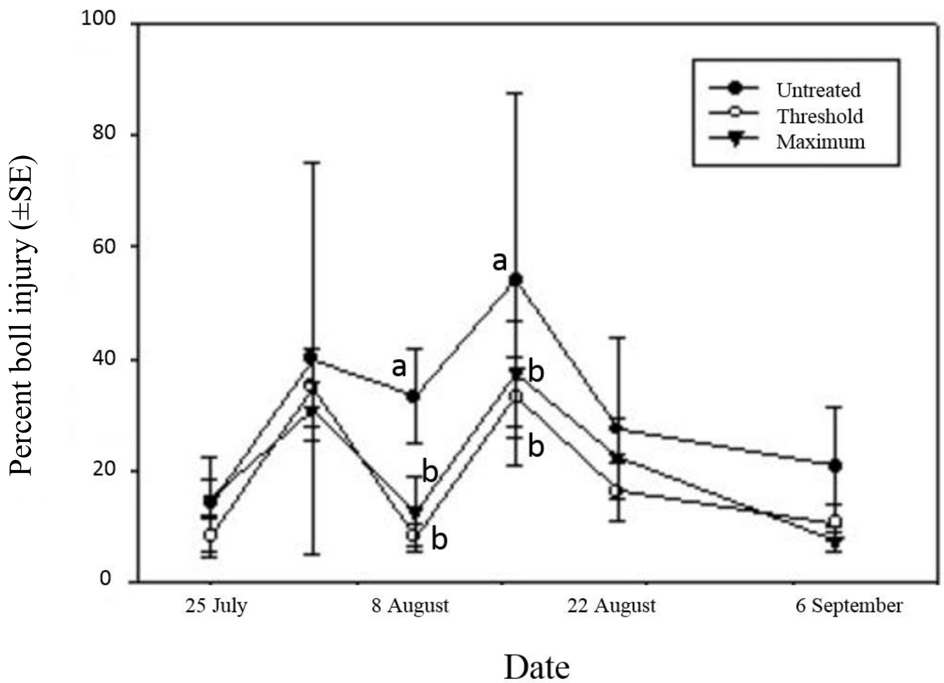
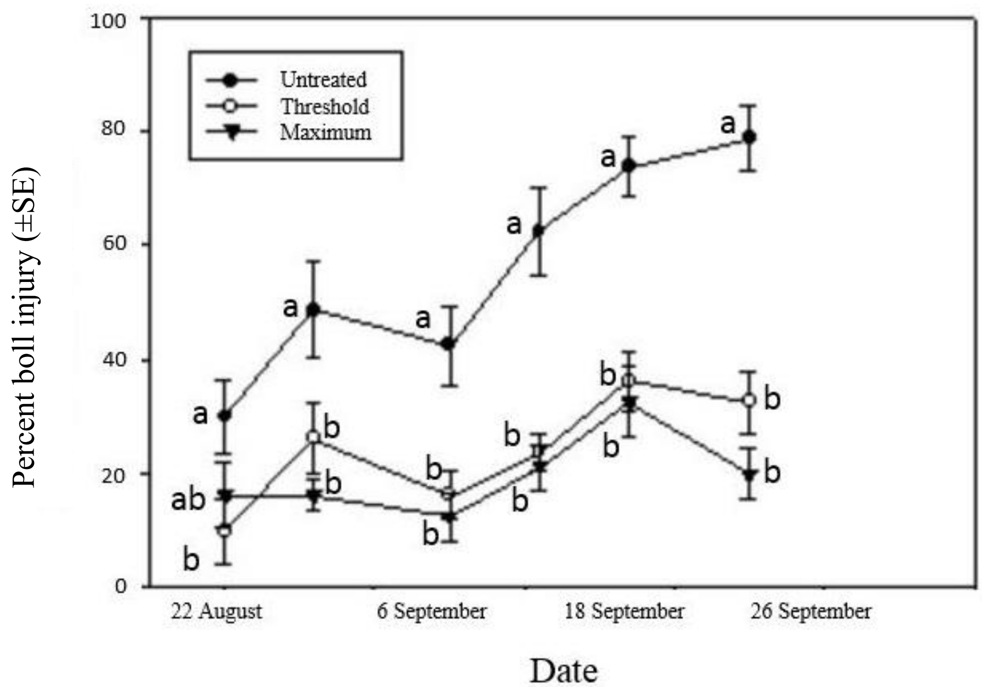

Untreated
Threshold
Maximum
Percent boll injury (±SE)
100
80
60
40
20
0
a
a
b
b
b
b
25 July
8 August
22 August
6 September
Date

Figure 2.2


Percent boll injury (±SE)
100
80
60
40
20
0
Untreated
Threshold
Maximum
a
a
a
a
a
a
b
b
b
b
b
ab
b
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b
22 August
6 September
18 September
26 September
Date

Figure 2.3

Pretassel cage

Silk-Dent cage

Figure 2.4

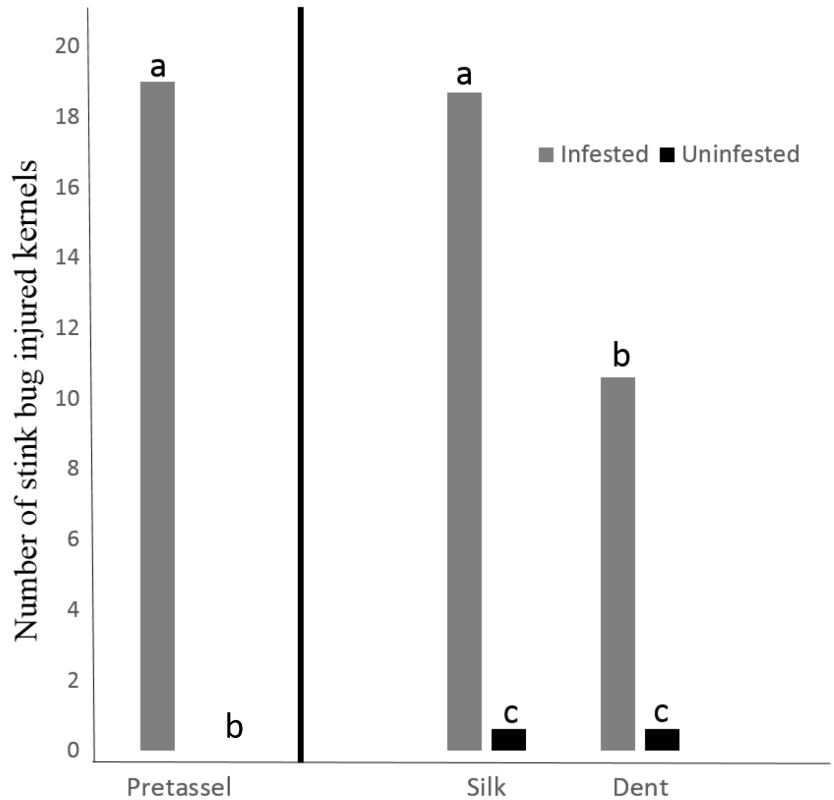
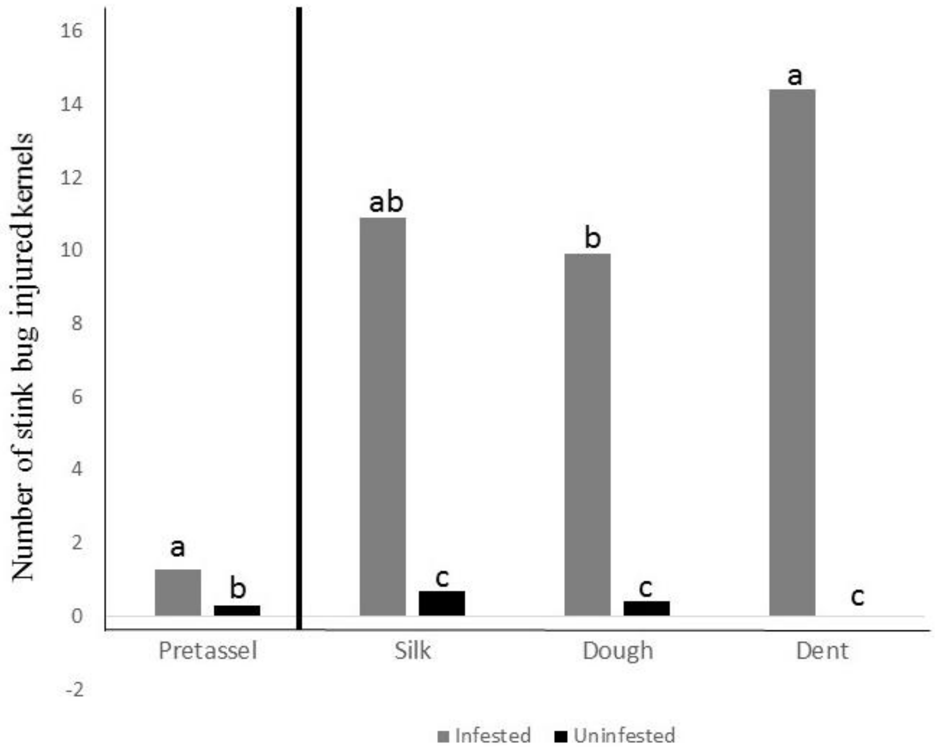

Number of stink bug injured kernels
20
18
16
14
12
10
8
6
4
2
0
a
b
a
c
b
c
Infested
Uninfested
Pretassel
Silk
Dent

Figure 2.5


Number of stink bug injured kernels
16
14
12
10
8
6
4
2
0
-2
a
b
ab
c
b
c
a
c
Pretassel
Silk
Dough
Dent
Infested
Uninfested

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Appendix

Table A1. North Alabama Corn Survey Locations 2014

Field Name	Latitude	Longitude
Limestone 1	34.690329	-86.885539
Limestone 2	34.700202	-86.878999
Limestone 3	34.750117	-86.929787
Limestone 4	34.743902	-86.956586
Limestone 5	34.807132	-87.048722
Limestone 6	34.806101	-87.026462
Limestone 7	34.752575	-87.001472
Lawrence 1	34.605926	-87.118905
Lawrence 2	34.644149	-87.189111
Lawrence 3	34.651349	-87.244706
Lawrence 4	34.664128	-87.160603
Lawrence 5	34.664407	-87.161813
Lawrence 6	34.634962	-87.106984
Lawrence 7	34.663749	-87.160485
Madison 1	34.583322	-86.845179
Madison 2	34.623063	-86.844336
Madison 3	34.638204	-86.841422

Table A1. North Alabama Corn Survey Locations 2014 (cont.)

Field Name	Latitude	Longitude
Morgan 1	34.536624	-86.806364
Morgan 2	34.542090	-86.80626
Morgan 3	34.545143	-86.889955
Dekalb 1	34.433128	-85.946592
Dekalb 2	34.360310	-85.964060
Dekalb 3	34.301401	-85.985697

Table A2. North Alabama Corn Survey Locations 2015

Field Name	Latitude	Longitude
Colbert C-1	34.683300	-87.510564
DeKalb C-1	34.296953	-85.967278
DeKalb C-2	34.273360	-86.037328
Franklin C-1	34.486493	-87.565347
Lauderdale C-1	34.828732	-87.309696
Lawrence C-1	34.752629	-87.405441
Lawrence C-2	34.643442	-87.188989
Lawrence C-3	34.663852	-87.158305
Lawrence C-4	34.676232	-87.155957
Lawrence C-5	34.461124	-87.248451
Limestone C-1	34.718583	-86.877686
Limestone C-2	34.887949	-86.987241
Limestone C-3	34.698762	-86.965980
Limestone C-4	34.732658	-87.061311
Madison C-1	34.587117	-86.844521
Madison C-2	34.829572	-86.645730
Madison C-3	34.888477	-86.656164
Marshall C-1	34.187698	-86.244271

Table A2. North Alabama Corn Survey Locations 2015 (cont.)

Field Name	Latitude	Longitude
Morgan C-1	34.535700	-86.833000
Morgan C-2	34.543393	-86.872397
Morgan C-3	34.543919	-86.888052
Shelby C-1	33.454638	-86.394096
Shelby C-2	33.342989	-86.377186
Shelby C-3	33.392416	-86.423039

Table A3. North Alabama Corn Survey Locations 2016

Field Name	Latitude	Longitude
Cherokee-C-1	34.157061	-85.716057
Colbert-C-W2	34.683016	-87.458811
Colbert-C-W1	34.685095	-87.581743
Dekalb -C-2	34.368720	-85.999606
Franklin-C-S1	34.487052	-87.552018
Franklin-C-2	34.482249	-87.715296
Jackson-C-S1	34.687609	-86.143062
Jackson-C-T1	34.622865	-86.246099
Jackson-C-1	34.621032	-86.146710
Lauderdale-C-W1	34.903513	-87.665110
Lauderdale-C-B1	34.919279	-87.529616
Lawrence-C-S1	34.487052	-87.552018
Lawrence-C-G	34.676502	-87.155080
Lawrence-C-D	34.640651	-87.190347
Lawrence-C-S2	34.462323	-87.407885
Limestone-C-L1	34.739942	-87.025015
Limestone-C-L2	34.740067	-87.022445

Table A3. North Alabama Corn Survey Locations 2016 (cont.)

Field Name	Latitude	Longitude
Limestone-C-U1	34.891590	-86.903635
Limestone-C-E1	34.888265	-86.987356
Madison-C-T1	34.869397	-86.508875
Madison-C-M1	34.906683	-86.713943
Madison-C-M2	34.857406	-86.697543
Marshall-C-2	34.249881	-86.428949
Marshall-C-1	34.169479	-86.343131
Morgan-C-3	34.544873	-86.894072
Morgan-C-B1	34.390300	-87.036793
Morgan-C-G2	34.535028	-86.830874
Shelby-C-T	33.372091	-86.420012
Shelby-C-D	33.457348	-86.394152
Dekalb-C-1	34.284019	-85.966019
DeKalb-C-3	34.291652	-85.960545

Table A4. Alabama Soybean Sweep Survey Locations 2015

Field Name	Latitude	Longitude	*H. halys*[1]
Morgan-S-1	34.53257	-86.83317	N
Morgan-S-2	34.536668	-86.806386	N
Madison-S-1	34.813048	-86.54052	Y
Limestone-S-2	34.897155	-86.989375	N
Shelby-S-1	33.4568006	-86.3935305	Y
Elmore-S-1	32.492107	-85.890759	N
Autauga-S-1	32.42701	-86.445289	Y
Limestone-S-1	34.64216222	-86.88901062	Y
Limestone-S-4	34.692921	-86.879381	N
Calhoun-S-1	33.772025	-85.853864	N
Talladega-S-2	33.534846	-85.927986	Y
Talladega-S-1	33.399531	-86.029047	N
Calhoun-S-2	33.75353	-85.913766	Y
Lamar-S-1	33.908988	-88.116704	N
Fayette-S-2	33.767867	-87.786844	N
Lamar-S-2	33.890357	-88.167057	N
Sumter-S-1	32.641234	-88.27785	N
Dallas-S-1	32.461955	-87.246994	N

Table A4. Alabama Soybean Sweep Survey Locations 2015 (cont.)

Field Name	Latitude	Longitude	*H. halys*[1]
Perry-S-1	32.449473	-87.459055	N
Marengo-S-1	32.464749	-87.581421	N
Dallas-S-2	32.43974	-87.255648	N
Marengo-S-2	32.457713	-87.555243	N
Marshall-S-1	34.184709	-86.244362	N
DeKalb-S-1	34.293982	-85.967265	Y
Lawrence-S-1	34.647847	-87.188155	N
Lawrence-S-2	34.680508	-87.155989	N
Colbert-S-1	34.683271	-87.506228	N
Lauderdale-S-1	34.833946	-87.338436	N
Franklin-S-1	34.48684	-87.561361	N

[1]Halyomorpha halys presence Y= insect found, N= insect not found

Table A5. Alabama Soybean Sweep Survey Locations 2016

Field Name	Latitude	Longitude	*H. halys*[1]
Limestone-S-BG	34.642102	-86.888768	N
Limestone-S-L	34.747257	-87.02482	N
Dallas-S	32.439724	-87.268385	N
Madison-S-M1	34.814128	-86.529948	Y
Madison-S-M2	34.814176	-86.524842	Y
Morgan-S-G2	34.536603	-86.806353	N
Morgan-S-G1	34.540352	-86.806618	N
Pike-S-W1	31.718866	-85.791472	N
Pike-S-W2	31.722191	-85.796215	N
Coffee-S	31.335881	-86.131361	N
Coffee-S-W	31.354044	-86.132678	N
Dale-S-C	31.52862	-85.669549	N
Houston-S-G1	31.135331	-85.175802	N
Houston-S-D1	31.000386	-85.264745	N
Geneva-S-S1	31.076348	-85.506417	N
Geneva-S-M1	31.140712	-85.498452	N
Geneva-S-M2	31.138914	-85.556755	N
Baldwin-S-E	30.53816	-87.882288	N

Table A5. Alabama Soybean Sweep Survey Locations 2016 (cont.)

Field Name	Latitude	Longitude	*H. halys*[1]
Escambia-S-1	31.144937	-87.048735	N
Escambia-S-H	31.046855	-87.54224	N
Escambia-S-2	31.069223	-87.505413	N
Escambia-S-3	31.051604	-87.439605	N
Escambia-S-4	31.078532	-87.52578	N
Pike-S-3	31.65465	-85.84179	N
Elmore-S-1	32.442077	-85.898929	N

[1]Halyomorpha halys presence Y= insect found, N= insect not found

Table A6. Corn Survey Data 2014

		Mean Injury Per Ear							
				No. Injured Kernels					
Field Name	Round[1]	Caterpillar[2] (cm²)	Borer[3] (cm²)	Stink Bug	Sap Beetle	Starburst[4]	Red Stripe[5]	*Aspergillus*[6]	Weevil
DeKalb 1	1	0.8875	5.45	4.8	4.15	1.2	0	0	0
DeKalb 1	2	0.2475	0	7.7	26.1	0.4	0	0	0
DeKalb 1	3	0.3	0	5.8	11.15	0	0	0	0
DeKalb 1	4	0	13	8.5	13.9	0	0	0	0
DeKalb 1	5	0	11.05	9.25	5.9	0.8	0	0	2.4
DeKalb 2	1	0.1	0	9.05	1.55	0	0	0	0
DeKalb 2	2	0	0	7.6	0.85	0.3	0.2	0	0
DeKalb 2	4	0	0	11.42	2.63	1.21	0	0	0
DeKalb 3	1	0	2.45	3	0.9	0	0	0	0
DeKalb 3	2	0	0	2.35	5.7	2.05	0	0	0
Lawrence 1	1	0	0.25	4.4	0.45	0	1.4	0	0
Lawrence 1	2	0	0.2	9.05	7.45	1.7	4.75	0.4	0
Lawrence 1	3	0	0.55	9.55	4.15	6.5	9.8	0	0.05
Lawrence 2	1	0	1.15	9.9	3.1	1.65	0.2	1.6	0
Lawrence 2	2	0	0.25	12.1	6.15	0.5	0.5	0	1.9

Table A6. Corn Survey Data 2014 (cont.)

		Mean Injury Per Ear							
				No. Injured Kernels					
Field Name	Round[1]	Caterpillar[2] (cm^2)	Borer[3] (cm^2)	Stink Bug	Sap Beetle	Starburst[4]	Red Stripe[5]	*Aspergillus*[6]	Weevil
Lawrence 2	3	0	0	24.8	10.2	10.4	0	1.45	4.25
Lawrence 2	4	0	0	18.1	0.55	2.3	4.45	0	19.75
Lawrence 3	1	0.25	0	13.85	2.3	0.15	0	0	0
Lawrence 3	2	0	2.05	24.05	0.95	0.45	0.25	0.25	0
Lawrence 3	3	0.081	0	29.8	1.3	3.9	0	0	0
Lawrence 4	1	0	1.05	9.7	2.2	5.15	0	0	0
Lawrence 4	2	0.22	1.75	14.45	0.55	12.95	2.2	0	0
Lawrence 4	3	0	0.95	27.5	1.85	4.45	9.4	0.25	0
Lawrence 5	1	0.025	0	5.7	0.3	4.1	0	0	0
Lawrence 5	2	0	0	10.25	1.6	7.75	0	0.5	0
Lawrence 5	3	0	0	7.2	0	0	6.35	0	0
Lawrence 6	1	0.35	1.85	5.95	1	0	0	0.45	0
Lawrence 6	2	0.12	0.85	17.3	9.95	12.1	0	0	0
Lawrence 7	2	0.19	0	6.6	5.35	19.7	0	1.75	0

Table A6. Corn Survey Data 2014 (cont.)

		Mean Injury Per Ear							
				No. Injured Kernels					
Field Name	Round[1]	Caterpillar[2] (cm^2)	Borer[3] (cm^2)	Stink Bug	Sap Beetle	Starburst[4]	Red Stripe[5]	*Aspergillus*[6]	Weevil
Limestone 1	1	0.3	0.2	4.55	0	1.4	0	0	0
Limestone 1	2	0	0	4.35	1.85	4.05	0	0	0
Limestone 1	3	0	0.75	6.25	0.4	2.7	0.6	0.1	0
Limestone 1	4	0	0.2	5.8	3.1	7.9	0	0	0
Limestone 2	1	0	0.6	16.3	1.3	6.5	1.75	0	0
Limestone 2	2	0	0	11.85	4.1	3	0.5	0	0
Limestone 2	3	0	0	18.45	2.65	8.2	0.65	0	0
Limestone 3	1	0.137	0	7.25	0.3	1.45	32.45	0.15	0
Limestone 3	2	0	2	11.8	8.55	5.2	14	0	0
Limestone 3	3	0	0	9.9	4.45	8.95	1.7	0.3	0.05
Limestone 4	1	0.35	1.35	5.1	1.95	0.6	0.75	0	0
Limestone 4	2	0	0.5	14.2	4.85	3.75	10.2	0	0
Limestone 4	3	0	0	20.1	3.15	6.2	4	0.45	0
Limestone 5	1	0.125	0	9.95	1.85	1.65	3.85	0.25	0

Table A6. Corn Survey Data 2014 (cont.)

		Mean Injury Per Ear							
				No. Injured Kernels					
Field Name	Round[1]	Caterpillar[2] (cm²)	Borer[3] (cm²)	Stink Bug (no. injured kernels)	Sap Beetle	Starburst[4]	Red Stripe[5]	*Aspergillus*[6]	Weevil
Limestone 5	2	0	0	12.8	11.5	6.4	4.15	0.15	0
Limestone 5	3	0	0	10.21	3.73	7.31	0	0	0
Limestone 5	4	0	0	11.6	4.2	5.75	3.35	0	0
Limestone 6	1	0	7.15	4.95	0.3	33.7	2.15	0	0
Limestone 6	2	0	3.05	12.4	3.05	9.55	5.65	0.5	0
Limestone 6	3	0	5.4	15.1	2.2	7.6	0	0	0
Limestone 6	4	0	0.35	7.55	1.45	11.15	3.55	2.6	0
Limestone 7	1	0.58	27.55	11.7	1.95	1	0	0.1	0
Limestone 7	2	0.15	15.75	14.7	10	2.85	0.1	2.45	0
Limestone 7	3	1.27	17.7	14.05	0.45	3.15	0	0	0
Madison 1	1	0.91	1.1	8.9	0.75	2.65	0.75	0	0
Madison 1	2	0	0	9.2	1.85	2.9	0	0	0
Madison 2	1	0.13	0	15.7	0.25	4.7	0.4	0	0
Madison 2	2	0.01	0	26.15	5.05	8.15	0	0	0

Table A6. Corn Survey Data 2014 (cont.)

		Mean Injury Per Ear							
				No. Injured Kernels					
Field Name	Round[1]	Caterpillar[2] (cm^2)	Borer[3] (cm^2)	Stink Bug (no. injured kernels)	Sap Beetle	Starburst[4]	Red Stripe[5]	*Aspergillus*[6]	Weevil
Madison 3	1	0.06	0	6.95	0.15	0.7	0	0	0
Morgan 1	1	1.18	1.8	8.8	0.35	5.75	3.65	0.65	0
Morgan 1	2	0	0	13.1	3.3	9.45	5.55	0.05	0
Morgan 2	1	1.83	0.05	4.15	0.15	0.75	0	0	0
Morgan 2	2	0	3.2	2.2	3.85	4.35	1.8	0	0
Morgan 2	3	0	1.8	1.4	0.15	39.3	0.2	0.2	0
Morgan 3	1	1.76	0	0.75	4.85	0.15	0	0	0
Morgan 3	2	1.12	0.1	3.6	1.8	0	0	1.35	0
Morgan 3	4	0	0.05	12.05	4.2	3.1	0	0.25	0

[1]Round 1 = 11 August, round 2 = 21 August, round 3 = 2 September, round 4 = 16 September, round 5 = 3 October. 20 ears were sampled from each field on each date.
[2]mostly corn earworm and fall armyworm
[3]Southwestern or European corn borer
[4]Symptom of *Fusarium* infection
[5]From unknown cause
[6]Showing sporulation of *Aspergillus* fungus

Table A7. Alabama Corn Survey Data 2015

			Mean Injury Per Ear						
					No. Injured Kernels				
Field Name	Round[1]	Field Position[2]	Caterpillar[3] (cm^2)	Borer[4] (cm^2)	Stink Bug	Sap Beetle	Starburst[5]	*Aspergillus*[6]	Red Stripe[7]
Autauga C-1	1	Edge	0.59	0.00	5.90	11.55	1.60	0.00	0.00
Autauga C-2	1	Edge	1.71	1.00	1.79	4.79	13.47	0.00	0.00
Colbert C-1	1	Edge	0.15	0.00	16.65	5.95	0.35	0.00	6.30
DeKalb C-1	1	Edge	0.00	0.00	12.45	5.10	1.60	0.05	5.00
DeKalb C-2	1	Edge	0.13	0.35	7.75	4.05	1.70	0.00	0.00
Franklin C-1	1	Edge	0.51	0.00	2.85	15.35	0.00	0.00	0.35
Lauderdale C-1	1	Edge	0.23	0.00	5.65	9.50	1.70	0.00	1.35
Lawrence C-1	1	Edge	0.16	0.00	8.37	4.63	0.00	0.00	2.47
Lawrence C-2	1	Edge	0.00	0.00	9.80	3.35	0.00	0.00	22.15
Lawrence C-3	1	Edge	0.20	1.00	22.10	5.95	0.00	0.00	12.45
Lawrence C-4	1	Edge	0.14	0.00	11.00	13.55	0.00	0.10	5.80
Lawrence C-5	1	Edge	0.16	0.00	10.58	5.21	0.00	0.00	4.89
Limestone C-1	1	Edge	0.76	0.00	6.05	8.40	0.20	1.60	7.05
Limestone C-2	1	Edge	0.11	0.00	18.67	10.48	2.05	0.00	0.00
Limestone C-3	1	Edge	0.00	0.00	4.10	2.80	7.00	0.00	1.90

Table A7. Alabama Corn Survey Data 2015 (cont.)

			Mean Injury Per Ear						
					No. Injured Kernels				
Field Name	Round[1]	Field Position[2]	Caterpillar[3] (cm^2)	Borer[4] (cm^2)	Stink Bug	Sap Beetle	Starburst[5]	*Aspergillus*[6]	Red Stripe[7]
Limestone C-4	1	Edge	0.00	0.00	14.25	4.10	0.55	0.00	9.10
Madison C-1	1	Edge	0.18	0.00	10.95	8.70	1.85	0.65	1.00
Madison C-2	1	Edge	0.00	0.00	4.85	3.90	2.90	0.00	2.40
Madison C-3	1	Edge	0.00	0.00	26.15	22.40	6.60	0.00	0.80
Marshall C-1	1	Edge	0.20	0.00	18.95	7.20	1.60	0.60	4.15
Morgan C-1	1	Edge	0.31	0.00	7.65	4.90	8.80	0.00	7.15
Morgan C-2	1	Edge	2.76	0.00	2.05	25.45	43.05	0.00	1.25
Morgan C-3	1	Edge	0.53	0.00	5.60	5.05	86.00	0.00	0.55
Shelby C-1	1	Edge	0.00	0.05	1.50	1.70	0.35	0.05	0.00
Shelby C-2	1	Edge	0.10	0.00	7.70	3.75	0.00	0.00	0.00
Shelby C-3	1	Edge	0.00	0.00	0.40	0.25	0.00	0.00	0.00
Autauga C-1	1	Center	0.44	0.00	1.40	9.35	0.30	0.00	0.00
Autauga C-2	1	Center	1.05	0.00	1.75	1.55	5.20	0.00	0.00
Colbert C-1	1	Center	0.33	0.00	11.15	9.65	0.00	0.00	14.80

Table A7. Alabama Corn Survey Data 2015 (cont.)

			Mean Injury Per Ear						
					No. Injured Kernels				
Field Name	Round[1]	Field Position[2]	Caterpillar[3] (cm^2)	Borer[4] (cm^2)	Stink Bug	Sap Beetle	Starburst[5]	*Aspergillus*[6]	Red Stripe[7]
DeKalb C-1	1	Center	0.89	0.00	4.60	3.35	0.00	0.00	0.00
DeKalb C-2	1	Center	0.08	0.00	1.47	4.37	0.00	0.00	0.00
Franklin C-1	1	Center	0.54	0.00	8.35	5.05	1.25	0.00	1.95
Lauderdale C-1	1	Center	0.00	0.00	7.95	3.00	0.75	0.00	1.55
Lawrence C-1	1	Center	0.07	0.00	13.15	5.50	0.00	0.15	11.40
Lawrence C-2	1	Center	1.40	0.00	25.15	12.70	0.65	0.10	28.85
Lawrence C-3	1	Center	0.30	0.00	6.25	2.60	0.00	0.00	6.70
Lawrence C-4	1	Center	0.56	0.00	3.00	3.00	0.00	0.14	1.38
Lawrence C-5	1	Center	0.00	0.00	4.35	3.65	1.75	0.00	8.00
Limestone C-1	1	Center	2.06	5.25	6.35	14.50	0.00	0.00	14.50
Limestone C-2	1	Center	0.00	0.00	12.65	4.50	7.30	0.00	0.50
Limestone C-3	1	Center	0.07	0.00	12.55	2.70	0.10	0.10	2.90
Limestone C-4	1	Center	0.00	0.00	3.35	1.45	0.60	0.00	10.55
Madison C-1	1	Center	0.15	0.00	12.10	12.05	4.30	1.00	0.00

Table A7. Alabama Corn Survey Data 2015 (cont.)

			Mean Injury Per Ear						
					No. Injured Kernels				
Field Name	Round[1]	Field Position[2]	Caterpillar[3] (cm^2)	Borer[4] (cm^2)	Stink Bug	Sap Beetle	Starburst[5]	*Aspergillus*[6]	Red Stripe[7]
Madison C-2	1	Center	0.31	0.00	5.05	3.75	2.85	0.15	3.95
Madison C-3	1	Center	0.91	0.00	8.26	5.32	3.63	0.00	0.00
Marshall C-1	1	Center	0.00	0.00	7.52	2.67	0.00	0.48	0.00
Morgan C-1	1	Center	0.44	0.00	6.70	4.55	5.25	0.10	2.40
Morgan C-2	1	Center	3.89	0.00	0.35	16.95	2.60	1.15	0.00
Morgan C-3	1	Center	1.08	0.00	5.53	4.58	39.68	0.00	0.00
Shelby C-1	1	Center	0.00	0.00	0.30	1.95	0.00	0.00	0.00
Shelby C-2	1	Center	0.00	0.00	0.11	4.00	0.00	0.00	0.00
Shelby C-3	1	Center	0.00	0.00	0.25	0.55	0.00	0.00	0.00
Colbert C-1	2	Edge	0.00	0.0	16.2	11.7	14.0	0.0	5.6
Lauderdale C-1	2	Edge	0.00	0.0	9.8	19.4	11.9	0.0	17.2
Lawrence C-1	2	Edge	0.00	0.0	23.5	11.7	1.7	0.0	4.1
Lawrence C-3	2	Edge	0.18	0.0	22.8	15.4	0.7	0.0	6.8
Lawrence C-4	2	Edge	0.00	0.0	9.0	11.4	0.0	0.0	10.7

Table A7. Alabama Corn Survey Data 2015 (cont.)

			Mean Injury Per Ear						
					No. Injured Kernels				
Field Name	Round[1]	Field Position[2]	Caterpillar[3] (cm^2)	Borer[4] (cm^2)	Stink Bug	Sap Beetle	Starburst[5]	*Aspergillus*[6]	Red Stripe[7]
Lawrence C-5	2	Edge	2.74	0.9	10.8	5.5	3.7	0.0	3.7
Limestone C-1	2	Edge	0.39	0.0	18.0	11.4	0.8	0.0	3.7
Limestone C-2	2	Edge	0.00	0.0	11.2	3.1	2.1	0.0	0.0
Limestone C-3	2	Edge	0.00	0.0	9.5	8.8	12.0	1.1	1.6
Madison C-2	2	Edge	0.81	0.0	3.0	5.1	4.3	0.0	3.4
Madison C-3	2	Edge	0.34	0.0	34.8	13.8	5.1	0.0	0.2
Marshall C-1	2	Edge	0.00	0.0	8.5	6.0	1.0	0.0	3.8
Morgan C-2	2	Edge	0.80	0.0	7.3	29.3	22.3	0.0	0.0
Morgan C-3	2	Edge	1.03	0.0	3.3	12.2	5.6	0.0	0.2

[1]Round 1 = 12-14 August, round 2 = 21-22 August. 20 ears were sampled from each field on each date.
[2]Edge samples taken from first two rows of field, and center samples taken from 31m in from the edge in the middle of the field.
[3]mostly corn earworm and fall armyworm
[4]Southwestern or European corn borer
[5]Symptom of *Fusarium* infection
[6]Showing sporulation of *Aspergillus* fungus
[7]From unknown cause

Table A8. Alabama Corn Survey Data 2016

Field Name	Round[1]	Field Position[2]	Mean Injury Per Ear: No. Injured Kernels: Stink Bug	Sap Beetles	Starburst[3]	Borer[4] (cm^2)
Cherokee-C-1	1	Edge	2.45	2.2	0.4	0
Cherokee-C-1	1	Center	1.75	2.1	2.4	0
Colbert-C-W1	1	Edge	2.95	4.2	3.85	0
Colbert-C-W1	1	Center	1.95	4.3	8.1	21.6
Colbert-C-W2	1	Edge	44.25	4.4	11.3	0
Colbert-C-W2	1	Center	14.45	8.75	17.75	0
Dekalb -C-1	1	Edge	9.4	0.8	0	0
Dekalb -C-1	1	Center	3.7	7.3	0.5	0
Dekalb -C-2	1	Edge	2.4	5.4	7.8	0
Dekalb -C-2	1	Center	2.95	2.55	8.35	0
Franklin-C-2	1	Edge	1.25	3.65	0.65	0
Franklin-C-2	1	Center	4.65	2.8	2.75	0
Franklin-C-S1	1	Edge	4.85	4.55	0.3	0.8
Franklin-C-S1	1	Center	0.45	0	0.05	1.65
Jackson-C-1	1	Edge	10.3	1	5.05	0
Jackson-C-1	1	Center	4.95	3.3	0.75	0
Jackson-C-S1	1	Edge	1.5	1.45	0	0.25

Table A8. Alabama Corn Survey Data 2016 (cont.)

			Mean Injury Per Ear			
			No. Injured Kernels			
Field Name	Round[1]	Field Position[2]	Stink Bug	Sap Beetles	Starburst[3]	Borer[4] (cm^2)
Jackson-C-S1	1	Center	1.4	2.8	0.15	0
Jackson-C-T1	1	Edge	4.2	1.35	1.1	0.3
Jackson-C-T1	1	Center	1.52	1.15	1.31	0.63
Lawrence-C-D	1	Edge	22.6	0.4	7.15	5.75
Lawrence-C-D	1	Center	6.75	1.75	4.85	1.75
Lawrence-C-G	1	Edge	11.75	5.2	3.1	0
Lawrence-C-G	1	Center	11.55	1.7	40.55	0.65
Lawrence-C-S2	1	Edge	8.95	1.45	5.1	0.4
Lawrence-C-S2	1	Center	3.1	2.3	1.05	0.25
Limestone-C-L1	1	Edge	4.7	4.05	2.65	0.05
Limestone-C-L1	1	Center	3.15	3.5	3.95	0.6
Limestone-C-U1	1	Edge	8.4	2.05	1	0
Limestone-C-U1	1	Center	10.68	3.36	42	0.421
Limestone-C-E1	1	Edge	36.05	2.7	23.8	0
Limestone-C-E1	1	Center	13.9	0.95	17.95	0.4
Madison-C-M1	1	Edge	38.05	6.5	12.9	0.9
Madison-C-M1	1	Center	7.3	0.75	1.35	0

Table A8. Alabama Corn Survey Data 2016 (cont.)

			Mean Injury Per Ear			
			No. Injured Kernels			
Field Name	Round[1]	Field Position[2]	Stink Bug	Sap Beetles	Starburst[3]	Borer[4] (cm^2)
Madison-C-M2	1	Edge	4.5	4.75	0.8	0
Madison-C-M2	1	Center	15.5	3.95	5	0
Morgan-C-B1	1	Edge	0	2.35	0	0
Morgan-C-B1	1	Center	1.8	0.75	2.8	0
Morgan-C-G1	1	Edge	4.6	0.4	4	0
Morgan-C-G1	1	Center	2.2	6.6	1.6	0
Morgan-C-3	1	Edge	0	8.8	0	0
Morgan-C-3	1	Center	1.9	3.6	1.4	0.1
Autauga-C-P	1	Edge	13.7	11.9	12.8	0
Autauga-C-P	1	Center	33.87	10.75	35.12	0
Shelby-C-D	1	Edge	2.9	1.8	109.7	0
Shelby-C-D	1	Center	1	0.1	217.7	0
Shelby-C-T	1	Edge	3.25	0	6.85	0
Shelby-C-T	1	Center	1.5	0	6.35	0
Cherokee-C-1	2	Edge	4.65	0.65	0.55	0
Colbert-C-W1	2	Edge	2.73	10.15	23.31	0
Colbert-C-W2	2	Edge	29.65	3.15	13.55	2.65

Table A8. Alabama Corn Survey Data 2016 (cont.)

			Mean Injury Per Ear			
			No. Injured Kernels			
Field Name	Round[1]	Field Position[2]	Stink Bug	Sap Beetles	Starburst[3]	Borer[4] (cm^2)
DeKalb -C-2	2	Edge	8.5	2	9.55	0
Franklin-C-2	2	Edge	3.95	1.6	3.4	0
Jackson-C-1	2	Edge	9.94	0.38	6.66	0
Jackson-C-S1	2	Edge	1.35	0.25	0.45	0
Jackson-C-T1	2	Edge	2.9	3.65	2.45	0.85
Lauderdale-C-B1	2	Edge	6.6	2.35	66.8	0
Lauderdale-C-B1	2	Center	12.4	3.1	76	0
Lauderdale-C-W1	2	Edge	10.5	6	19.6	0
Lauderdale-C-W1	2	Center	9.35	6.8	21.3	0
Lawrence-C-D	2	Edge	13.65	2.3	4.25	0
Lawrence-C-G	2	Edge	24.1	7.1	2.15	0
Lawrence-C-S2	2	Edge	3.65	0.25	0.85	0
Limestone-C-L1	2	Edge	10.7	3.65	11.45	0
Limestone-C-U1	2	Edge	7.3	1.65	18.6	0
Limestone-C-E1	2	Edge	25.73	5.21	18.05	0
Madison-C-M1	2	Edge	26.9	6.6	30.5	0.5
Madison-C-M1	2	Center	58.3	4.4	46.8	0

Table A8. Alabama Corn Survey Data 2016 (cont.)

			Mean Injury Per Ear			
			No. Injured Kernels			
Field Name	Round[1]	Field Position[2]	Stink Bug	Sap Beetles	Starburst[3]	Borer[4] (cm^2)
Madison-C-M2	2	Edge	9.9	2.5	1.7	0
Madison-C-T	2	Edge	8.65	1.65	4.75	0
Madison-C-T	2	Center	9.1	4.05	24.35	0.65
Marshall-C-1	2	Edge	4.25	9.65	9.1	0
Marshall-C-1	2	Center	2.5	1.95	0.75	0
Marshall-C-2	2	Edge	8.15	13.05	37.05	0
Marshall-C-2	2	Center	3.4	7.75	33.8	0
Morgan-C-B1	2	Edge	0.2	2.2	3.15	1.55
Morgan-C-G2	2	Edge	2.85	0.05	0.4	0
DeKalb-C-3	2	Edge	12.5	0.5	8.35	0
DeKalb-C-3	2	Center	11	3.05	7.9	0
DeKalb-C-2	3	Edge	5.45	3.1	18.95	0
Jackson-C-T1	3	Edge	6.2	3.5	1.15	0
Lauderdale-C-B1	3	Edge	12.05	2.45	49.15	0
Lauderdale-C-W1	3	Edge	11.9	5.25	7.8	0
Limestone-C-E1	3	Edge	35.7	5.6	32	0.75

Table A8. Alabama Corn Survey Data 2016 (cont.)

			Mean Injury Per Ear			
			No. Injured Kernels			
Field Name	Round[1]	Field Position[2]	Stink Bug	Sap Beetles	Starburst[3]	Borer[4] (cm^2)
Marshall-C-2	3	Edge	5.5	4.25	28.75	0
Shelby-C-T	3	Edge	2.7	0.85	4.05	0

[1]Round 1 = 8-18 August, round 2 = 24-30 August, round 3 = 9-12 September. 20 ears were sampled from each field on each date.
[2]Edge samples taken from first two rows of field, and center samples taken from 31m in from the edge in the middle of the field.
[3]Symptom of *Fusarium* infection
[4]Southwestern or European corn borer

Table A9. Cotton Boll Injury, Prattville AL 2016

Treatment	Plot #	Number of Injured Bolls (Out of 10)						Yield (lbs/plot)
		25 July	1 August	8 August	15 August	22 August	6 September	
Untreated	101	0	2	1	9	7	4	5.8
Maximum	102	1	5	1	1	0	1	19.7
Threshold	103	0	6	0	0	2	1	23.7
Threshold	104	0	1	2	4	2	1	10.4
Untreated	105	5	3	1	5	0	0	27
Maximum	106	2	2	1	4	2	1	30.8
Maximum	107	0	4	0	4	3	1	10.6
Threshold	108	3	4	1	0	1	2	28.7
Untreated	109	2	0	3	3	5	5	26.8
Threshold	201	0	1	2	5	-	1	20.6
Untreated	202	2	0	2	4	0	0	26.2
Threshold	203	0	0	0	1	1	0	27.9
Maximum	204	2	3	0	5	3	0	12
Threshold	205	1	3	1	1	0	0	28.7
Maximum	206	1	4	1	0	1	0	25.3
Untreated	207	0	5	6	8	4	3	16.1

Table A9. Cotton Boll Injury, Prattville AL 2016 (cont.)

		Number of Injured Bolls (Out of 10)						
Treatment	Plot #	25 July	1 August	8 August	15 August	22 August	6 September	Yield (lbs/plot)
Maximum	208	3	1	0	0	0	1	29.2
Untreated	209	0	6	10	2	5	2	23.6
Maximum	301	2	2	7	10	8	1	23.1
Maximum	302	0	2	2	2	0	0	22.2
Untreated	303	1	5	4	4	0	0	16.8
Untreated	304	2	8	1	4	2	2	27.6
Threshold	305	0	7	0	4	0	0	27.2
Maximum	306	0	4	0	6	0	0	28.8
Threshold	307	4	6	1	6	3	2	22
Untreated	308	2	5	5	5	0	1	23.1
Threshold	309	0	2	0	8	2	4	28.3
Untreated	401	0	8	2	8	9	4	17.1
Untreated	402	0	5	5	6	1	2	23.9
Maximum	403	1	1	0	3	1	2	27.1
Threshold	404	1	6	1	5	6	1	21

Table A9. Cotton Boll Injury, Prattville AL 2016 (cont.)

		Number of Injured Bolls (Out of 10)						
Treatment	Plot #	25 July	1 August	8 August	15 August	22 August	6 September	Yield (lbs/plot)
Threshold	405	1	2	2	2	1	0	24.5
Untreated	406	3	1	0	7	0	2	21.7
Maximum	407	2	7	2	9	5	1	19.4
Maximum	408	4	2	-[1]	1	4	1	25.1
Threshold	409	0	4	0	4	0	1	22.7

[1] - = missing sample

Table A10. Cotton Boll Injury, Prattville AL 2017

		Number of Injured Bolls (Out of 10)						
Treatment	Plot #	22 August	28 August	6 September	12 September	18 September	26 September	Yield (lbs/plot)
Maximum	101	2	2	3	2	6	2	25.1
Threshold	102	1	0	2	2	5	2	20.2
Untreated	103	4	3	3	3	7	6	16.3
Threshold	201	0	2	1	3	5	3	26.1
Maximum	202	0	1	1	1	1	1	23
Untreated	203	5	4	2	4	4	9	17.9
Untreated	301	1	7	4	7	8	6	14.2
Maximum	302	3	2	0	1	4	4	18.5
Threshold	303	0	2	1	2	2	3	27.2
Threshold	104	3	2	2	2	3	6	19.1
Untreated	204	4	8	7	10	9	10	14.8

Table A10. Cotton Boll Injury, Prattville AL 2017 (cont.)

		Number of Injured Bolls (Out of 10)						
Treatment	Plot #	22 August	28 August	6 September	12 September	18 September	26 September	Yield (lbs/plot)
Maximum	304	1	2	1	3	3	3	20.7
Untreated	105	1	7	7	7	8	9	12.3
Maximum	205	0	3	3	1	3	3	21.4
Threshold	305	0	5	4	4	5	2	20.5
Untreated	106	1	6	5	6	7	9	17.2
Maximum	107	3	1	1	2	3	0	20.8
Threshold	108	0	3	0	1	2	3	19.3
Untreated	206	5	2	2	7	8	6	18.1
Threshold	207	0	2	1	2	2	2	18.8
Maximum	208	0	1	1	3	5	1	16.8
Maximum	306	4	1	0	4	1	2	17.2
Threshold	307	4	5	2	3	5	5	19.9
Untreated	308	3	2	4	6	8	8	13.2

Table A11. Injury to corn ears in cage study, Shorter, AL 2017

			Injury Per Ear					
Stage	Infested[1]	Sample Number	Stink Bug (no. injured kernels)	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area Damaged[3] (cm^2)	Starburst[4] (%)
Pretassel	Y	2	2	90	5.5	4	2	0
Pretassel	Y	4	0	95	6	4	7	0
Pretassel	Y	5	1	90	6.5	10	5	0
Pretassel	Y	8	1	95	5.75	4	6	0
Pretassel	Y	9	0	90	6.5	15	1	0
Pretassel	Y	10	2	95	5.75	4	8	0
Pretassel	Y	11	3	95	5.75	10	8	0
Pretassel	Y	12	0	95	6.5	10	7	0
Pretassel	Y	13	3	95	6	4	4	0
Pretassel	N	1	0	95	7	4	0	0
Pretassel	N	3	0	95	5	10	5	0
Pretassel	N	6	0	90	6.5	4	0	0
Pretassel	N	7	2	90	6.25	0	0	0

Table A11. Injury to corn ears in cage study, Shorter, AL 2017 (cont.)

			Injury Per Ear					
Stage	Infested[1]	Sample Number	Stink Bug (no. injured kernels)	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area Damaged[3] (cm^2)	Starburst[4] (%)
Pretassel	N	14	0	90	6.25	4	8	0
Pretassel	N	15	0	95	6.5	0	0	0
Pretassel	N	17	1	95	7	4	0	0
Pretassel	N	18	0	95	6.25	0	0	0
Pretassel	N	19	0	95	5.75	5	0	0
Pretassel	N	20	0	85	6.5	0	6	0
Silk	Y	54	10	90	6	4	2	12
Silk	Y	30	10	90	5	0	0	4
Silk	Y	45	15	90	6.5	0	0	30
Silk	Y	31	4	90	7	0	12	30
Silk	Y	68	5	90	7	0	0	30
Silk	Y	22	15	85	6	0	17	1
Silk	Y	52	11	90	4.75	0	12	0

Table A11. Injury to corn ears in cage study, Shorter, AL 2017 (cont.)

			Injury Per Ear					
Stage	Infested[1]	Sample Number	Stink Bug (no. injured kernels)	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area Damaged[3] (cm^2)	Starburst[4] (%)
Silk	Y	69	4	80	6	4	15	0
Silk	Y	73	14	90	6.5	0	29	0
Silk	Y	71	21	95	5	9	15	0
Silk	N	26	2	95	6.5	15	14	0
Silk	N	47	0	95	6.25	4	8	0
Silk	N	41	0	90	6.5	0	10	0
Silk	N	57	5	80	5.75	4	6	0
Silk	N	39	0	85	5.75	5	11	0
Silk	N	58	0	90	6.5	4	4	0
Silk	N	70	0	95	6.5	20	5	0
Silk	N	75	0	90	6	20	9	0
Silk	N	59	0	95	6.5	4	7	0
Silk	N	65	0	95	7	4	7	0

Table A11. Injury to corn ears in cage study, Shorter, AL 2017 (cont.)

			Injury Per Ear					
Stage	Infested[1]	Sample Number	Stink Bug (no. injured kernels)	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area Damaged[3] (cm^2)	Starburst[4] (%)
Dough	Y	66	6	90	7	0	0	0
Dough	Y	25	6	90	6.5	0	0	0
Dough	Y	21	13	90	6.5	0	0	0
Dough	Y	53	9	90	7	0	0	5
Dough	Y	60	5	95	6.5	0	1	15
Dough	Y	40	6	90	5.5	0	0	1
Dough	Y	35	10	90	5.5	0	0	10
Dough	Y	29	6	90	6.5	0	0	10
Dough	Y	77	20	90	6	0	0	5
Dough	Y	63	18	95	6	0	0	30
Dough	N	33	0	90	6.25	10	4	0
Dough	N	28	0	95	6	15	11	0
Dough	N	49	0	95	5.5	9	2	0

Table A11. Injury to corn ears in cage study, Shorter, AL 2017 (cont.)

			Injury Per Ear					
Stage	Infested[1]	Sample Number	Stink Bug (no. injured kernels)	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area Damaged[3] (cm^2)	Starburst[4] (%)
Dough	N	44	0	95	7	15	0	0
Dough	N	37	0	90	6.25	4	9	0
Dough	N	61	0	90	6.75	4	9	0
Dough	N	80	0	95	6.75	4	6	0
Dough	N	72	4	95	5.5	0	5	0
Dough	N	62	0	90	7	0	5	0
Dough	N	23	0	100	6.25	0	15	0
Dent	Y	67	16	90	6	0	0	0
Dent	Y	46	31	90	5.5	0	0	5
Dent	Y	38	12	90	6.5	0	0	5
Dent	Y	51	12	95	6.5	0	0	5
Dent	Y	64	13	90	7	0	0	20
Dent	Y	79	13	95	6	0	0	5

Table A11. Injury to corn ears in cage study, Shorter, AL 2017 (cont.)

			Injury Per Ear					
Stage	Infested[1]	Sample Number	Stink Bug (no. injured kernels)	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area Damaged[3] (cm^2)	Starburst[4] (%)
Dent	Y	48	13	90	6	0	0	10
Dent	Y	74	14	90	7	0	0	10
Dent	Y	78	13	90	5.5	0	0	5
Dent	Y	32	7	70	6.5	0	21	60
Dent	N	34	0	85	5.75	4	6	0
Dent	N	42	0	90	7.5	0	7	0
Dent	N	50	0	95	7	10	2	0
Dent	N	24	0	90	6.25	4	5	0
Dent	N	76	0	90	6.5	10	12	0
Dent	N	55	0	85	7	4	8	0
Dent	N	27	0	85	7	0	5	0
Dent	N	43	0	95	6.5	5	7	0
Dent	N	36	0	90	7	0	8	0

Table A11. Injury to corn ears in cage study, Shorter, AL 2017 (cont.)

			Injury Per Ear					
Stage	Infested[1]	Sample Number	Stink Bug (no. injured kernels)	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area Damaged[3] (cm^2)	Starburst[4] (%)
Dent	N	56	0	95	6	10	13	0

[1]Y = ear was infested with 2 adult *Halyomorpha halys,* N= ear was not infested with insects.
[2]Ear deformation measured with protractor
[3] Area damaged by non-stink bug insect feeding (including caterpillars and sap beetles) or unknown cause.
[4]Symptom of *Fusarium* infection

Table A12. Injury to corn ears in cage study, Prattville, AL 2017

Treatment	Infested[1]	Sample Number	Injury Per Ear					
			Stink Bug (no. injured kernels	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area of Damage[3] (cm^2)	Starburst[4] (%)
Pretassel	Y	2	27	90	7	0	1.5	45
Pretassel*	Y	7	.	.	.	.	.	.
Pretassel	Y	8	40	90	7	0	2	55
Pretassel*	Y	1	.	.	.	.	.	.
Pretassel	Y	3	33	90	8	0	6	100
Pretassel	Y	9	9	90	6.5	0	1	0
Pretassel*	Y	10	.	.	.	.	.	.
Pretassel	Y	5	7	85	6.5	0.4	8	50
Pretassel	Y	6	5	80	7	0	8	0
Pretassel	Y	4	13	90	7	0	15	45
Pretassel	N	17	65	6	0	0	22	26
Pretassel	N	16	65	5	0	0	30	18
Pretassel	N	14	95	7.5	0	0	30	15
Pretassel	N	11	85	7	0	0	40	29

Table A12. Injury to corn ears in cage study, Prattville, AL 2017 (cont.)

Treatment	Infested[1]	Sample Number	Injury Per Ear					
			Stink Bug (no. injured kernels	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area of Damage[3] (cm^2)	Starburst[4] (%)
Pretassel	N	20	75	5	0	0	90	33
Pretassel	N	15	70	5.5	10	0	35	26
Pretassel	N	19	70	6.5	10	0	20	21
Pretassel	N	13	90	8	0	0	30	15
Pretassel	N	12	95	8	0	0	25	12
Pretassel	N	18	95	7.5	0	0	20	0
Silk	Y	66	28	80	6	7	23	0
Silk	Y	53	24	80	4.5	0	10	40
Silk	Y	49	28	90	7	0	7	0
Silk	Y	54	22	70	6.5	0.4	13	50
Silk	Y	34	18	90	7.5	0	9	25
Silk	Y	74	8	80	5	5	19	15
Silk	Y	37	17	90	7.5	0	8	0
Silk	Y	27	13	90	7.5	0	6	25

Table A12. Injury to corn ears in cage study, Prattville, AL 2017 (cont.)

Treatment	Infested[1]	Sample Number	Injury Per Ear: Stink Bug (no. injured kernels	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area of Damage[3] (cm^2)	Starburst[4] (%)
Silk	Y	28	18	95	8.5	0	0	80
Silk	Y	41	11	85	6	0	14	0
Silk	N	32	0	90	7.5	0	22	25
Silk	N	67	0	90	6.5	5	18	20
Silk	N	72	1	80	5.5	20	31	15
Silk	N	48	0	55	7	10	47	15
Silk	N	39	0	85	6.5	15	23	25
Silk	N	24	0	85	7	10	29	40
Silk	N	42	0	85	7	0	21	15
Silk	N	64	0	70	5.5	0	27	75
Silk	N	65	5	90	7	0	20	10
Silk	N	45	0	85	7.5	0	11	10

Table A12. Injury to corn ears in cage study, Prattville, AL 2017 (cont.)

Treatment	Infested[1]	Sample Number	Injury Per Ear					
			Stink Bug (no. injured kernels	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area of Damage[3] (cm^2)	Starburst[4] (%)
Dent*	Y	78	.	40	6	0	80	0
Dent	Y	63	8	90	7	0	11	2
Dent	Y	69	10	80	6.5	0	12	50
Dent	Y	46	10	95	7	0	3	0
Dent	Y	51	11	90	7.5	0	13	5
Dent	Y	80	13	85	6.5	0	20	35
Dent	Y	71	10	90	6	0	9	10
Dent	Y	33	15	95	8.5	0	11	20
Dent	Y	56	11	80	6	0	25	5
Dent	Y	77	9	90	7	0	50	0
Dent	N	59	3	90	7.5	0	14	65
Dent	N	29	0	80	7.5	0	36	40
Dent	N	60	0	95	7	0	10	30
Dent	N	69	0	90	6	0	13	20

Table A12. Injury to corn ears in cage study, Prattville, AL 2017 (cont.)

Treatment	Infested[1]	Sample Number	Injury Per Ear					
			Stink Bug (no. injured kernels	Ear Fill (%)	Ear Length (in)	Ear Deformation[2] (◦)	Area of Damage[3] (cm^2)	Starburst[4] (%)
Dent	N	36	0	90	8.5	0	14	90
Dent	N	62	0	90	6.5	0	17	20
Dent	N	26	1	80	9	0	23	15
Dent	N	44	0	90	8	0	24	20
Dent	N	35	0	65	6.5	0	54	30
Dent	N	22	0	60	6.5	0	60	90

[1]Y = ear was infested with 2 adult *Halyomorpha halys*, N= ear was not infested with insects.
[2]Ear deformation measured with protractor
[3] Area damaged by non-stink bug insect feeding (including caterpillars and sap beetles) or unknown cause.
[4]Symptom of *Fusarium* infection
*In a row indicates the ear was heavily damaged or completely lost to smut fungus (*Ustilago maydis)*