Seasonal Occurrence and Vertical Distribution of *Euschistus servus* (Say) and *Euschistus tristigmus* (Say) (Hemiptera: Pentatomidae) in Pecan Orchards[1,2]

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Abstract *Euschistus servus* (Say) and *E. tristigmus* (Say) were monitored near and in pecan orchards at ground level only and in pecan orchards from the ground to the upper canopy. Modified pyramidal traps, baited with *Euschistus* spp. aggregation pheromone, were placed on the ground along a hedgerow adjacent to a pecan orchard, at the orchard edge, and at the orchard center to monitor seasonal occurrence. Vertical distribution of *E. servus* and *E. tristigmus* was monitored by placing pheromone-baited traps at preselected heights. Traps on the ground along the hedgerow, orchard edge, and orchard center captured similar numbers of stink bugs each month from May through September, with an increase in October at all locations (combined data for both species). Single traps placed at different heights captured peak numbers of *E. servus* in early and late season; whereas, traps captured peak numbers of *E. tristigmus* during the late season. More *E. servus* were captured in traps on the ground than in traps in the canopy, but more *E. tristigmus* were captured in the canopy at 9 m. With two baited traps placed at different heights at the same tree, more *E. servus* were captured on the ground than in the lower or upper canopy, but most *E. tristigmus* were captured in the lower and upper canopy than on the ground. Placement of traps on the ground or at 9 m resulted in more captures of *E. servus* on the ground and more captures of *E. tristigmus* at 9 m. Although *E. servus* and *E. tristigmus* were captured both on the ground and in the pecan canopy, numbers of captured *E. servus* and *E. tristigmus* were affected by trap height. Thus, sampling *Euschistus* species in pecan, and possibly other arboreal habitats, should be done throughout the canopy.

Key Words Hemiptera, Pentatomidae, *Euschistus servus, Euschistus tristigmus,* stink bug, distribution, *Carya illinoensis,* pecan

Phytophagous stink bugs (Hemiptera: Pentatomidae) are economically important pests of many agricultural crops, including annual row crops and perennial orchard crops (Woodside 1946, Toscano and Stern 1976, Yeargan 1977, Jones and Sullivan 1982, Barbour et al. 1988, McPherson et al. 1993, 1994). Ellis and Dutcher (1999) reported that stink bugs and other kernel-feeding hemipterans cost Georgia pecan growers an estimated $1.8 million during 1997. The predominant stink bug pests of pecan, *Carya illinoensis* (Wang.) K. Koch, in the southeastern United States are the

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southern green stink bug, *Nezara viridula* (L.), green stink bug, *Acrosternum hilare* (Say), and brown stink bug, *Euschistus servus* (Say) (Demaree 1922, Turner 1923, Dutcher and Todd 1983). The dusky stink bug, *E. tristigmus* (Say), also attacks pecan (Dutcher and Todd 1983, Polles et al. 1973), but little has been reported on its occurrence.

Damage to pecan nuts by different pentatomids is similar (Dutcher and Todd 1983, Yates et al. 1991). Their feeding reduces both kernel quality and yield. Stylet penetration of the shell of developing fruit before shell-hardening causes the kernel to rot (commonly called blackpit) and usually fruit abscission; whereas, post shell-hardening punctures induce localized, black lesions on the kernel (commonly called kernel spot) and fruits do not abscise (Demaree 1922, Osburn et al. 1966). Lesions on kernels are bitter and must be separated after harvesting (Turner 1918, Demaree 1922, Osburn et al. 1966). Payne and Wells (1984) reported that 52% of these lesions harbored various genera of fungi including *Penicillium, Alternaria, Fusarium,* and *Aspergillus.*

Most damage to pecan by Pentatomidae generally has been considered a result of late-season movement into orchards when host row crops and groundcovers are harvested or senesce (Turner 1918, Mizell et al. 1997, Smith 1998). Therefore, monitoring stink bugs typically begins later in the season (Ellis et al. 1998). Turner (1918) correlated increased kernel damage and high *N. viridula* populations in orchards where cowpea, *Vigna unguiculata* (L.), was used as a groundcover. Dutcher and Todd (1983) showed that more hemipteran kernel damage occurred in orchards planted with a cowpea groundcover than without that groundcover. Demaree (1922) reported that most nut damage by Pentatomidae occurred lower in the canopy, although stink bugs were found throughout the canopy. In support, Dutcher and Todd (1983) showed that more nuts were damaged at heights <8 m than >8 m.

Mizell and Tedders (1995) reported the development of a pyramidal trap which was more practical than visual sampling and knockdown sprays for detection of stink bugs in pecan. Mizell et al. (1997) further modified the trap by adding a *Euschistus* spp. aggregation pheromone. The aggregation pheromone, methyl 2,4-decadienoate, is attractive to males and females of at least five species of *Euschistus* including *E. servus* and *E. tristigmus* as well as certain parasitic tachinids (Aldrich et al. 1991). Yonce and Mizell (1997) found that 93% of stink bugs captured in pheromone-baited traps in a pecan orchard were *E. servus* and *E. tristigmus.*

Our objectives were to use pheromone-baited traps to examine the seasonal occurrence of *E. servus* and *E. tristigmus* adults within, and adjacent to, pecan orchards at ground level. We also used pheromone-baited traps to document vertical distribution of both species within pecan orchards.

Materials and Methods

Traps were made by placing 2.8-liter clear plastic PET® jars (United States Plastic Corp., Lima, OH) with screw-cap lids on top of 1.22-m-tall yellow pyramidal traps (Mizell and Tedders 1995). The bottom of each jar was cut away and replaced with an inverted, wire-screen funnel. The larger opening of the funnel (12-cm diam) was stapled around the inside bottom of the jar with the funnel protruding into the jar. This allowed the smaller funnel opening (5-cm diam) to serve as an attachment point for the jar to the top of the pyramidal trap. The pyramidal trap baffles fit snugly into this smaller opening with ~3 cm of the baffles protruding past the opening and into the jar.

The jar was vented with 2 rows (4 cm apart) of 6 equidistant 2.3-cm diam holes around the circumference of the jar. A 10-cm wide strip of wire screen stapled around the circumference of the jar prevented stink bugs from escaping. A 7.5-cm diam vent also was made in the jar lid and covered with wire mesh. Stink bugs entered by crawling up baffles of the pyramidal trap, through the funnel, and into the jar.

Test 1. In 1997, near Montezuma, GA, seasonal occurrence of *E. servus* and *E. tristigmus* was monitored by placing pheromone-baited traps on the ground at locations near and within, a 20-yr-old orchard of 'Stuart' and 'Desirable' trees. Traps were placed along a hedgerow adjacent to the orchard, at the orchard edge, and at the orchard center. Ten traps were aligned at each site and traps within the same row were separated by 37 m. Distance between the hedgerow trap row and the orchard edge trap row was 27 m; whereas, the orchard edge trap row and orchard center trap row were 137 m apart. A rubber septum baited with 20 µl of pheromone, methyl 2,4-decadienoate (Bedoukian Research, Inc., Danbury, CT) was added to the jar of each trap. Traps were checked 3 times each week during the growing season and once each week during the winter. Numbers of trapped *E. servus* and *E. tristigmus* were recorded, and pheromone-baited septa were replaced weekly. Mean numbers of *E. servus* per trap at the hedgerow, orchard edge, and orchard center were compared using analysis of variance as were mean numbers of *E. tristigmus* per trap (SAS Institute Inc. 1995).

Test 2. Seasonal occurrence and vertical distribution of *E. servus* and *E. tristigmus* was determined in an ~50-yr-old 'Moneymaker' orchard near Montezuma, GA from April through December 1997 and from March 1998 through February 1999. Trees in this orchard were ~15 to 18 m tall. Ten trees, at least 90 m apart, were selected for this study. Trap locations were randomly assigned to one of five heights (0, 3, 6, 9, or 12 m above ground) at each tree such that all positions were replicated twice. Traps used were as previously described, except when raised to 3, 6, 9, and 12 m above ground, traps were attached to a rope that ran through a pulley mounted on a limb in the upper canopy of the tree, thus allowing traps to be raised to specified heights. A rope attached to the bottom of the trap ran to the ground and served as an anchor. When a trap was at ground level, a metal rod extending ~20 cm from the bottom center of the trap was set into a piece of conduit that had been driven into the ground. Traps remained at the same tree throughout the study, but trap height (0, 3, 6, 9, 12 m) was randomized weekly.

In 1997, 5 traps (one at each height) were each baited using 20 µl of pheromone impregnated on a rubber septa. The remaining 5 traps, one at each height, were not baited. In 1998, the study was done similarly except that all traps were baited with 40 µl of pheromone impregnated on rubber septa. In each year, *E. servus* and *E. tristigmus* were collected from traps 3 times each week during the growing season and once each week during the winter. Pheromone-baited septa were changed weekly when trap positions were re-randomized. Vertical distribution of *E. servus* and *E. tristigmus* in 1997 and 1998 was separately analyzed using analysis of variance (SAS Institute Inc. 1995). In 1997 and 1998, data collected from May through October (i.e., when pecan nuts were on trees) were used to compare the vertical distribution of *E. servus* with that of *E. tristigmus* using analysis of variance. The Tukey-Kramer Honestly Significant Difference test (HSD) was used to separate means when a significant difference was found ($P \leq 0.05$) (SAS Institute Inc. 1995).

Test 3. In 1997, three mature pecan trees (~15 to 18 m tall), each tree in a different orchard on the same farm near Montezuma, GA, were selected and two baited traps, as described previously, were placed at each of the trees. Distance between trees was at least 335 m. The following trap positions were randomly assigned to trees each week: (1) ground and lower half of canopy, (2) ground and upper half of canopy, or (3) lower half and upper half of canopy. All traps were baited with 20 µl of pheromone on rubber septa. Traps were checked 3 times each week and septa were replaced weekly when trap positions were re-randomized. The test was run for 11 wks from June through August. Trap captures of *E. servus* in each treatment were compared using analysis of variance and same was done for *E. tristigmus.* Also, we compared trap captures of *E. servus* and *E. tristigmus,* separately, at each height (ground, lower canopy, and upper canopy) (SAS Institute Inc. 1995).

Test 4. In 1999, using 1 trap per tree, we placed 5 baited traps (40 µl of pheromone per septa) on the ground and 5 baited traps at 9 m. Specimens were collected from traps 3 times each week, baited septa were replaced and trap positions (ground or 9 m) were randomized weekly. The study was run for 10 wks from June through mid-August. Trap captures of *E. servus* and *E. tristigmus* at ground level and at 9 m were separately compared using analysis of variance (SAS Institute Inc. 1995).

Results and Discussion

Throughout this study, *E. servus* and *E. tristigmus* were the predominant pentatomid species captured. Other herbivorous pentatomids (predominantly *N. viridula* and *A. hilare*) were not captured consistently, represented a low percentage of trap captures and, therefore, are not presented.

Test 1. *Euschistus servus* and *E. tristigmus* were captured during all months in pheromone-baited traps on the ground, although trap captures were low during December, January, and February (Fig. 1). *Euschistus servus* was not trapped in the hedgerow or orchard edge during December, and *E. tristigmus* was not trapped at the orchard center in January or December nor at the orchard edge in December. More *E. servus* and *E. tristigmus* were captured during October at each site than other months and their numbers remained relatively stable at all sites from May through September. Overall, trap captures of *E. servus* and *E. tristigmus* were greatest in the center of the orchard compared with the hedgerow and orchard edge but differences for neither species were significant ($F = 2.24$; df = 2, 153; $P > 0.05$, $F = 1.16$; df = 2, 153; $P > 0.05$, respectively). Hedgerow traps and orchard edge traps were nearer (~27 m apart) than orchard edge and orchard center traps (~137 m apart). Traps at the hedgerow and orchard edge may have attracted *E. servus* and *E. tristigmus* from the same area, thus reducing *E. servus* and *E. tristigmus* captures per trap and preventing detection of relative abundance at the hedgerow versus the orchard edge. Similar to findings by Yonce and Mizell (1997), we captured more *E. servus* in these pheromone-baited traps (60, 56, and 52% at the hedgerow, orchard edge, and orchard center, respectively) than *E. tristigmus.*

Test 2. When pheromone-baited and unbaited traps were placed not only on the ground but also at heights of 3, 6, 9, and 12 m, all unbaited traps captured low numbers of *E. servus* and *E. tristigmus*. The combined mean (±SE) of *E. servus* + *E. tristigmus* captured in unbaited traps at the ground, 3, 6, 9, and 12 m was 0.26 ± 0.13, 0.03 ± 0.03, 0.00 ± 0.00, 0.11 ± 0.07, and 0.06 ± 0.04 stink bugs per trap per week, respectively. Pheromone-baited traps did, however, catch *E. servus* and *E. tristigmus* during most months this study was done (Figs. 2, 3). Trap captures of *E. servus* and *E. tristigmus* adults peaked at different times of the season. During both years, *E.*

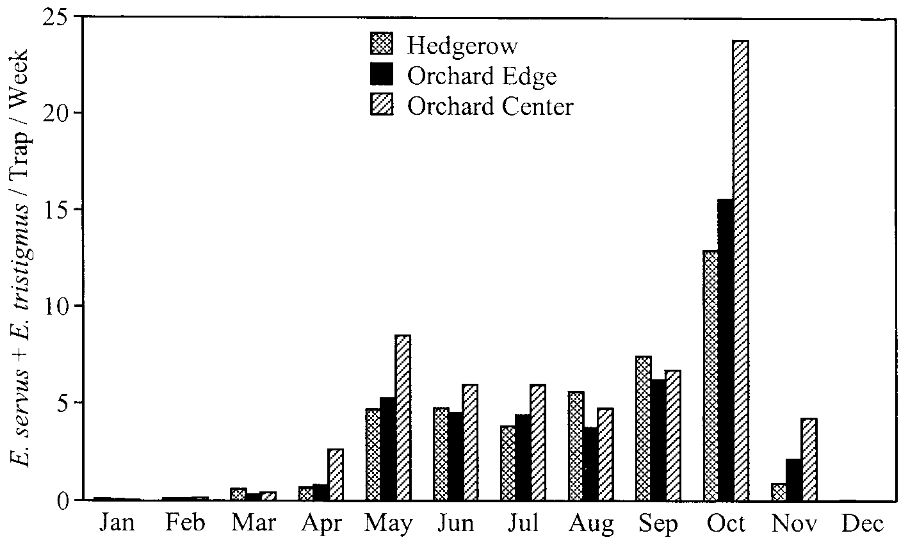

Fig. 1. Combined seasonal occurrence of adult *E. servus* and *E. tristigmus* captured in pheromone-baited traps on the ground during 1997. Traps were located along a hedgerow between a peanut field and a pecan orchard and at the edge and center of the same pecan orchard.

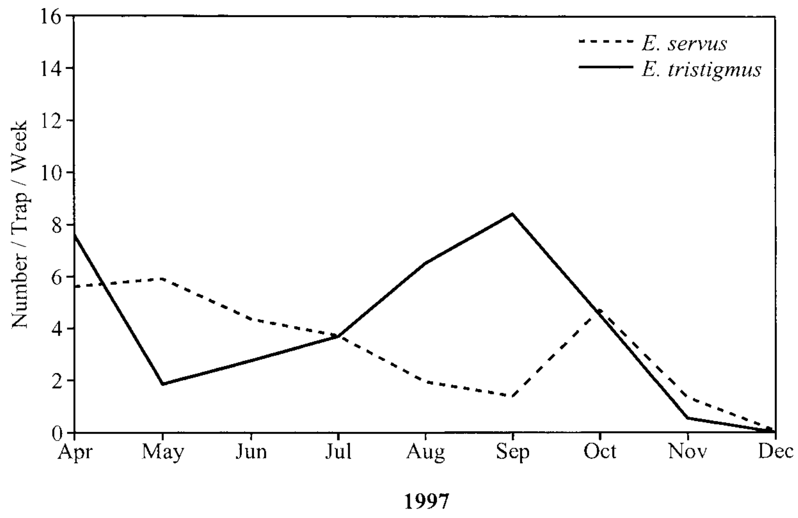

Fig. 2. Captures of *E. servus* and *E. tristigmus* in pheromone-baited traps when traps were placed at heights of 0, 3, 6, 9, and 12 m within a pecan orchard, April-December 1997. Data from all heights for each species have been combined.

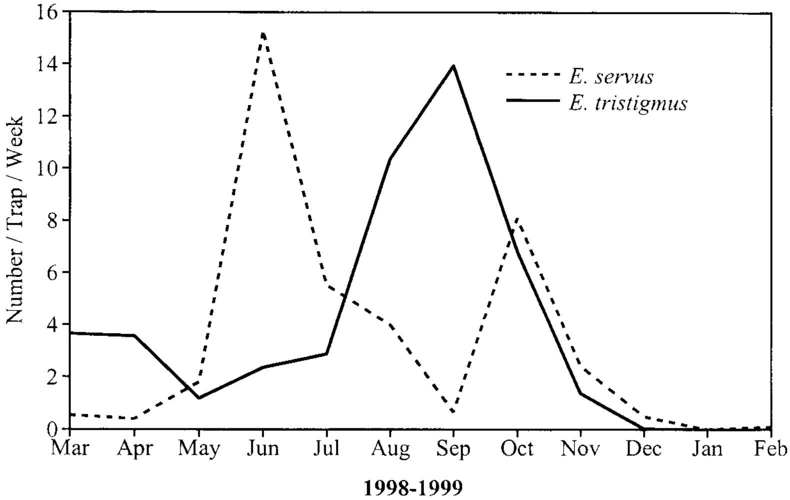

Fig. 3. Captures of *E. servus* and *E. tristigmus* in pheromone-baited traps when traps were placed at heights of 0, 3, 6, 9, and 12 m within a pecan orchard, March 1998-February 1999. Data from all heights for each species have been combined.

servus peaks occurred between May and June and again during October, whereas *E. tristigmus* peaked during September of each year.

When we examined vertical distribution of *E. servus* and *E. tristigmus* in the orchard (from May through October), we found a season-long trend of more *E. servus* adults in ground traps than at 3, 6, 9, or 12 m for each year (Fig. 4A). In fact, the difference was significant in 1997 ($F = 6.13$; df = 4, 125; $P < 0.05$); however, in 1998 trap captures were greater in traps on the ground than at 3 or 6 m ($F = 3.68$; df = 4,125; $P < 0.05$) but not at 9 or 12 m. In both years, there was a trend to catch more *E. tristigmus* higher in the canopy (Fig. 4B). Trap captures of *E. tristigmus* at different heights were not significantly different during 1997, although statistical significance was approached ($F = 2.32$; df = 4, 125; $P = 0.06$). During 1998, more *E. tristigmus* were captured at 9 m than at the ground or at 3 m ($F = 4.07$; df = 4,125; $P < 0.05$). When trap captures of *E. servus* were compared with trap captures of *E. tristigmus* (May through October of 1997 and 1998), more *E. servus* were captured in traps at the ground than were *E. tristigmus* ($F = 9.57$; df = 1, 50; $P < 0.05$ and $F = 9.69$; df = 1,50; $P < 0.05$, respectively). In contrast, during 1997, more *E. tristigmus* were captured at 9 m than *E. servus* ($F = 11.18$; df = 1, 50; $P < 0.05$) and the same trend occurred in 1998 although the difference was not significant. During both years, the trend was that more *E. servus* than *E. tristigmus* were captured in traps on the ground and more *E. tristigmus* than *E. servus* were captured in traps at 6, 9, and 12 m. Although both species were captured at all trap positions and peak captures of each species occurred at different times of the season, our results show that *E. tristigmus* was more abundant in the pecan canopy than on the ground.

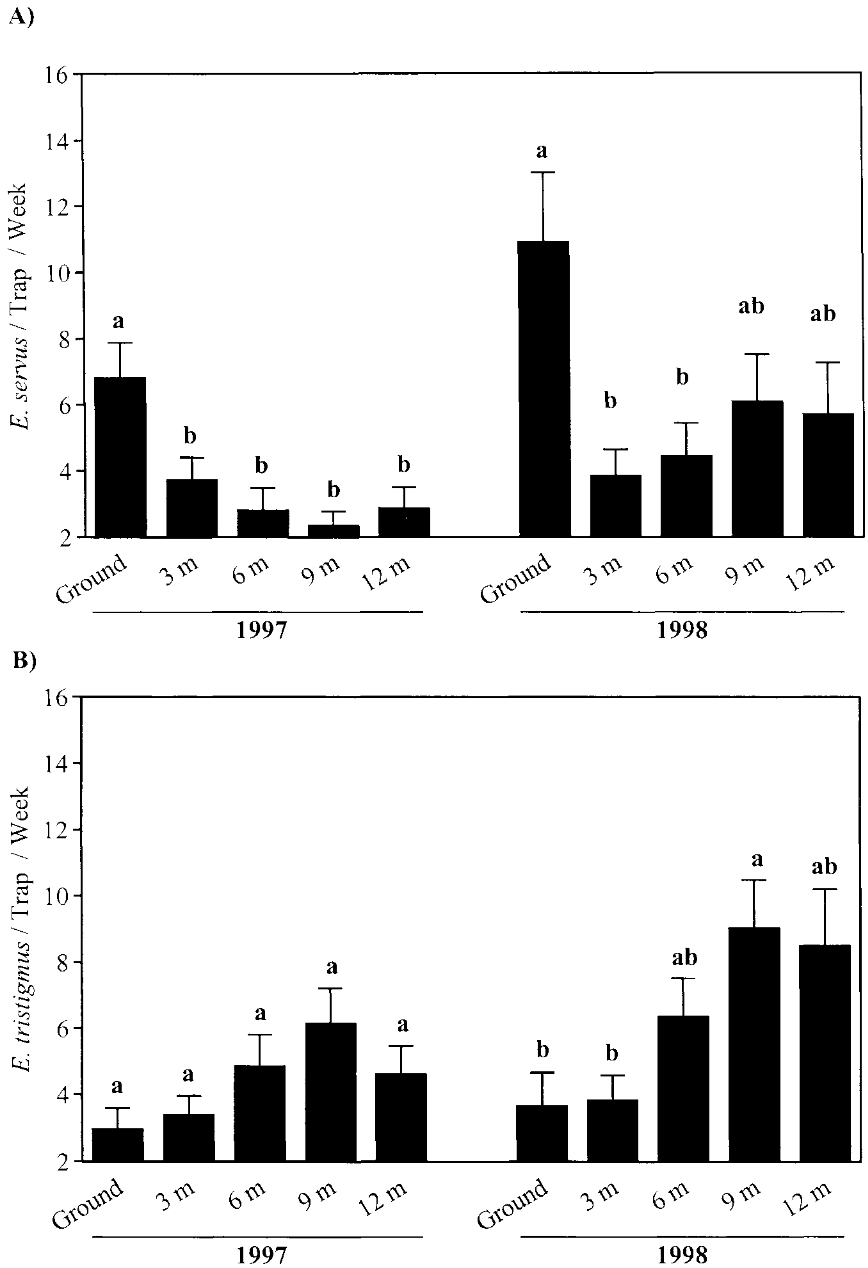

Fig. 4. Vertical distribution of (A) *E. servus* and (B) *E. tristigmus* in a pecan orchard, May-October 1997 and 1998. Traps were positioned on the ground and at 3, 6, 9, and 12 m above the orchard floor. Within years, unlike letters above vertical bars indicates significant differences ($P < 0.05$) in trap captures at different heights.

Test 3. Even when two pheromone-baited traps were placed at different heights in the same tree, we found that *E. servus* and *E. tristigmus* retained the vertical distribution as previously described (Fig. 5). Although there was no overall treatment effect (F = 1.83; df = 2,30; P > 0.05), trap height did affect captures of *E. servus* and *E. tristigmus.* More *E. servus* were captured in traps on the ground than in traps in the upper or lower canopy (F = 10.53; df = 2, 63; P < 0.05), and the previous trend of catching more *E. tristigmus* in the canopy than on the ground was consistent. Additionally, trap captures of *E. servus* on the ground were greater compared with *E. tristigmus* (F = 16.55; df = 1, 42; P < 0.05). In contrast, *E. tristigmus* was captured more frequently in the canopy than was *E. servus* and significantly so in the lower canopy (F = 5.76; df = 1, 42; P < 0.05).

Test 4. In 1999, when baited traps were placed on the ground or at 9 m, more *E. servus* were captured on the ground than at 9 m but the difference was not significant (F = 1.59; df = 1, 19; P > 0.05) (Fig. 6). Nonetheless, the previous trend of catching more *E. servus* on the ground than in the canopy continued and significantly more *E. tristigmus* were captured at 9 m than on the ground (F = 5.67; df = 1, 19; P < 0.05) (Fig. 6).

Generally, we found total numbers of captured *E. servus* and *E. tristigmus* to be inversely related between April and October of each year. Yonce and Mizell (1997) used the same pheromone in similar traps placed on the ground (from August through December) and reported that 93% of all pentatomids captured were *E. servus* and *E.*

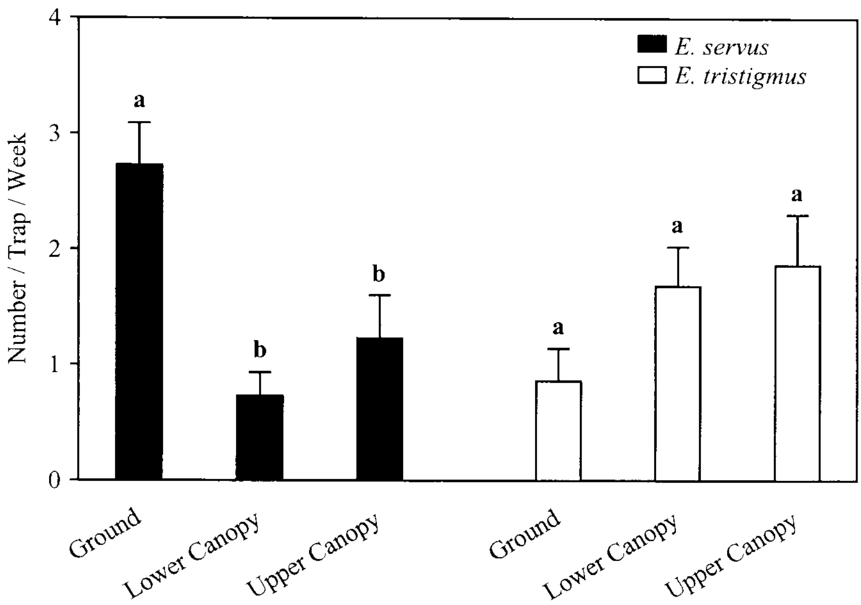

Fig. 5. Vertical distribution of *E. servus* and *E. tristigmus* when two pheromone-baited traps were placed at different heights at the same tree, 1997. Within each species, unlike letters above vertical bars indicates significant differences (P < 0.05) in trap captures at different heights.

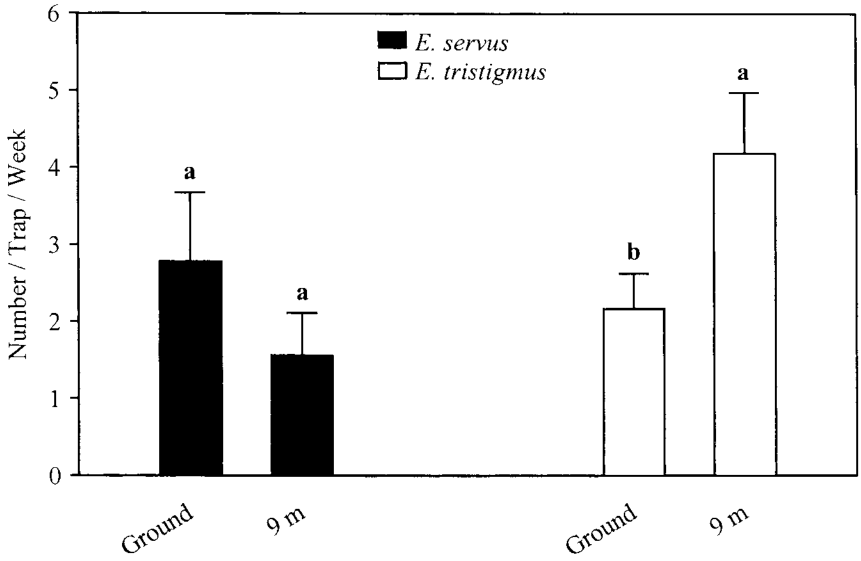

Fig. 6. Trap captures of *E. servus* and *E. tristigmus* when traps were placed on the ground or at 9 m, 1999. Within each species, unlike letters above vertical bars indicates significant differences ($P < 0.05$) in trap captures between the ground and 9 m.

tristigmus and 77% of only those two species were *E. servus*. We also captured more *E. servus* than *E. tristigmus* in traps on the ground (from August through December) of each year (55% vs. 45% and 57% vs. 43%, respectively). However, vertical placement of traps affected trap captures of *E. servus* and *E. tristigmus,* and trap captures from throughout the canopy and ground contrast with Yonce and Mizell (1997). When we combined trap captures from all heights (ground, 3, 6, 9, and 12 m), *E. servus* comprised a lower percentage than *E. tristigmus* (August through December) of each year (34% vs 66% and 32% vs 68%, respectively).

Aldrich et al. (1991) tested the *Euschistus* aggregation pheromone within and around a deciduous forest (traps were hung from tree limbs) in Maryland, and more *E. tristigmus* were captured than were *E. servus.* However, in non-arboreal habitats, *E. tristigmus* populations may be much lower as shown by McPherson et al. (1993). Those authors reported that numbers of *E. tristigmus* were very low on soybeans in Georgia; whereas, *E. servus* was one of the four most-abundant pentatomids on soybeans. Additionally, Jones and Sullivan (1982) reported that *E. servus* in South Carolina was the third most-abundant herbivorous pentatomid in soybeans after *N. viridula* and *A. hilare,* but *E. tristigmus* was fifth.

Results from this study indicate that *E. servus* and *E. tristigmus* are present in the orchard throughout the season and that *E. servus* is more abundant earlier during the season rather than later. The vertical distribution of *E. servus* and *E. tristigmus* in pecan strongly suggests that sampling in arboreal habitats should be done throughout tree canopies since only high or low sampling positions in the orchard may not accurately represent species populations. These factors should, therefore, be considered in the development of monitoring and control strategies for stink bugs attacking pecan.

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