Brown Stink Bug (Hemiptera: Pentatomidae) Damage to Seedling Corn and Impact on Grain Yield

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Abstract

Brown stink bugs, Euschistus servus, are an important early-season pest of field corn in the southeastern United States. Feeding in the early stages of corn development can lead to a number of growth deformities and deficiencies and, ultimately, a reduction in yield. An observational and two experimentally manipulated trials were conducted in 2017 and 2018 to 1) determine optimal timing for assessing brown stink bug damage, 2) assess the level of damage from which yield compensation can occur, and 3) examine the relationship between brown stink bug density and early-season damage and yield. Fields were identified with infestations of brown stink bugs and a damage rating system for early stages of corn was established. Varying rates of brown stink bug densities were introduced using field cages and damage was assessed throughout the season. The density and duration of stink bug infestations were critical factors for damage potential, with each day of active feeding per plant resulting in a loss of ~14 kg/ha in yield. The level of damage in early stages of corn was categorized into easily identifiable groups, with only the most severe damage leading to a reduction in yield. Moderate and minimal feeding damage did not result in yield loss. This study emphasizes the need for early and frequent scouting of corn to determine the risk of damage and yield loss from brown stink bugs. Results from this study can be used to help develop management programs for brown stink bugs in the early vegetative stages of field corn.

Key words: brown stink bug, field corn, damage rating scale

The brown stink bug, Euschistus servus (Say), is a common pest of many cultivated crops in the southeastern United States. It has recently emerged as a major pest of corn in the Southeast and can be found in large numbers annually. Multiple factors have been suggested as the reason for recent outbreaks of brown stink bugs in the southeastern United States, including, increased adoption of no-till practices in corn, reduced broad-spectrum pesticide use, and a reduction in competition between stink bugs and heliothine caterpillars as a result of increased Bt adoption in cotton (Greene et al. 2001, Zeilinger et al. 2011). It successfully overwinters in crop residues, weeds, or woodlands where large populations can emerge and move into noncrop hosts such as weeds or directly into seedling corn (Rolston and Kendrick 1961, Jones and Sullivan 1981, McPherson and McPherson 2000, Herbert and Toews 2011, Babu et al. 2019).

Brown stink bugs can feed on corn throughout various growth stages (Babu and Reisig 2018) and there are several periods of development that are susceptible to yield-limiting damage (Bryant et al. 2020). Feeding on early stages of corn development from emergence (VE) until around 3-wk postplanting (V6) is generally considered to be the most susceptible growth stage ranges for yield-limiting damage (Townsend and Sedlacek 1986, Annan and Bergman 1988). The level of damage from feeding is dependent on the duration and density of insect pressure (Townsend and Sedlacek 1986, Annan and Bergman 1988, Sedlacek and Townsend 1988, Apriyanto et al. 1989a, Bryant et al. 2020), and can lead to a number of detrimental effects on plant growth. Overall stunting of growth, characteristic ‘window-pane’-like leaf injury, and plant death have all been reported as common symptoms of stink bug damage (Townsend and Sedlacek 1986; Sedlacek and Townsend 1988; Apriyanto et al. 1989a, b; Bryant et al. 2020). Multiple shoots extended from the same root system, known as tillers or suckers, is another common symptom of severe stink bug damage (Townsend and Sedlacek 1986, Apriyanto et al. 1989b).

Compounding injury early in the season has the potential to lead to yield loss. Yield loss has been attributed to tillers (shoots from the base of the plant which can draw away nutrients from the main ear-developing tiller), a decrease in overall plant vigor, or stunting, ultimately leading to delays in important developmental stages later in the season and a subsequent reduction in yield (Apriyanto et al. 1989b). Although there is some evidence that plants can recover...
from some level of damage throughout the season, this has not been extensively studied. Therefore, it is important to determine the level of damage which plants can compensate and result in no yield loss as well as the proper timing to assess damage. The objectives of this study were to 1) determine optimal timing for assessing brown stink bug damage, 2) assess the level of damage from which yield compensation can occur using a damage rating scale, and 3) examine the relationship between brown stink bug density and early-season damage and yield.

Materials and Methods

Observational Trial

Plots and Damage Ratings
In 2017, two corn fields in Beaufort, NC (field 1; 34.836, −76.572, field 2; 34.822, −76.557) were identified with brown stink bugs present and with plants exhibiting symptoms of brown stink bug damage. Symptoms of stink bug feeding varied from plant to plant, but included stunting, tillers, transverse leaf injury, and dead plants. In these fields, the corn hybrid DKC64-87 (Dekalb Seeds, St. Louis, MO) was planted on 19 and 20 April in fields 1 and 2, respectively, at a rate of 75,000 seeds/ha. Each field was managed without tillage and using standard agronomic practices throughout the season. In each field, plots of 68 plants in two adjacent rows (34 plants per row) were marked on either end with flags. In field one, four separate plots were established at V6, and, in field two, two plots were established at V8. In each location, all plants were individually rated for stink bug damage when the plots were established (n = 406). Stink bug damage ratings ranged from one to six (Fig. 1). Plants with a rating of one were severely damaged, displayed multiple symptoms of stink bug damage, and likely would not produce an ear. A damage rating of two was assigned to plants with less severe damage and multiple symptoms of stink bug damage, and a plant displaying some symptoms of stink bug damage, but not as severe as a damage rating of two. Plants with damage ratings of four through six displayed no visible symptoms of stink bug damage and ranged from below-average growth to excellent growth.

Data Collection
In addition to the rating, when plots were established, plants that produced tillers were also recorded, along with the number of tillers produced. Stem height was also recorded for each plant. Plots were revisited during the early-silking (R1) stage to assess damage and recovery. At R1, stem height, the number of tillers present, and the height of each tiller were recorded for each plant. The presence or absence of a developing ear was also recorded. The first samples (V6/V8) were taken on 17 and 22 May, for field one and two, respectively. All plots were revisited at R1 on 14 June. In this way, the damage was tracked for individual corn plants across the vegetative growth stages.

On 9 August, near physiological maturity, all ears were hand-harvested and individually placed in labeled brown paper bags. Prior to harvest, the number of ears on each plant was recorded. Several ears were missing at the time of harvest due to disease or mechanical injury. Harvested ears were separated by field and replication within each field and brought back to the lab for processing. For each ear, the number of kernel rows was recorded; kernels were then removed from the cob using a hand sheller and the total kernel weight was recorded. The weight of 100 representative kernels from each ear was also recorded. If an ear developed less than 100 kernels total, the number of kernels was recorded and weighed.

Statistical Analysis
All data were analyzed with R version 3.6.3 (R Core Team 2019). Stem height at V6/V8 and R1, number of kernel rows, and kernel
weight were fitted to normal distributions and analyzed using linear mixed (LM) with the package lme4 \citep{bates2015}. Tiller data were tested for zero inflation at both V6/V8 and at R1, as a large number of sampled plants developed no tillers. These data were not zero inflated at V6/V8 ($\chi^2 = 2.77$, df = 1, $P = 0.096$) or at R1 ($\chi^2 = 1.55$, df = 1, $P = 0.213$), so the number of tillers present was analyzed using a generalized linear mixed model (GLMM) fitted to a Poisson distribution with the package lme4. The number of ears per plant was also analyzed with a GLMM fitted to a Poisson distribution. The presence of a developing ear at R1 was analyzed using a GLMM fitted to a binomial distribution. Maximum likelihood ratio tests were used to determine the significance of the fixed effect in the GLMMs. The fixed effect in all models was the damage rating at V6 or V8, and the random effect was the location nested within the field in GLMM models. Residual plots for each model were inspected for violations of the assumptions of each model. A small number of the total plants sampled received a damage rating of four ($n = 12$). Damage ratings of four and five did not display symptoms of stink bug feeding and had similar growth rates, thus ratings of four were combined with ratings of 5 for analysis.

In addition to the analysis described above, kernel weight was analyzed using an LMM with the location as a fixed effect and the field as a random effect. The average kernel weight for an individual location was compared with the percentage of plants in each damage category for that plot to determine the field level effect of early damage. All figures were generated using the package ggplot2 \citep{gomezrubio2017}.

**Cage Trial**

In addition to the observational study described above, controlled experiments were conducted during 2017 and 2018, in Plymouth, NC, to confirm symptoms of brown stink bug feeding seen in the described observational study and to assess the impact of the insect density on plant growth and damage.

For use in this experiment, adult brown stink bugs were collected from winter wheat and stored in mesh containers with surface-sterilized green beans until use. The male to female ratio of insects applied in these experiments was similar to the collected field populations.

In 2017 and 2018, the corn variety P1137VYHR was planted at a rate of 79,000 seeds/ha. Fields were managed using all standard agronomic practices throughout the experiments, except that no insecticidal seed treatment was used at planting.

Around 14 d after planting, three to six adjacent plants were enclosed in mesh cloth (Lumite 18 x 14, BioQuip Products, Rancho Dominguez, CA) supported by PVC pipe. The base of each enclosure was buried throughout the experiment to prevent insects from escaping. Varying levels of stink bug densities were applied to each enclosure. Treatments included 0, 2, 4, 8, or 16 adult brown stink bugs per enclosure, maintained for 8 d in 2017. Since tillers did not form during 2017, the infestation time was increased to 18 d in 2018. Treatments were arranged in a randomized complete block design and replicated five times. Enclosures were checked daily and the number of insects found actively feeding was recorded for each enclosure. Dead or missing insects were replaced as needed throughout.

**Data Collection**

To assess the level of feeding within each treatment, cumulative insect days were calculated based on the procedure described in \cite{ruppel1983}. Insect days were calculated using the following equation:

$$\text{Insect Days} = (X_{i-1} - X_i) \times [(Y_i + Y_{i+1})/2]$$

where $X$ is the sampling date and $Y$ is the observed number of actively feeding insects. The sequential sum of each insect day throughout the experiment represents the cumulative insect days used in statistical analysis.

Once enclosures were removed, the distance from the soil to the highest leaf collar was measured for each plant. The level of damage from feeding was recorded on a scale of 1–3 corresponding to the damage ratings used in the observational study (1 = ratings 1 and 2, 2 = rating 3, and 3 = ratings 4, 5, and 6). The number of tillers each plant produced and plant mortalities during the experiment were also recorded. Plots were marked on either end with flags to identify treated plants later in the season. In 2017, plants were revisited at milk stage (R3) and the damage was reassessed for all treated plants as described above. Around physiological maturity (R6), all ears from treated plants were hand-harvested. The number of kernel rows, the average number of kernels per row, the total kernel weight, and the weight of 100 kernels was recorded for each ear. Each individual component of yield was analyzed separately as well as the overall field-scale yield in kg/ha. Overall yield was calculated with the following equation:

$$\text{Yield (kg/ha)} = (\# \text{ of plants/ hectare}) \times (\# \text{ of kernel rows}) \times (\# \text{ of kernels/ row}) \times (\text{avg. kernel weight (kg/kernel)})$$

**Statistical Analysis**

The number of plant mortalities in each plot after enclosures were removed was analyzed as a percentage of the number of plants initially infested. The stem height, plant mortalities, number of kernel rows, number of kernels per row, total kernel weight, and overall yield were analyzed using LMs in the package lme4. The number of tillers produced by each plant was analyzed using a GLM, fitted to a Poisson distribution. Maximum likelihood ratio tests were used to determine the significance of the fixed effect in the GLMs. The cumulative insect days was the fixed effect in all models. The analysis was performed separately for each year of this experiment. All figures were generated using the package ggplot2.

**Results**

**Observational Trial**

**Damage Ratings**

Of the 406 plants in this experiment, 95 (~23%) plants were assigned a damage rating of one. An additional 155 plants (~39%) were assigned damage ratings of two or three. Plants that displayed some level of stink bug damage accounted for around 62% of the total plants sampled.

**Plant Height**

At V6/V8, plant height was not significantly related to the damage rating ($R^2 = 0.01$, $P = 0.122$). However, at R1, plant height was related to damage rating ($y = 93.7 + 18.2x$; $R^2 = 0.40$, $n = 400$, $P < 0.001$). At this growth stage, plants which that were rated with
significant damage (rating 1) were ~43% shorter on average than plants that displayed moderate to no early stink bug damage (ratings 3–6; Fig. 2).

Tillers
The number of tillers developing on each plant was significantly higher in plants that were severely damaged at V6/V8 (χ² = 78.65, df = 4, P < 0.001; Table 1). This trend was still observed when plants were revisited at R1 (χ² = 76.33, df = 4, P < 0.001). By R1, plants that were severely injured early on (rating 1) developed ~31% more tillers than less damaged plants on average (ratings 3–6).

Yield
When damage was reassessed at R1, plants with severe early stink bug damage (rating 1) were significantly less likely to have developed any ears compared with plants with less, or no, visible early season stink bug damage (ratings 3–6; χ² = 131.25, df = 4, P < 0.001). However, at the time of harvest, there was no significant difference between damage ratings and the number of ears on individual plants (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (χ² = 2.87, df = 1, P = 0.090).

Cage Trial
Plant Height and Damage
Plant height was negatively related to cumulative insect days in both 2017 (y = 11.11 – 0.11x; R² = 0.31, n = 25, P = 0.004) and 2018 (y = 29.42 – 0.19x; R² = 0.55, n = 25, P < 0.001) (Fig. 4). In 2017, cumulative insect days were not related to plant height at R3 (R² = 0.02 and P = 0.522). In 2017, cumulative insect days were not related to plant mortality (R² = 0.02 and P = 0.53). In 2018, plant mortality was positively related to cumulative insect days (y = 1.02 – 0.01x; R² = 0.52, n = 25, P < 0.001). One additional insect day per plant resulted in the additional mortality of 0.6% of the treated plants. Tillers did not develop in 2017; in 2018, some plants did develop tillers; however, they were not significantly related to cumulative insect days (χ² = 2.87, df = 1, P = 0.090). Damage ratings of plants were negatively related to cumulative insect days in 2017 (y = 2.62 – 0.01x; R² = 0.43, n = 25, P < 0.001) and 2018 (y = 2.40 – 0.01x; R² = 0.51, n = 25, P < 0.001) (Fig. 4).

Yield
Overall yield (kg/ha) was negatively related to cumulative insect days in 2018 (y = 1392 – 13.76x; R² = 0.27, n = 25, P = 0.007), but was not related to cumulative insect days in 2017 (R² = 0.05 and P = 0.304). When individual components of the yield estimation were explored, the number of kernel rows was negatively related to cumulative insect days in 2018 (y = 20.47 – 0.13x; R² = 0.22, n = 25, P = 0.017), but not in 2017 (R² = 0.13 and P = 0.083). The same trend was observed in the number of kernels per row: 2017 (R² = 0.03 and P = 0.447); 2018 (y = 8.16 – 0.08x; R² = 0.46, n = 25, P < 0.001), and the overall kernel weight per ear: 2017 (R² = 0.02 and P = 0.543); 2018 (y = 69.13 – 0.68x; R² = 0.43, n = 25, P < 0.001) (Fig. 5).

Fig. 2. Relationship of stink bug damage rating and plant height at stage: A) V6/V8 (R² = 0.01, P = 0.122) and B) R1 (y = 93.7 + 18.2x [R² = 0.40, n = 406, P < 0.001]).
Discussion

The present studies confirmed many symptoms of brown stink bug damage in corn previously described including stunting, leaf injury, tiller development, and plant mortality (Townsend and Sedlacek 1986; Sedlacek and Townsend 1988; Apriyanto et al. 1989a, b; Bryant et al. 2020). The present study additionally illustrated the influence of the severity of damage on the overall impact on plant growth, and classified the severity of damage into easily identifiable groups. This study also confirmed that severe feeding during the early stages of corn growth is capable of reducing both early growth and ultimately the yield. Moderate and minor damage found here had some impact on the early growth; however, most plants compensated throughout the season and yield was unaffected. Moreover, the lack of impacts on yield observed after eight days of feeding in the 2017 cage study, compared with the impacts on yield observed after 18 d of feeding in the 2018 cage study, imply that duration of a feeding is important to impact yield. This also implies that once damage from stink bug feeding is observed in the field, it may be too late to apply insecticide management. This emphasizes the need for early and frequent scouting of seedling corn to ensure effective management of brown stink bugs in high-risk scenarios.

Plant height was reduced early in the season in highly damaged plants in both caged and observational studies. In caged trials, this difference was observed when enclosures were removed, but when plots were revisited at R1 in 2017, there was no significant difference in plant heights. In the observational study, this difference in plant height was not observed until plants were revisited at R1. This implies that differences in plant height may not be as obvious early in the season compared with later in the season in some cases. Therefore, other indicators of early damage such as the number of tillers, level of leaf injury, or numbers of dead plants may be more effective metrics to determine whether yield could be impacted from brown stink bug damage.

Table 1. Number of tillers per plant (SE) within each brown stink bug damage rating

| Growth stage | Damage rating | Number of tillers/plant |
|--------------|---------------|-------------------------|
| V6/V8        | 1             | 1.93a (0.10)            |
|              | 2             | 1.42ab (0.09)           |
|              | 3             | 1.17b (0.10)            |
|              | 4–5           | 0.43c (0.08)            |
|              | 6             | 0.61c (0.09)            |
| R1           | 1             | 2.06a (0.12)            |
|              | 2             | 1.49ab (0.10)           |
|              | 3             | 1.26b (0.10)            |
|              | 4–5           | 0.64c (0.09)            |
|              | 6             | 0.63c (0.09)            |

Values within each growth stage followed by the same letter are not statistically different at alpha = 0.05.

Fig. 3. Relationship of stink bug damage rating and A) number of kernel rows per ear \( y = 68.6 + 21.6x \) \( [R^2 = 0.17, n = 377, P < 0.001] \), and B) Kernel weight per ear \( y = 13.0 + 0.7x \) \( [R^2 = 0.37, n = 377, P < 0.001] \).
from stink bug damage. In our study, moderately damaged plants were able to recover. On average, plants that received a damage rating of 3 (some leaf injury) did not have significantly reduced kernel weight when compared with average and excellent-rated plants that had no damage. Hence, it is important to make the distinction between severe damage symptoms (stunting, dead plants, Fig. 4. Effect of increasing cumulative insect days on A) plant height (2017: $y = 11.11 - 0.01x$ [$R^2 = 0.31$ and $P = 0.004$]; 2018: $y = 29.42 - 0.19x$ [$R^2 = 0.55$ and $P < 0.001$]) and B) plant damage rating (2017: $y = 2.62 - 0.01x$ [$R^2 = 0.43$, $n = 25$, $P < 0.001$]; 2018: $y = 2.40 - 0.01x$ [$R^2 = 0.51$, $n = 25$, $P < 0.001$]) after infestation in 2017 and 2018.

Table 2. Total number of plants within each damage rating by field and location (locations are a single row within each two-row plot), and average kernel weight within each plot

| Field | Location | Damage rating | Average kernel weight per ear (g) |
|-------|----------|---------------|----------------------------------|
|       |          | 1  2  3  4  5  6       |                                  |
| 1 (V6)| 1        | 4  3  6  3  9  9       | 169 abc                          |
|       | 2        | 3  5  0  3  10 13      | 182 ab                           |
|       | 3        | 3  2  7  1 14 7        | 189 a                            |
|       | 4        | 7  6  6  1  7  8       | 169 abc                          |
|       | 5        | 9  7  0  6  4          | 139 abcd                         |
|       | 6        | 9  6  9  0  3  6       | 137 bcd                          |
|       | 7        | 4  13 6  2  5  4       | 108 d                            |
|       | 8        | 3  6  6  0  11 8       | 120 cd                           |
| 2 (V8)| 1        | 14 10 5 0 2 3         | 120 cd                           |
|       | 2        | 13 12 6 1 0 2         | 112 d                            |
|       | 3        | 13 10 6 0 1 3         | 114 d                            |
|       | 4        | 13 8 4 1 4 3         | 132 bcd                          |

Totals: 95 (23%) 87 (22%) 68 (17%) 12 (3%) 74 (18%) 70 (17%)

Kernel weights followed by the same letter are not statistically different at alpha = 0.05.
and multiple tillers early in the vegetative stage) and minor symptoms (leaf injury) when assessing a field for yield impacts due to brown stink bug damage. Moreover, although individual plants recovered in our study, even when they did not, neighboring plants did not compensate adequately to improve overall yield.

The density of stink bug infestation had a significant effect on the damage level in both years of the caged trial. This illustrates the importance of the density of infestation on the level of damage occurring. The duration of infestation could also be an important factor for yield loss. Yield reduction was only seen in this trial in 2018 when cages were applied for 18 d compared with 8 d in 2017. This was accounted for in analysis through the use of cumulative insect days. While the increased duration of infestation caused additional damage, this level of infestation was analyzed on the same scale for both ears of the experiment. While the calculation of cumulative insect days for analysis accounted for the duration of infestation to an extent, further study explicitly investigating the effect of duration could be conducted.

In 2018 caged trials, each yield component of an individual ear was reduced, resulting in an overall reduction in yield as expected. These results indicate that reduction in yield is not exclusively caused by any one component of ear development, but by an overall reduction in the size of the ear. This could result from delays in the early reproductive stages of development as previously described (Apriyanto et al. 1989b). The number of kernel rows can be established as early as V6, and is adversely affected by stress during this time (Ritchie et al. 1986, Abendroth et al. 2011). This is also an important stage for shoot elongation and delays in vegetative growth can reduce a plant's ability to compete for water and nutrients, ultimately affecting the size of ears. The difference in plant height between severely injured plants and healthy plants increased throughout the season in the observational study, provides further evidence of a delay in overall plant growth leading to the yield loss seen here.

There was no significant change in the number of ears produced per plant in highly damaged plots at harvest; however, the damage was assessed when most of the field was at R1, a growth stage where a significant portion of severely damaged plants was delayed and had not yet produced an ear. All levels of damaged plants still produced ears on par with healthy plants; however, the size and kernel weight of ears from damaged plants was significantly reduced in both observational and controlled trials. This was likely a direct result in delays of developmental stages as evidenced by the analysis of ear development at R1. Although not statically significant, a plant that was severely damaged was numerically more likely to produce a second or third ear with no

![Fig. 5. Effect of increasing cumulative insect days on A) number of kernel rows (2017: \( R^2 = 0.13 \) and \( P = 0.083 \); 2018: \( y = 20.47 - 0.13x \) \[ \( R^2 = 0.22, n = 25, P = 0.017 \) \]), B) kernels per row (2017: \( R^2 = 0.03 \) and \( P = 0.447 \); 2018: \( y = 8.16 - 0.08x \) \[ \( R^2 = 0.46, n = 25, P < 0.001 \) \]), C) kernel weight (g) (2017: \( R^2 = 0.02 \) and \( P = 0.543 \); 2018: \( y = 69.13 - 0.68x \) \[ \( R^2 = 0.43, n = 25, P < 0.001 \) \]), and D) overall yield (kg/ha) (2017: \( R^2 = 0.05 \) and \( P = 0.304 \); 2018: \( y = 1392 - 13.76x \) \[ \( R^2 = 0.27, n = 25, P = 0.007 \) \]) in 2017 and 2018.]
grain which is likely a physiological response to that early damage. A second or third ear could also have no grain develop due to a lack of pollen availability when silks emerge on these ears. Plants that produced multiple ears in the observational study often had little to no grain on secondary and tertiary ears. A plant producing multiple ears likely has poor pollination on several of those ears, in addition to suboptimal inputs for filling grain on multiple ears.

The controlled cage study results, in combination with the observational study, confirm previous research findings about the effects of brown stink bug feeding on early growth and yield. When assessing damage at V6/V8 (around 3 wk post-planting), early damage capable of causing yield loss had already occurred in most cases. Severely damaged plants also have the potential to reduce the field scale yield, even in the presence of adjacent healthy plants. Early and frequent scouting of corn, especially in high-risk fields for brown stink bug infestations, is critical for applying effective management strategies. Previous research has indicated that at field-realistic population levels, corn is no longer susceptible to damage after V6 until the late vegetative stages of development (Townsend and Sedlacek 1986, Annan and Bergman 1988). We have shown here that severe damage can be manifested prior to this stage, suggesting that scouting should likely begin at emergence. The risk factors that elevate the likelihood of an early infestation may include fields surrounded by weedy borders, crop residues from other suitable hosts, or pine forests (Tillman 2011, Babu et al. 2019). Reduced tillage in corn fields may also complicate scouting efforts as stink bugs are generally less active in the daytime hours and may shelter in residues during that time (Ni et al. 2016).

Although brown stink bugs were observed in the observational study fields feeding prior to V6 and other pests were not, it is possible that, for some plants, the symptoms classified as stink bug damage could have been caused by southern corn billbug (Sphenophorus callosus Olivier) feeding. The symptoms of feeding in the early stages of corn development are nearly indistinguishable, and if southern corn billbugs were present, they could have confounded the results of this experiment. Stink bug infestations are also commonly confined to the edges of corn fields (Reisig et al. 2013, Ni et al. 2016) near woods, where southern corn billbugs also tend to occur (Wright et al. 1983).

It is important to note the limitations in conclusions drawn here due to the sample size of the presented experiments. The number of plots in the observational study described here was limited due to being conducted in a commercial field, but the two locations were distinct for the purposes of stink bug population dynamics. While further replication is needed in future studies, the conclusions presented here provide support for previously published research regarding the effects of stink bug feeding on seedling corn and do not detract from those findings. More replications of controlled trials presented here would continue to confirm the results presented here on the effect of insect density on the level of damage and the yield potential.

Conclusions

The frequency and severity of brown stink bug infestations have increased in corn in the southeastern United States in recent years. Brown stink bugs are capable of causing severe damage during the early stages of corn development that can lead to later yield loss; the present studies illustrate the importance of the density of infestation and severity of plant damage on the impact on yield. In both the observational field trial, and in controlled trials presented here, early feeding was capable of impacting both early growth and grain yield on a field level scale. Results from this study can be used in conjunction with previous work to help inform management recommendations on when to be scouting corn for brown stink bugs as well as the level and severity of damage that ultimately has an impact on grain yield.

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Author Contributions

Conceived and designed experiments: D.D.R. and A.B. Performed the experiments: D.D.R. and A.B. Data Analysis: T.B.B. and D.D.R. Manuscript preparation and editing: T.B.B., A.B., and D.D.R.

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