An Improved Trap for Monitoring Stink Bugs (Heteroptera: Pentatomidae) in Apple and Peach Orchards

Henry W. Hogmire and Tracy C. Leskey

Tree Fruit Research and Education Center, West Virginia University, Kearneysville, West Virginia 25430 USA

Abstract Capture of stink bugs (Heteroptera: Pentatomidae) in apple orchards with yellow pyramid traps baited with Euschistus spp. (Heteroptera: Pentatomidae) aggregation pheromone, methyl (2E,4Z)-decadienoate, was 4 fold greater when traps were topped with a 3.8-L jar with a 1.6 cm diameter opening and trimmed wire edging than with a 1.9-L jar with a 5 cm diameter opening with no wire edging. Stink bug capture in the 3.8-L jar top was unaffected by the presence or size of an insecticide ear tag, indicating that this improved design led to increased captures by reducing escape. Sixty-four percent fewer stink bugs escaped from 3.8-L jar tops with the improved capture mechanism than from the 1.9-L jar tops. Green stink bug, Acrosternum hilare (Say), was more susceptible to the presence of the insecticide ear tag than the brown stink bug, Euschistus servus (Say), with dusky stink bug, E. tristigmus (Say), exhibiting high mortality in traps with and without ear tags. Among baited and unbaited pyramid traps with different visual stimuli, fewer captures were recorded in black pyramid traps than in clear, yellow, green or white pyramid traps. Similar numbers of brown stink bugs were captured in yellow pyramid traps deployed on the ground between trees or on horizontal branches within trees in the orchard border row. Captures of dusky and green stink bugs were greater in the tree pyramid, especially from August to mid-October. Relationships between stink bug capture and injury will need to be determined before this trap can be incorporated as a decision-making tool in pest management programs.

Key Words Euschistus servus, Euschistus tristigmus, Acrosternum hilare, monitoring, insect traps, pyramid trap

Three stink bug species [brown stink bug, Euschistus servus (Say); dusky stink bug, E. tristigmus (Say); and green stink bug, Acrosternum hilare (Say)] have historically been major pests of peach fruit in the eastern U.S. (Hogmire 1995). Recently, the importance of this pest complex has increased in eastern apple orchards (Pfeiffer 2004), where fruit injury is easily misdiagnosed as the physiological disorders cork spot (Brown 2003) and/or bitter pit (Ohlendorf 1999). Stink bugs are especially difficult to manage because they are highly mobile, polyphagous pests (McPherson and McPherson 2000). Furthermore, narrow-spectrum chemistries that are replacing...
broad-spectrum materials because of the Food Quality Protection Act (FQPA) provide less effective control (Pfeiffer 2004). In addition, monitoring procedures consisting of beating tray and sweep net sampling, and fruit injury assessments have limited effectiveness in aiding pest management decisions as no action thresholds have been developed for stink bug species in the eastern U.S. (Hogmire 1995).

The identification of an aggregation pheromone, methyl (2E,4Z)-decadienoate (Aldrich et al. 1991), which could be used in trapping systems, has enhanced the ability to monitor *Euschistus* spp. Tube-traps baited with the aggregation pheromone are recommended for monitoring *E. conspersus* Uhler in California (Ohlendorf 1999), but failed to adequately capture this same species in a Washington study (Krupke et al. 2001). Yellow pyramid traps baited with methyl (2E,4Z)-decadienoate have been the most common tool investigated for monitoring stink bugs in pecan (Mizell and Tedders 1995, Mizell et al. 1996), apple, and peach orchards (Johnson et al. 2002, Leskey and Hogmire 2005). Cottrell et al. (2000) used a yellow pyramid trap baited with methyl (2E,4Z)-decadienoate to determine the seasonal occurrence and canopy distribution of brown and dusky stink bugs in pecan orchards. In apples and peaches, Leskey and Hogmire (2005) found that stink bug captures were similar with yellow pyramid traps constructed of plywood or plastic with plastic jar tops, and masonite with an aluminum screen top, but that significantly more stink bugs were captured in baited versus unbaited traps.

Cottrell (2001) demonstrated that inclusion of an insecticide ear tag (containing 10% lambda-cyhalothrin and 13% piperonyl butoxide) in pyramid trap jar tops significantly increased stink bug captures in baited traps. This was presumed to be due to a reduction in escape, although the proportion of bugs that escaped was not measured. In baited pyramid trap jar tops provisioned with ¼ piece of an insecticide ear tag (containing 10% permethrin and 13% piperonyl butoxide), Leskey and Hogmire (2005) found that 58% of female and 67% of male brown stink bugs had escaped after 7 d, whereas only 21% of female and 27% of male brown stink bugs were killed by the insecticide ear tag over the same period. This high rate of escape and poor kill of stink bugs with insecticide ear tags would have significantly reduced stink bug captures in pyramid traps provisioned with plastic jar tops in our studies. Consequently, these traps would significantly underestimate the stink bug population and would be ineffective for use as a monitoring tool in pest management programs.

This study was conducted to determine the effects of a modified jar top design, trap deployment strategy, and various insecticide ear tag treatments on stink bug capture. Stink bug escape from jar tops and the effect of insecticide ear tag on stink bug mortality also were measured. In a separate experiment, we investigated the effect of different visual stimuli provided by pyramid traps, with and without the addition of pheromone, on stink bug capture.

**Materials and Methods**

**Modified capture mechanisms and deployment strategies.** This study was conducted during 2004 in a 1.2-ha commercial orchard of 'Rome' apples on M7 rootstock, planted in 1989 in Hampshire Co., WV. The orchard received applications of acetamiprid, esfenvalerate, indoxacarb, pyridaben, thiacloprid, and thiamethoxam for arthropod pest management under a RAMP (Risk Avoidance and Mitigation Program) project.
Pyramid trap bases were constructed of 0.61 and 1.22-m high plastic (Coroplast®, AIN Plastics, VA Beach, VA) and 1.22-m high masonite (Leskey and Hogmire 2005) which were painted with two coats of exterior latex gloss enamel paint, color-matched to professional industrial safety yellow (Mizell and Tedders 1995). Plastic pyramid bases of 1.22 m were fitted with tops constructed of either 1.9-L (Leskey and Hogmire 2005) or 3.8-L clear plastic Rubbermaid® jars with screw-cap lids (Fig. 1). Jars were constructed identically except for the diameter of the internal cone opening, which was 5 cm in the 1.9-L jar and 1.6 cm with trimmed wire edging in the 3.8-L jar. The 0.61 m high plastic pyramid base was fitted with only the 3.8-L jar top. The masonite pyramid base was topped with a two-layer cone-shaped aluminum screen cage (Leskey and Hogmire 2005). All traps were baited with lures containing 200 mg of methyl (2E,4Z)-decadienoate (IPM Technologies, Inc., Portland, OR) (now Advanced Pheromone Technologies, Inc., Maryhurst, OR). The 3.8-L jar tops on 1.22-m high pyramids were provisioned with either none, 1/4, 1/2 or a whole piece of Atroban Extrak insecticide ear tag (Schering-Plough Animal Health Corporation, Union, NJ). A 1/4-piece of ear tag was used in the 3.8-L jar tops on 0.61 m high pyramids, in the 1.9-L jar tops on 1.22-m high pyramids, and in the screen top on the masonite pyramids (Leskey and Hogmire 2005).

Four replications of the seven trap treatments were installed in border rows of the orchard adjacent to a wood lot. Within each replicate, trap location was randomly

Fig. 1. 1.9 L (left) and 3.8 L pyramid trap plastic jar tops. Internal opening of 5 cm in 1.9 L jar and 1.6 cm with trimmed wire fringe in 3.8 L jar.
assigned, and traps were at least 4.9 m apart. The 1.22 m high pyramids were positioned between trees, and the 0.61 m high pyramids were attached with four cable straps through holes in the base to horizontal branches so that the jar top was about 2 m above the ground. Traps were installed on 7 April and inspected weekly through 14 October, with lures and ear tags replaced every 4 wk. Stink bugs were collected in labeled vials of 70% ethanol and identified with taxonomic keys (McPherson and McPherson 2000). The number of dead versus live stink bugs was determined weekly for the final 15 wk of sampling. Data on stink bug capture and percent mortality were accumulated across weeks and subjected to ANOVA with mean separation by Tukey’s HSD test at $P < 0.05$ (SAS Institute 2001).

A separate experiment was conducted at the West Virginia University Kearneysville Tree Fruit Research and Education Center in 2004 to determine the ability of brown stink bugs to escape from pyramid trap jar tops. Five replications of the 1.9-L plastic jar tops with a 5 cm internal cone opening and of the 3.8-L tops with a 1.6-cm internal cone opening and trimmed wire edging (used in previous experiment) were provisioned with IPM Tech lures and a 1/4-piece of insecticide ear tag. A sleeve of insect netting was installed over each bottom jar opening, and jars were suspended randomly ~1.2 m apart from the rungs of ladders positioned horizontally in a large room in the research facility. The room was maintained at a temperature of 21°C and a 8:16 h L:D photoperiod. Brown stink bugs that had been collected from common mullein were sexed and maintained on green beans in an environmental chamber under the same conditions until used in this study. Five males or five females were introduced into jar tops. Jars were inspected daily for 7 d, and escaped and dead stink bugs were counted and removed upon inspection. The cumulative percentage of stink bugs that escaped from 1.9- and 3.8-L jar tops each day was compared using a t-test at $P = 0.05$ (SAS Institute 2001).

**Visual stimuli associated with pyramid traps.** This experiment was conducted in an unmanaged orchard consisting of 12-yr-old ‘Loring’ peach trees in Jefferson Co., WV. Standard-sized pyramid traps (1.22 m in height, Leskey and Wright 2004) were constructed of white Sintra® (partially extruded PVC) sheets (Laird Plastics, Pittsburgh, PA) and painted with flat latex exterior paint in the following colors: black, green, yellow, or white. Another set of traps was constructed of clear polycarbonate. Traps represented the following visual stimuli: standard trunk mimic (black), foliar mimics (green and yellow), and no visual stimulus (white Sintra® and clear polycarbonate). Spectral reflectances of black, green, yellow, and white flat exterior latex paint and of clear polycarbonate were determined using a StellarNet EPP 2000C fiberoptic spectrometer fitted with an IC2-UV/visible light integrating sphere. Spectral reflectance curves were generated using SpectraWiz® (StellarNet, Tampa, FL). Traps were baited with 200 mg of methyl (2E,4Z)-decadienoate or left unbaited. Four replicates of each baited and unbaited trap type were deployed on the ground between tree trunks within orchard rows. Trap location was randomly assigned within each replicate. Traps were deployed on 23 June 2004, checked weekly until 26 August 2004, and the number of brown stink bugs was recorded. As the homogeneity-of-variances assumption was met in all cases, nontransformed data were analyzed using a factorial ANOVA based on the GLM procedure (SAS Institute 2001) to evaluate the effects of trap color, presence of bait, and the interaction between trap color and bait across all traps. Multiple comparisons were calculated using Tukey’s HSD ($P < 0.05$).
Results

Modified capture mechanisms and deployment strategies. Total stink bug capture was significantly different among trap treatments \((F = 6.65; \text{df} = 6, 21; P = 0.0008)\). For ground pyramid traps provisioned with \(\frac{1}{4}\) ear tag, the 3.8-L jar top with small internal cone opening captured significantly more (4-fold) stink bugs than the 1.9-L jar top with the larger cone opening, with intermediate captures in the masonite pyramid trap with screen top (Table 1). Although total capture was numerically highest in the tree pyramid, it was not significantly greater than that in the ground pyramid trap, both deployed with jar tops with small internal cone openings. Capture by species was also significantly different by trap type for brown \((F = 11.10; \text{df} = 6, 21; P = 0.0001)\), dusky \((F = 5.15; \text{df} = 6, 21; P = 0.0031)\), and green \((F = 2.95; \text{df} = 6, 21; P = 0.0349)\) stink bugs. Brown stink bug was the most abundant species found in all traps. Captures of brown stink bug in ground and tree pyramids with 3.8-L jar tops with small internal cone opening were significantly greater than captures in the 1.9-L jar top with larger internal cone opening, and the masonite/screen trap, all with \(\frac{1}{4}\) ear tag (Table 1). For dusky stink bug, the tree pyramid provisioned with 3.8-L jar top with small internal cone opening had the highest captures. Captures of dusky stink bug were significantly greater in this trap than in the ground pyramid with 1.9-L jar top with large internal cone opening and the screen top, but not the 3.8-L jar top with identical small internal cone opening, all provisioned with \(\frac{1}{4}\) ear tag (Table 1). The tree pyramid provisioned with the 3.8-L jar top with smaller internal cone opening also had the highest captures of green stink bug, which were only significantly greater than the ground pyramid with 1.9-L jar top and larger internal cone opening (Table 1).

Similar low levels of brown stink bugs were detected by ground and tree pyramid traps through June, followed by an increase in both traps beginning in July, and slightly higher levels detected by ground pyramids from August through mid-October (Fig. 2A). For dusky stink bugs, captures were relatively low but slightly higher in the tree pyramids than in the ground pyramids from May through July, and substantially higher from August through mid-October (Fig. 2B). Very low levels of green stink bugs were detected by both trap types through July, followed by a sharp increase in capture that was substantially higher in the tree pyramid from August to mid-October (Fig. 2C). By mid-October, the mean cumulative capture of both dusky and green stink bugs was about 2-fold greater in tree than in ground pyramid traps (Table 1, Fig. 2B, 2C).

The presence and size of insecticide ear tag had no significant effect on the total capture of stink bugs or on the capture of brown, dusky or green stink bugs in pyramid traps with the 3.8-L jar top and small internal cone opening (Table 1). In fact, total stink bug captures and captures of brown stink bugs were significantly higher in the 3.8-L jar with no ear tag and small internal cone opening than in the 1.9-L jar with \(\frac{1}{4}\) ear tag and larger internal cone opening (Table 1). In a laboratory experiment, when brown stink bugs were released into both jar top types, 16 and 2% escaped from 1.9-L jar tops with a 5 cm internal opening and 3.8-L jar tops with a 1.6 cm internal opening, respectively, after 1 d (Fig. 3). Escape was significantly higher from 1.9-L jar tops with 5 cm internal opening than from 3.8-L jar tops with 1.6 cm internal opening for 2-7 d following release, with almost a 3-fold greater escape from the 1.9-L jar after the seventh day.

Mean mortality of all stink bugs was significantly different among traps with various ear tag treatments (none, \(\frac{1}{4}, \frac{1}{2}, \) whole) \((F = 9.20; \text{df} = 3, 12; P = 0.0042)\). Traps with
Table 1. Comparison of accumulated stink bug captures (mean ± SE) in various baited pyramid trap and ear tag treatments in a commercial apple orchard in 2004*

<table>
<thead>
<tr>
<th>Trap type-trap top (volume/opening size)-ear tag</th>
<th>Stink bugs</th>
<th>Total†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brown</td>
<td>Dusky</td>
</tr>
<tr>
<td>Ground pyramids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic-jar (3.8 L/1.6 cm)-no ear tag</td>
<td>130.8 ± 18.93a</td>
<td>16.3 ± 3.57b</td>
</tr>
<tr>
<td>Plastic-jar (3.8 L/1.6 cm)-1/4 ear tag</td>
<td>134.8 ± 17.92a</td>
<td>18.5 ± 2.40ab</td>
</tr>
<tr>
<td>Plastic-jar (3.8 L/1.6cm)-1/2 ear tag</td>
<td>118.5 ± 13.67a</td>
<td>18.5 ± 3.93ab</td>
</tr>
<tr>
<td>Plastic-jar (3.8 L/1.6 cm)-whole ear tag</td>
<td>121.0 ± 15.34a</td>
<td>19.8 ± 2.32ab</td>
</tr>
<tr>
<td>Plastic-jar (1.9 L/5.0 cm)-1/4 ear tag</td>
<td>24.3 ± 3.94b</td>
<td>8.8 ± 3.94b</td>
</tr>
<tr>
<td>Masonite-screen-1/4 ear tag</td>
<td>46.0 ± 19.43b</td>
<td>14.3 ± 5.12b</td>
</tr>
<tr>
<td>Tree pyramid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic-jar (3.8 L/1.6 cm)-1/4 ear tag</td>
<td>120.3 ± 10.36a</td>
<td>34.0 ± 5.49a</td>
</tr>
</tbody>
</table>

* Means in the same column followed by a different letter are significantly different (P = 0.05; Tukey's HSD test).
† Includes Brochymena spp. and unidentified nymphs.
Fig. 2. Mean accumulated seasonal capture of brown (A), dusky (B), and green (C) stink bugs in ground and tree pyramid traps in a commercial apple orchard in 2004.
Fig. 3. Mean accumulated brown stink bug escape through 7 d from 1.9 L and 3.8 L pyramid trap jar tops. Asterisks indicate significant difference by t-test at $P = 0.05$.

½ and whole ear tags had similar levels of mortality, which were significantly greater than traps with no ear tags (Fig. 4). Although mortality increased with ear tag size, it was only 24% greater with a whole as compared with no ear tag. Mean mortality of stink bug species was significantly different among ear tag treatments for brown ($F = 9.48; \text{df} = 3, 12; P = 0.0038$) and green ($F = 17.25; \text{df} = 3, 12; P = 0.0004$), but not for dusky ($F = 0.87; \text{df} = 3, 12; P = 0.4912$) stink bugs. For brown stink bug, mortality was significantly greater in traps with a whole ear tag than in traps with no or ½ ear tag (Fig. 4). Mortality increased with ear tag size, but was only 57% with a whole ear tag. For green stink bug, similar high levels of mortality (80-93%) occurred in traps with all ear tag sizes, which were significantly greater than in traps with no ear tag (44%) (Fig. 4). Dusky stink bug exhibited a high level of mortality (80%) in traps with no ear tag present; mortality was not significantly different in traps with various sizes of ear tag and no ear tag (Fig. 4).

**Visual stimuli associated with pyramid traps.** Spectral reflectance curves were generated for all pyramid trap colors (Fig. 5). Across baited and unbaited traps, the factorial ANOVA indicated significant effects ($F = 28.09; \text{df} = 9, 30; P < 0.001$) of both lure ($F = 218.80; \text{df} = 1, 30; P < 0.001$), trap color ($F = 4.92; \text{df} = 4, 30; P = 0.0036$), and the interaction between lure and trap color ($F = 3.58; \text{df} = 4, 30; P = 0.0168$). Significantly more stink bugs were captured in baited (mean ± SE, 109.4 ± 8.7) than in unbaited pyramid traps (9.15 ± 1.2). In terms of trap color, captures in clear, green, and white pyramid traps were significantly greater than in black pyramid traps, with captures in yellow pyramid traps being intermediate among all baited and unbaited traps (Table 2).

**Discussion**

To be a useful monitoring tool for pest management, a trap must accurately detect the pest population that has the potential to inflict injury. Due to an increased likeli-
Brown Dusky Green Total

Fig. 4. Effect of insecticide ear tag on mean mortality of brown, dusky, green and total stink bugs in a baited yellow pyramid trap with a 3.8 L plastic jar top. Means for a given stink bug species and total with a different letter are significantly different ($P = 0.05$; Tukey’s HSD test).

HOGMIRE AND LESKEY: Stink Bug Monitoring

Hood of stink bug escape from 1.9-L jar tops with 5 cm internal cone openings (Leskey and Hogmire 2005), baited yellow pyramid traps fitted with these trap tops would likely underestimate the size of the stink bug population. Theoretically, stink bug escape can be decreased (and capture increased) either by inducing rapid mortality after bugs enter a trap or by creating a more effective capture and retention mechanism. Cottrell (2001) found that trap capture was increased by adding an insecticide ear tag containing 10% lambda-cyhalothrin and 13% piperonyl butoxide, although stink bug escape was not measured directly. Because of the likelihood of stink bug escape from 1.9-L jar tops (with 5 cm internal cone openings provisioned with $\frac{1}{4}$ ear tag containing 10% permethrin and 13% piperonyl butoxide) (Leskey and Hogmire 2005), we felt it necessary to design a capture mechanism that would reduce escape. Reducing the internal cone opening and increasing the jar size (from 5 cm in the 1.9-L jars to 1.6 cm, with trimmed wire edging, in the 3.8-L jars) (Fig. 1) increased stink bug capture by 4-fold (Table 1) and reduced escape by 64% after 7 d (Fig. 3). Increasing the size of insecticide ear tag in the redesigned jar top did not, however, increase stink bug captures (Table 1), indicating that reducing the internal opening and increasing the size of the jar top were the most important factors contributing to increased captures. Even though the ear tag did not contribute to increased captures in our redesigned jar top, its use may have other benefits. Cottrell (2001) noted that the presence of an insecticide ear tag prevented foraging red imported fire ants, Solenopsis invicta Buren, from removing captured stink bugs, and prevented spiders from building webs that could block the entrance into trap tops. In our study, fewer spiders were observed...
Fig. 5. Spectral reflectance curves obtained from flat exterior latex black, green, yellow, and white paint on Sintra® plastic and from clear polycarbonate.

Table 2. Mean number ± SE of brown stink bugs captured in all baited and unbaited pyramid traps (N = 8) with various visual stimuli deployed in an unsprayed peach orchard in 2004*

<table>
<thead>
<tr>
<th>Pyramid trap</th>
<th>Brown stink bug captures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>74.6 ± 26.0a</td>
</tr>
<tr>
<td>Green</td>
<td>67.9 ± 22.1a</td>
</tr>
<tr>
<td>White</td>
<td>63.3 ± 21.4a</td>
</tr>
<tr>
<td>Yellow</td>
<td>59.4 ± 18.5ab</td>
</tr>
<tr>
<td>Black</td>
<td>31.0 ± 13.8b</td>
</tr>
</tbody>
</table>

*Means followed by a different letter are significantly different (P = 0.05; Tukey’s HSD test).

in traps provisioned with ¼ ear tags compared with traps without ear tags. By reducing the number of spiders that could block entry into trap tops, the ear tag may help to maintain the integrity and effectiveness of the trap.

Poor captures in the 1.9-L jar top were not only due to escape, but poor kill with the insecticide ear tag (Leskey and Hogmire 2005). In this study, total stink bug mortality with a whole ear tag was only 65%, and only 24% greater than in traps with no ear tag (Fig. 4). Stink bug species differed in susceptibility to the insecticide ear tag. A ¼-piece of ear tag and a whole ear tag elicited, respectively, 80% mortality of green stink bug and 57% mortality of brown stink bug. Dusky stink bug showed poor survival in the trap tops, regardless of the presence of an ear tag, with 80% mortality in
untreated tops. Pyrethroid insecticides are considered the most effective chemical class for stink bug control (Pfeiffer 2004). In this study, brown stink bug exhibited the lowest mortality to the insecticide ear tag, which contains a pyrethroid (permethrin). In a study of stink bugs collected from soybean, Snodgrass et al. (2005) found that brown stink bug was less susceptible to both pyrethroid and organophosphate insecticides than green and southern green stink bugs. The abundance of brown stink bug in commercial fruit orchards (Leskey and Hogmire 2005) and their potential to cause fruit injury (Brown 2003) necessitates an evaluation of the susceptibility of orchard populations to pyrethroid insecticides to maintain an effective pest management program for this species.

Foraging herbivorous insects may respond to particular visual cues associated with host plants. Prokopy and Owens (1983) noted that a large number of phytophagous insects respond positively to yellow and, thus, this particular pigment is considered to be a supernormal foliage-type stimulus and has been incorporated in trap designs for a number of species. Mizell and Tedders (1995) found that unbaited pyramid traps coated with 'industrial safety yellow' paint captured more stink bugs than traps coated with light and dark green, black, or covered with aluminum foil. Here, we found that when black [trunk-mimicking stimulus (Tedders and Wood 1994)], yellow and green (foliar mimics), and white and clear (no particular visual stimulus) pyramid traps were baited with methyl (2E,4Z)-decadienoate or unbaited, significantly more stink bugs were captured in clear, green, and white pyramid traps than in black pyramid traps, with captures in yellow pyramid traps being intermediate (Table 2). Captures in black pyramid traps were lower than all others possibly because stink bugs do not orient to the tall dark upright silhouette created by this stimulus, as opposed to other species such as plum curculio, Conotrachelus nenuphar (Herbst) (Leskey 2006) and the pecan weevil, Curculio caryae (Horn) (Tedders et al. 1996). Alternatively, the dark surface of these traps seemed to absorb a great deal of heat, and we found them very warm to the touch when in direct sunlight. Thus, the higher temperatures may have deterred stink bugs from walking on trap surfaces. However, across all baited and unbaited traps, baited traps captured significantly more stink bugs (11x more) than unbaited traps, indicating the relative importance of this olfactory stimulus. In this case, it appears that when pyramid traps are baited with methyl (2E,4Z)-decadienoate lures, trap captures are increased substantially, regardless of the visual stimulus, with the exception of the trunk-mimicking black pyramid trap.

Our finding that stink bug captures in clear pyramid traps were greater than or statistically equivalent to all other pyramid trap types could indicate that stink bug adults are not specifically orienting to the hue of host plants that they visit. This pattern of visual response is similar to that observed for the tarnished plant bug, Lygus lineolaris (Palisot de Beauvois). Captures of this species were similar among clear Plexiglas rectangles and rectangles painted with pigments that approximated apple buds, blossoms, foliage and bark (Prokopy et al. 1979). In our studies, spectral reflectance curves associated with clear pyramid traps revealed very little reflectance of UV (300-400 nm) (Fig. 5). White, nonUV reflecting traps [based on a super normal visual mimic of apple bud and blossom reflectance patterns (Prokopy et al. 1979)] are currently used to monitor tarnished plant bug in apple orchards (Hogmire 1995). Perhaps, nonUV reflecting surfaces elicit positive responses from stink bugs as well. A more thorough understanding of the visual ecology of members of this group is
required to incorporate a truly biologically relevant and effective visual stimulus into a trap design.

Even the most effective trap must be properly deployed to be an efficient monitoring tool. For trapping *Euschistus* spp., one study conducted in a pecan orchard found that baited yellow pyramid traps deployed on the ground captured more brown stink bugs than identical traps deployed within the tree canopy at heights up to 12 m by a rope and pulley system (not attached to a horizontal limb). However, more dusky stink bugs were captured in the canopy at 9 m than on the ground or at 3 m (Cottrell et al. 2000). We found that captures of brown stink bugs in an apple orchard were similar with baited 1.22 m tall yellow pyramid traps installed on the ground, and with baited 0.61 m tall yellow pyramid traps attached to horizontal limbs within the tree canopy (Table 1, Fig. 2A). These tree-deployed pyramid traps captured greater numbers of dusky and green stink bugs than ground-deployed pyramid traps (Table 1), especially from August to mid-October (Fig. 2B, 2C). Based on the fact that most stink bug injury to apple occurs from late July until harvest (Brown 2003), a tree-deployed pyramid trap with improved capture mechanism (a 3.8-L trap top with a 1.6 cm internal cone opening and trimmed wire fringe) would appear to have the greatest potential as a monitoring tool, especially when all three species of stink bugs are considered. However, the relationship between stink bug captures in tree-deployed pyramid traps and fruit injury must be evaluated before this trap type can be used as a threshold-based monitoring tool for making pest management decisions.

**Acknowledgments**

We thank Corina Adams, Deborah Blue, Shelley Pearson, Torri Thomas, Tim Winfield, and Starker Wright for technical support, Phillip Parrott and Garry Shan Holtz for the use of their orchards, and J. Christopher Bergh and Dean F. Polk for review of an earlier version of this manuscript.

**References Cited**


Leskey, T. C. and S. E. Wright. 2004. Monitoring plum curculio, *Conotrachelus nenuphar*
(Herbst) (Coleoptera: Curculionidae) populations in apple and peach orchards in the mid

mid-Atlantic apple and peach orchards. J. Econ. Entomol. 98: 143-153.

North of Mexico. CRC Press. Boca Raton, FL.


Mizell, R. F., H. C. Ellis and W. L. Tedders. 1996. Traps to monitor stink bugs and pecan

Statewide integrated pest management project. Univ. Cal. Div. Agric. and Nat. Res. Publi-
cation 3340.

West Virginia and Maryland Cooperative Extension Publication 456-419.

Rev. Entomol. 28: 337-364.

plant bug on apple. Environ. Entomol. 8: 202-205.


bioassay to adult brown, green, and southern green stink bugs (Heteroptera: Pentatomidae).
J. Econ. Entomol. 98: 177-181.

Tedders, W. L. and B. W. Wood. 1994. A new technique for monitoring pecan weevil emer-

Tedders, W. L., R. F. Mizell and B. Wood. 1996. Effects of color and trunk wrap on pecan