Diurnal Activities of the Brown Stink Bug (Hemiptera: Pentatomidae) in and near Tasseling Corn Fields[1]

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Abstract The demand for effective management of the brown stink bug, *Euschistus servus* (Say), in corn and other crops has been increasing in recent years. To identify when and where the stink bugs are most likely to occur for targeted insecticide application, diurnal activities of stink bugs in and near the fields of tasseling corn plants were monitored using pheromone traps. Trap capture of the brown stink bugs in the corn field showed that the number of females was greater at corn field edges than in the interior, but there was no difference in male capture between the edge and interior. Stink bug dispersal within corn fields was further monitored using a mark–release–recapture technique, but the technique was not effective because only one of 158 marked individuals was recovered in the pheromone trap. To further understand the movement pattern among host plants, brown stink bugs were monitored continuously for 6 d near the tasseling corn fields using the pheromone traps. The number of females caught in pheromone traps near the corn fields in early mornings and evenings was greater than in the midafternoon. Within each sampling time across the 6-d monitoring period, total number and number of each sex caught in early mornings were greater on the first 2 d when compared to the remaining 4-d monitoring period. The implications of the findings for brown stink bug management are discussed.

Key Words *Euschistus servus* (Say), diurnal movement, mark–release–recapture, pheromone-baited trap

Populations of the brown stink bug, *Euschistus servus* (Say) (Hemiptera: Pentatomidae), have steadily increased during the last decade in the southeastern United States on corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogaea* L.), and soybean (*Glycine max* [L.] Merrill). Reasons for the population increase are thought to be attributed to the reduced broad-spectrum insecticide usage after boll weevil eradication, and significantly less insecticide usage due to widespread adoption of transgenic *Bt* corn and cotton in the region. Common host crops in Georgia include wheat (*Triticum aestivum* L.), rye (*Secale*

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cereale L.), corn, cotton, soybean, peanut, peach (*Prunus persica* [L.] Batsch), and pecan (*Carya illinoinensis* [Wangenh.] K. Koch).

Among the host crop plants, Buntin and Greene (2004) reported that the most abundant nymphs were brown stink bug in the headed wheat fields, while the most abundant adults in the wheat fields were rice stink bug, *Oebalus pugnax* (F.) (Hemiptera: Pentatomidae). These studies indicated that wheat is a good host for the first generation of brown stink bug development in the spring. Tillman (2010) reported that the dominant stink bug species in corn fields are the southern green (*Nezara viridula* [L.] [Hemiptera: Pentatomidae]) and brown stink bugs, although populations of the two species vary among years. Additionally, Ni et al. (2010) reported that brown stink bug damage impacted the quality of corn grain more than corn yield when ears were fed upon by the brown stink bugs.

Jones and Sullivan (1982), Herbert and Toews (2011), and Tillman (2011) reported that stink bugs move among host plants to feed on the available reproductive fruits or pods, which generally coincides with flowering of host plants. In mark–release–recapture experiments conducted by Jones and Sullivan (1982), low recapture rates were obtained on different stink bug host plants. Brown stink bug damage at early reproductive growth stages—tasseling and midsilking stages—of corn plants affected the yield and quality more than its later damage at the blister stage (Ni et al. 2010).

In addition to crop phenological patterns, hemipteran insect activities in relation to weather conditions have been reported previously. Tuda and Shima (2002) reported that dispersal and activities of *Orius minutus* (L.) (Hemiptera: Anthocoridae) are temperature dependent. Kamminga et al. (2009) used an 18-yr dataset (1990–2007) and demonstrated that black light trap capture of *Chinavia hilare* (Say) (Hemiptera: Pentatomidae) adults were positively related to the number of days below freezing, and negatively related to mean monthly precipitation from January to April. Because brown stink bugs and other stink bugs prefer to feed on the fruits or seeds of their host plants, corn tasseling and flowering across the southern Coastal Plain region of the United States is typically synchronized with harvest of small grains (i.e., rye and wheat) (Buntin and Greene 2004, Reay-Jones 2010), which may lead to increased movement of adult brown stink bugs to other crops, including corn. Reay-Jones (2010) reported that the brown stink bug adults show a strong field edge effect in the wheat field. However, frequency and diurnal movement of brown stink bugs among its host crops is not well understood. In particular, across the southeastern United States, detailed information on diurnal movement of brown stink bugs among surrounding host plants (e.g., wheat and rye harvest and adjacent tasseling corn fields) are still not clear (Reisig 2011). Thus, the objective of the current research was to monitor the diurnal activities of brown stink bug adults within and around the tasseling corn fields. Brown stink bug activities within a corn field were monitored in 2005 using the pheromone-baited traps at the edge and the interior, and a mark–release–recapture method. In addition, in 2008, trap capture of the brown stink bugs near the tasseling corn fields associated with a harvested rye field on one side and a pine tree nursery on another was also monitored four times per day continuously for 6 d using the pheromone-baited traps.

Materials and Methods

Experimental sites. All experiments were conducted on the USDA–Agricultural Research Service (ARS) Belflower Farm (N 31°31′, W 83°34′) and the University of Georgia Lang-Rigdon Farm (N 31°31′, W 83°33′), which are located northwest of Tifton, GA. The corn hybrid 'DKC64-10' (DeKalb Seeds, St. Louis, MO) was planted on 22 March 2005 and on 25 March 25 2008. The plants were at the tasseling stage according to Lee et al. (2007) when the experiments were conducted.

Diurnal movement of the brown stink bugs in a tasseling corn field in 2005. The pheromone trap used in this study was described in detail by Mizell and Tedders (1995) and Cottrell et al. (2000). The *Euschistus* spp. aggregation pheromone (i.e., methyl [2E, 4Z]-decadienoate) (Aldrich et al. 1991) and the yellow pyramid trap provide a chemical and a visual cue for attracting brown stink bug adults. Traps were provisioned with a 10% lamda-cyhalothrin + 13% piperonyl butoxide–impregnated cattle ear tag (Sabre™ Extra, Merck Animal Health, Madison, NJ) to prevent escape of stink bugs.

To determine patterns of diurnal activities of brown stink bug adults in corn fields for designing effective management strategies (e.g., the timing of the insecticide applications), 10 pheromone-baited traps were placed in a corn field (approximately 0.4 ha) before tasseling stage at the Belflower Farm (Fig. 1A). Trap capture of *E. servus* adults was examined three times (i.e., early morning [8 a.m.], the late afternoon [4 or 5 p.m.], and evening [8 p.m.]) per 24 h to determine when the insects were active. Trap samples were collected six times starting at 5 p.m. on 26 May and ended at 8 a.m. on 28 May 2005 when the migration occurred. Sex of the stink bug adults in the trap was recorded. Mean number of stink bugs (i.e., each sex and total number) caught per trap per sampling time between the edge and interior part of the corn field was compared.

Mark, release, and recapture of brown stink bugs in corn fields in 2005. To further determine the movement of brown stink bugs within a corn field, mark–release–recapture of adults was used when corn plants were tasseling and brown stink bug population was at the peak of its movement. The mark–release–recapture experiment was conducted in 2005 in two corn fields (approximately 0.4 ha) on the Belflower Farm and the Lang-Rigdon Research Farms near Tifton, GA. Adults caught previously (within 10 d) using the pheromone-baited traps were marked individually using a nontoxic, acid-free permanent white marker (Elmer's Products, Inc., Columbus, OH). Marked adults were released at the center of each corn field; traps were positioned at the edge and interior part of the corn fields as shown in Fig. 1A. At the Belflower Farm, 58 adults were marked and released at 10:30 a.m. on 6 June 2005. In a similar manner, 100 adults were released at the Lang-Rigdon Research Farm site at 2 p.m. on 7 June 2005. The recapture of the marked brown stink bugs in each trap was monitored for 3 d after the release of the marked stink bugs. The number of the marked brown stink bugs per trap was recorded and compared.

Brown stink bug movement near tasseling corn fields in 2008. Because previous experiments detected only limited activities within a corn field, a follow-up experiment on diurnal trap capture of *E. servus* adults near the corn fields was conducted. The experiment was conducted using 10 traps (five traps on the west

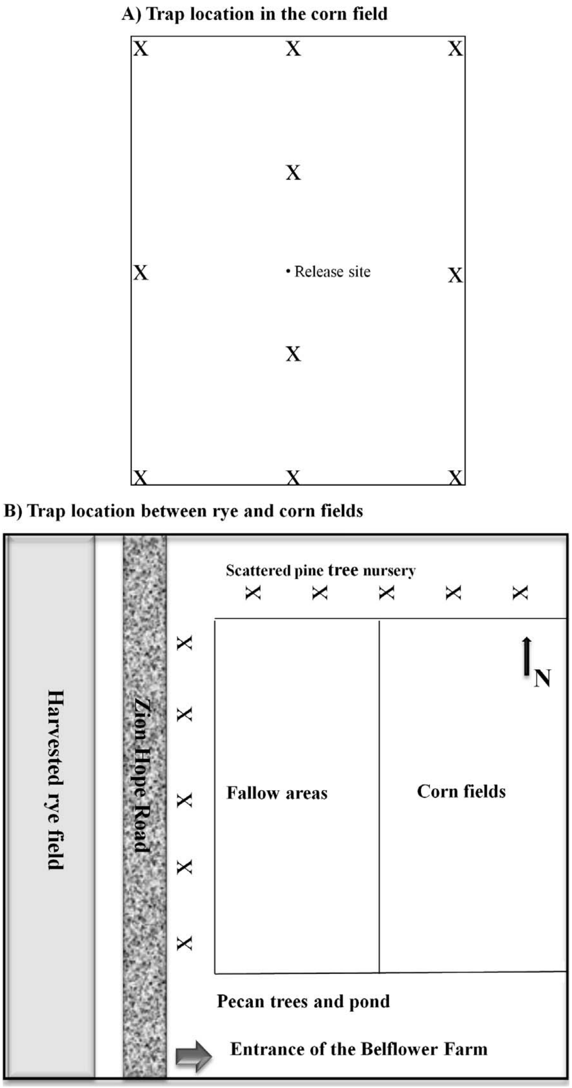

Fig. 1. Pheromone trap locations for monitoring brown stink bug movement. (A) Location of the 10 pheromone traps (marked as "X") used for monitoring the movement within a corn field. "Release site" was the point at which the marked adults were released for the mark–release–recapture experiment. (B) Location of the 10 pheromone traps (marked as "X") used for monitoring the movement outside of the corn fields. Five traps on the west side of the farm were between a harvested rye field and the tasseling corn fields, and five traps on the north side were between a pine tree nursery and the tasseling corn fields.

side that were near a harvested rye field, and five traps on the north side that were next to a pine tree nursery) (Fig. 1B). Of the five traps on the north side, two traps were next the fallow field, and three traps were next to corn fields. Monitoring was initiated 2 d after the harvest of the rye crop, and lasted for 6 d (from 1 June to 6 June 2008). Ten traps were placed at 20-m intervals away from the corn fields at the perimeter of the research farm to collect live brown stink bugs, as shown in Fig. 1B. Specifically, the first five traps were on the west side of the farm between the harvested rye field (harvested on 30 May 2008) and the tasseling corn fields, whereas the other five traps were placed on the north side of the Belflower Farm between the pine tree nursery and the corn fields (Fig. 1B). During the 6-d monitoring period, trap capture was recorded four times with an interval of approximately 2 to 4 h, that is, early morning (10–10:30 a.m.), late morning (11 a.m.–12 p.m.), midafternoon (2–4 p.m.), and in the evening (around 8 p.m.). The number of male and female stink bugs was recorded for each sampling time, starting at 10 a.m. on 1 June and ended at 8 p.m. on 6 June. The only exception to this collection schedule occurred in the evening on the first sampling day (Sunday, 1 June) which was considered a missing data point.

Correlation of stink bug capture with daily weather data in 2008. To further understand the relationship among weather data and trap capture of the brown stink bug adults, potential correlation between brown stink bug trap capture and weather data (i.e., high and low temperature and precipitation) during the 6-d experimental period in 2008 was further examined. The daily high and low temperature and precipitation data in Tifton used for correlation analysis were retrieved from www. GeorgiaWeather.net. The correlation analysis used in the current study was based on the method described by Tuda and Shima (2002) on *O. minutus* dispersal and activities in relation to temperature data, as well as the method by Kamminga et al. (2009) for the black light trap capture of *C. hilare* and weather data.

Experimental design and data analysis. Trap capture data within the corn field in 2005 and near the corn fields in 2008 were analyzed separately by utilizing a split plot design, by splitting in time (day as main plot factor and the time within a day as the subplot factor). The stink bug capture data were transformed with a reciprocal transformation because of the heteroscedastic data set (Zar 1999). All data were analyzed using analysis of variance (PROC MIXED) (SAS Institute 2010). Stink bug capture in the traps was compared among the sampling dates, and among the sampling times within each date. For the data collected in both 2005 and 2008 for stink bug capture within the corn field, the number of traps nested in the sampling days was used as the random factors, whereas trap location and sampling time were used as the fixed factors in the mixed model. Means were separated using the Fisher's protected least significant difference test ($\alpha = 0.05$). The correlation of brown stink bug capture with weather data was determined using PROC CORR procedure (SAS Institute 2010).

Results

Diurnal movement of the brown stink bugs in the tasseling corn field in 2005. When the total number of stink bugs caught across all traps within the corn field was compared among the three sampling times of a day (i.e., early mornings,

Table 1. The number of brown stink bugs caught in the traps at the edge and interior of the corn field.

Location	*n*	Female	Male	Total
Edge	48	1.60 ± 0.19 aX*	0.58 ± 0.14 aY	2.19 ± 0.28 a
Interior	12	0.67 ± 0.19 bX	0.58 ± 0.19 aX	1.25 ± 0.18 a

* Lowercase letters (a, b) denote a significant difference within a column, and uppercase letters (X, Y) denote a difference within a row between the two sexes ($P < 0.05$).

late afternoons, and evenings) in 2005, no differences were detected for male ($F = 0.05$; df = 2, 3; $P = 0.95$), female ($F = 0.17$; df = 2, 3; $P = 0.85$), or total number of stink bugs ($F = 0.12$; df = 2, 3; $P = 0.89$). The data indicated that the spatial distribution pattern (i.e., edge versus center) of brown stink bugs within the corn field did not have any specific active period throughout the day. Because there was no difference in stink bug capture among the 10 traps, the data for each trap collected from the tasseling corn field were not shown here.

The capture of females was not affected by sampling time × location interaction ($F = 0.4$; df = 2, 52; $P = 0.67$). The number of females differed between the edge and interior of the corn field ($F = 4.93$; df = 1, 52; $P = 0.03$) (Table 1), but was not influenced by sampling time ($F = 1.32$; df = 2, 52; $P = 0.28$). Analyses of male adult data indicated no influence of location × sampling time interaction ($F = 0.02$; df = 2, 52; $P = 0.98$), or trap location (edge versus interior of the corn field) ($F = 0.38$; df = 1, 52; $P = 0.54$) (Table 1), or sampling time ($F = 0.03$; df = 2, 52; $P = 0.97$) occurred. When total number of the brown stink bugs in each of the 10 traps was analyzed, trap location and sampling time interaction did not affect stink bug capture ($F = 0.17$; df = 2, 53; $P = 0.84$), either among the three sampling times per day ($F = 0.18$; df = 2, 53; $P = 0.84$), or between the edge and interior of the corn field ($F = 0.19$; df = 1, 53; $P = 0.66$) (Table 1).

Mark, release, and recapture of the brown stink bugs within the tasseling corn fields in 2005. A total of 58 stink bugs were released at the center of the corn field on 6 June 2005. Only a single marked male was caught within 48 h (on 8 June 2005) in a trap at interior of the corn field. In addition, on 7 June 2005, 100 marked brown stink bug adults were released, and none of the marked stink bugs were caught within 72 h. Overall, a total of 158 marked brown stink bugs were released for the two replications of the experiment, but only one male stink bug was captured in the pheromone traps during the 3-d (72-h) monitoring period.

Diurnal movement patterns near tasseling corn in 2008. Brown stink bug capture varied significantly among the four daily sampling times ($F = 5.24$; df = 3, 211; $P = 0.002$) (Fig. 2A) and among the sampling days ($F = 2.51$; df = 5, 211; $P = 0.03$), but was not affected by the physical location of the traps (i.e., next to the harvested rye field or pine tree nursery) ($F = 1.33$; df = 1, 211; $P = 0.25$). In general, more brown stink bugs were caught in early mornings and evenings compared to late morning and midafternoon (Fig. 2A). There were differences among the four sampling times ($F = 4.93$; df = 3, 211; $P = 0.003$) within a day for females (Fig. 2B), but no differences among the sampling days ($F = 2.2$; df = 5, 211; $P = 0.06$), or between the locations of the traps (i.e., near either the harvested rye field or next to

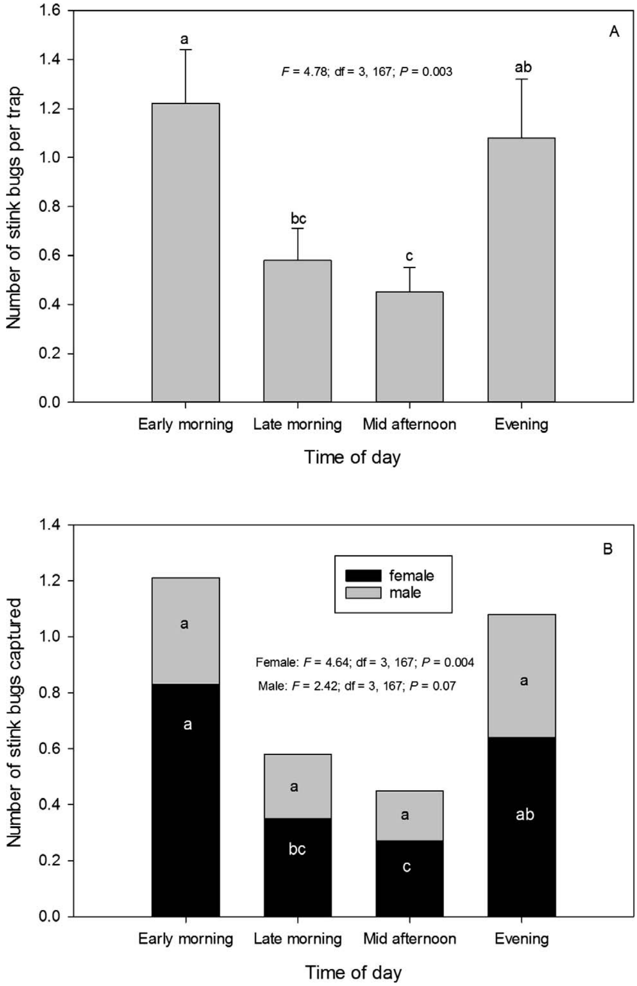

Fig. 2. Trap capture of brown stink bug adults during 2008 in pheromone traps associated with tasseling corn. Traps were sampled four times (i.e., early morning, late morning, midafternoon and evening). (A) Mean number ± SE of adult brown stink bug capture at each sampling time; (B) male and female caught at each sampling time.

the pine tree nursery) ($F = 1.5$; df = 1, 211; $P = 0.22$). Male capture was not different among the four sampling times throughout the day ($F = 2.62$; df = 3, 211; $P = 0.07$) (Fig. 2B), among the sampling days ($F = 1.42$; df = 5, 211; $P = 0.22$), or among the locations of the traps (i.e., near the harvested rye field or near the pine nursery) ($F = 1.49$; df = 1, 211; $P = 0.22$). Although male trap capture was similar among different sampling times within a single day, the number of females was significantly different (Fig. 2A, B).

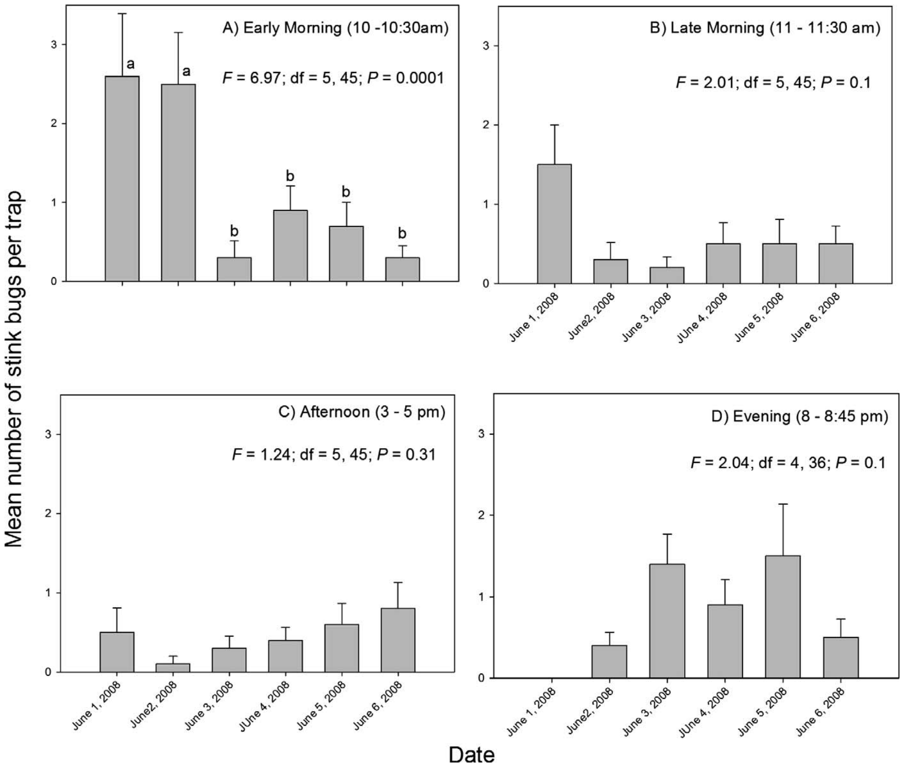

Fig. 3. Daily variation of trap capture of brown stink bug adults at each of the four sampling times throughout the day ($n = 10$). (A) Early morning, (B) late morning, (C) midafternoon, and (D) evening.

When the total trap capture was further examined by location (five traps near the harvested rye field versus five traps adjacent to the pine tree nursery), the total number of brown stink bugs was not different at each of the four daily sampling times ($P > 0.05$). The data suggest that the sources of stink bug movement into the tasseling corn fields might not be solely from the harvested rye field.

When trap capture of brown stink bugs was further examined across the 6-d experiment period at each of the four sampling times, the response varied among the sampling times (Fig. 3A, B, C, D). In the early morning, stink bug capture varied among the 6-d experiment period ($F = 6.97$; df $= 5, 45$; $P = 0.0001$) (Fig. 3A), but the variation was not significant in any other three sampling times during the 6-d monitoring period (Fig. 3B, C, D). The data suggest that trapping *E. servus* early in the morning could be vital for monitoring stink bug movement from the newly harvested small-grain fields to the tasseling corn fields. It is also possibly the best time to sample or collect migrating stink bug adults in the corn fields.

When the number of males and females was compared among the 6-d period at each of the four sampling times, trap capture of brown stink bugs varied across the 6-d experiment period at each sampling time. For early morning samples, the

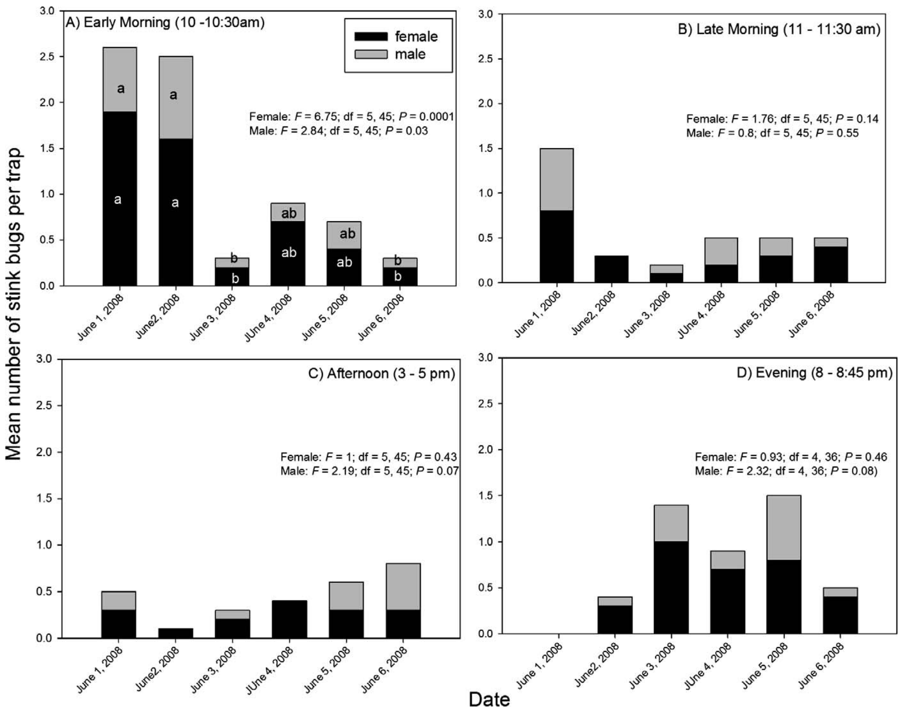

Fig. 4. Trap capture of male and female brown stink bugs at each of the four sampling times throughout the day ($n = 10$). (A) Early morning, (B) late morning, (C) midafternoon, and (D) evening.

number of females ($F = 6.75$; df = 5, 45; $P = 0.0001$) and males ($F = 2.84$; df = 5, 45; $P = 0.03$) differed across the sampling days (Fig. 4A), but no difference was detected in late morning samples for either females ($F = 1.76$; df = 5, 45; $P = 0.14$) or males ($F = 0.8$; df = 5, 45; $P = 0.55$) (Fig. 4B). Neither midafternoon samples (females: $F = 1$; df = 5, 45; $P = 0.43$; males: $F = 2.19$; df = 5, 45; $P = 0.07$) (Fig. 4C) nor evening samples (females: $F = 0.93$; df = 4, 36; $P = 0.46$; males: $F = 2.32$; df = 4, 36; $P = 0.08$) (Fig. 4D) differed significantly. During the 6-d monitoring period, the number of brown stink bugs caught in the early morning of the first 2 d was greater than the other 4 d (Figs. 3A, 4A). This could be due to high number of migrating adults in the first 2 d (1–2 June), which was shortly after the rye was harvested on 30 May 2008. Nevertheless, the pooled 6-d data showed that brown stink bug captures in the early mornings and evenings were greater than that in the midafternoons (Fig. 2A, B).

Correlation of stink bug number with weather data in 2008. The weather data during the 6-d experiment period were consistent. The mean daily maximum temperature was 33.6 ± 0.21°C (range of 32.9°C to 34.5°C) and the minimum was 21.72 ± 0.41°C (between 20.3°C and 23.1°C). Average daily temperature variation between the high and low was 11.88 ± 0.45°C. Precipitation occurred once during the study and measured 0.3 cm on 2 June 2008. There was no correlation of stink bug capture with recorded weather data ($P > 0.24$). The correlation analysis suggests that stink bug movement would not be influenced by high and low temperature if the daily temperature was between 20°C and 35°C.

Discussion

These results support previous reports that brown stink bug movement occurs among its crop hosts in agricultural ecosystems, which is a phenological event based on the harvest time of small-grain crops (e.g., rye and wheat) and along with the tasseling stage, or flowering time, of corn in the southeastern region of the United States. This generally occurs after the brown stink bugs complete a generation in small winter grain crops in southern Georgia (Buntin and Greene 2004) and the southeastern United States (Blinka 2008, Reay-Jones 2010, Reisig 2011). In addition, more females were caught in traps located at the edge of the tasseling corn field, although the total number of the stink bugs was not different between the edge and interior of the corn field. Reisig (2011) also reported that more stink bugs were at the edge than the interior at the time when stink bug movement between host crop plants occurs.

The current research may have practical ramifications to reduce brown stink bug populations and their damage to corn. In particular, when corn plants were at the tasseling stage, the number of females at the edges of the corn field was twice more than that in the interior. Also, in the traps near the corn fields, more brown stink bug adults were captured in the early mornings and evenings than that in the midafternoons. The findings are useful in determining the best time for insecticide applications to suppress migrating stink bug populations. The best way and best time to apply insecticides, according to the findings from the current study, could be at the edges of the corn fields in either early mornings or the evenings. Tillman (2010) reported that the pheromone-baited traps can be used to monitor the dispersing stink bugs between crops. Trap capture of brown stink bugs could be used to guide insecticide applications by targeting the most active period during a day in either source crop fields (e.g., rye, wheat, or triticale) or the receiving crop fields (e.g., corn). In addition, targeting the edges of the corn fields where most immigrating females were recorded could be critically important to reduce brown stink bug reproduction on corn. The results of the mark–release–recapture experiment confirmed that the technique has limited value in monitoring stink bug movement using the pheromone traps within a corn field, as Jones and Sullivan (1982) reported by sampling stink bugs on common mullein, *Verbascum thapsus* L., in a weedy field. They recorded a total of 58 marked stink bugs on *V. thapsus* after the release of 281 marked stink bugs (i.e., 194 *E. servus*, 47 *Euschistus tristigmus* [Say], and 40 *C. hilare*). Only 7 of the 58 marked stink bugs were found on the common mullein. The current study also differed from the report by Jones and Sullivan (1982). The current study monitored recapture of *E, servus* adults in pheromone traps instead of recording the number of stink bugs on plants. This could be the reason for a much lower recapture of the marked stink bugs in the 10 traps located in a corn field in the current study (i.e., 1 of 58 and 0 of 100 for two replications, respectively).

Reay-Jones (2010) reported that a strong edge effect of multiple species of stink bugs existed in wheat during the spring; perhaps stink bug populations in maturing wheat fields could be targeted spatially at the edges of fields to reduce their numbers before moving into corn in adjacent fields. The data from the 6-d continuous monitoring experiment suggested that the first few days after harvest of the small-grain crops are critical for monitoring stink bug migration to the corn fields. In addition, Reeves et al. (2010) also reported that boll injury was greatest at the edges of a cotton field adjacent to other crops, and the injury decreased as the distance between crops increased. The findings suggested that stink bugs are likely to be mobile within a crop field, and management of the initial movement of adults in a crop field is crucial in reducing losses to crop yield and quality. Tillman (2011) reported that monitoring changes in brown stink bug populations in corn fields and adjacent/subsequent maturing crop systems (e.g., corn–cotton, corn–peanut, and corn–peanut–cotton crop hosts) were valuable for designing landscape-scale stink bug management tactics in the southern United States. Thus, the combination of population monitoring using pheromone traps and use of the trap-and-kill technique and insecticide application at the peak of stink bug movement on the edges of both maturing (or the emigrant) host crop plants (e.g., maturing rye or wheat) and new hosts (e.g., corn, cotton, peanut, or orchard crops) has the potential to synergistically reduce the initial stink bug populations. Cottrell and Horton (2011) suggested that pheromone-baited traps with insecticide strips could be used as a trap-and-kill technique for stink bug management in orchard crops. The trap-and-kill techniques (or pheromone traps with insecticide strips) and sentinel trap crops that target adult movements can suppress or even possibly eliminate the initial brown stink bug infestation at the edge of a crop field. Further detailed studies are needed to validate these types of preventative management measures in the multiple cropping systems to manage a common pest—the brown stink bug.

Acknowledgments

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