Comparison of Two Insect-Collecting Devices for Trapping Stink Bugs (Hemiptera: Pentatomidae)[1]

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Abstract Stink bugs (Hemiptera: Pentatomidae), including *Euschistus* spp., *Chinavia hilaris* (Say), and *Nezara viridula* (L.), are economic pests in most fruit, grain, vegetable, and row crops in the United States. An insect-collecting device made from a 2.8-L clear plastic PET® jar loaded with a pheromone lure attractive to *Euschistus* spp. and seated atop a 1.22-m-tall yellow pyramid base has been used to effectively capture *Euschistus* spp., *C. hilaris*, and *N. viridula* in orchards and field crops. The 2.8-L clear plastic PET jar is no longer commercially available, but a 3.8-L clear plastic PET jar can be purchased. This study was conducted to compare stink bug capture of a pyramid trap with the 2.8-L insect-collecting device to that of a trap with a 3.8-L one. *Euschistus servus* (Say) was the predominant stink bug species captured (92.9%) in pheromone-baited yellow pyramid traps in peanuts, followed by *Euschistus tristigmus* (Say) (4.5%), *Euschistus quadrator* (Rolston) (2.3%), *Euschistus ictericus* (L.) (1%), *C. hilaris* (1%), and *N. viridula* (1%). Total trap capture for *E. servus* and *E. tristigmus* in pyramid traps in peanut was similar regardless of the size of the insect-collecting device on the traps. So, the new 3.8-L top can be substituted for the old 2.8-L top on pyramid traps to capture these stink bugs.

Key Words brown stink bug, dusky stink bug, pheromone-baited traps

Native stink bugs (Hemiptera: Pentatomidae), including the brown stink bug *Euschistus servus* (Say), dusky stink bug *Euschistus tristigmus* (Say), green stink bug *Chinavia hilaris* (Say), and southern green stink bug *Nezara viridula* (L.) are economic pests in most fruit, grain, vegetable, and row crops in the United States (McPherson and McPherson 2000). Pheromones attractive to stink bugs have been identified and synthesized for Nearctic *Euschistus* spp., including *E. servus*, *E. tristigmus*, *Euschistus quadrator* Rolston, and *Euschistus ictericus* (L.) (Aldrich et al. 1991), *C. hilaris* (Sugie et al. 1996, Aldrich et al. 2007), and *N. viridula* (Aldrich et al. 1987). Lures of the aggregation pheromone of Nearctic *Euschistus* spp., methyl (2*E*,4*Z*)-2,4-decadienoate (MDD), are commercially available. Unfortunately, lures with the reported pheromones for *N. viridula* and *C. hilaris* are not commercially available. However, *C. hilaris* is cross-attracted to the aggregation pheromone of *Plautia stali* Scott, methyl (2*E*,4*E*,6*Z*)-2,4,6-decatrienoate (MDT), under field

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conditions (Aldrich et al. 2007, Tillman et al. 2010), and MDT lures are commercially available. Stink bug traps coupled with attractive pheromone lure(s) in the insect-collecting device of the traps can be used as monitoring tools to assess the presence and seasonal activity of these stink bugs in various cropping systems. For example, traps baited with MDD lures capture more *Euschistus* spp. than nonbaited traps (Leskey and Hogmire 2005, Tillman et al. 2010, Cottrell and Horton 2011).

A pyramid trap consists of an insect-collecting device seated atop a 1.22-m-tall pyramid base (like the plum curculio trap base; Great Lakes IPM, Vestaburg, MI). Various insect-collecting devices, including plastic jars of various sizes, have been tested and used atop a pyramid trap for monitoring stink bugs (Cottrell et al. 2000, Leskey and Hogmire 2005, Hogmire and Leskey 2006). An insect-collecting device made from a clear plastic 2.8-L PET® jar with a screw-cap lid (10.2 cm diameter) (United States Plastic Corp., Lima, OH) (Cottrell et al. 2000) has been used to effectively capture *Euschistus* spp., *C. hilaris*, and *N. viridula* in orchards and field crops (Tillman et al. 2010, Cottrell and Horton 2011, Tillman and Cottrell 2016a). A clear jar was used because stink bugs do not enter darkened insect collecting devices (Mizell and Tedders 1995). Indeed, total trap capture for three stink bug species, namely, *E. servus*, *E. quadrator*, and *C. hilaris*, was numerically lower for collecting jars painted yellow (dark inside) than for clear jars in commercial apple and peach orchards (Leskey and Hogmire 2005). The addition of an insecticide such as an insecticidal ear tag (10% λ-cyhalothrin and 13% piperonyl butoxide) (Saber Extra insecticide ear tags; Jeffers, Dothan, AL) in the insect-collecting device kills stink bugs when entering the device, reducing their escape from it (Cottrell 2001). The 2.8-L clear plastic PET jar is no longer commercially available, but a 3.8-L clear plastic PET jar is available for purchase. Because it was essential to replace the 2.8-L jar with another one, we opted to use the larger PET jar to make the insect-collecting device for the stink bug trap. Thus, the objective of this study was to compare stink bug capture of a pyramid trap with the 2.8-L insect-collecting device to that of a trap with a 3.8-L one.

Materials and Methods

The study was conducted in a peanut field ($\approx$10 ha) in Irwin Co., GA (31°34′12″ N, 83°17′56″ W) in 2017. The two insect-collecting devices tested were (a) the standard 2.8-L top made from a clear plastic PET jar (United States Plastic Corp., Lima, OH) and (b) a 3.8-L top made from a clear plastic PET jar (Fig. 1). The standard 2.8-L top designed by Cottrell et al. (2000) was slightly modified only for easier collection of stink bugs in the field. The modified jar was vented with two rows (3.8 cm apart) of four equidistant 3.8-cm-diameter holes (versus six smaller holes for the standard jar) around the circumference of the jar. Using a wood burner, we melted a relatively soft charcoal grey fiberglass screen wire (Saint-Gobain, Malvern, PA) onto the jar around its circumference to cover the holes. Substituting wire screen of the standard top with fiberglass mesh prevents damage to hands when collecting stink bugs in the field (Tillman, pers. obs.). Instead of cutting away the whole bottom of the jar, as with the standard top, only a 10.8-cm hole was cut in the center of the bottom of the jar so that an outer ring of plastic remained around the bottom of the jar. This prevents collected stink bugs

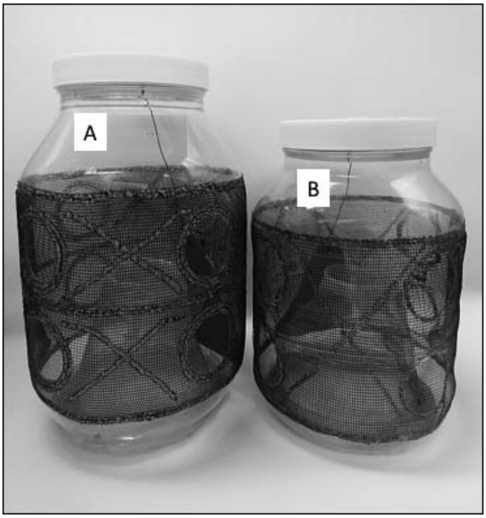

Fig. 1. Two types of insect-collecting tops, namely, one using a 3.8-L jar (A) and other with a 2.8-L jar (B), for stink bug pyramid traps.

from lodging between the side of the jar and the inverted screen funnel where the funnel attaches to the bottom of the jar, resulting in quicker field collection (Tillman, pers. obs.). Four holes (0.3 cm diameter) were drilled through the glue, screen, and jar around the bottom of the jar to allow water drainage during rain or overhead irrigation events. Brite aluminum screen wire (Phifer, Inc., Tuscaloosa, AL) was used to make an inverted funnel 11.5 cm in height with a 11-cm-diameter opening at the bottom and a 5-cm-diameter opening at the top. The larger opening of the funnel was hot-glued around the inside bottom of the jar with the funnel protruding into the jar. The wire mesh in the lid of the standard top was replaced by a stronger steel mesh circle (8.9 cm diameter) (T304 8/023 SS mesh; Argus Steel Products, Inc., Richmond, VA) over the 6.4-cm hole in the center of the lid; the metal circle was melted unto the inside of lid by using a wood burning tool. Using a Phillips screwdriver, we opened four circular holes (0.6 cm diameter) in the steel mesh 2.5 cm apart and 1.2 cm from the edges of the hole on top of the lid. These holes allow adult parasitoids of stink bugs to escape from the top (Tillman et al. 2015). A 15.2-cm length of 22-gauge green enamel floral wire (Panacea Products Corp., Columbus, OH) was attached to an insecticidal ear tag (10% λ-cyhalothrin and 13% piperonyl butoxide) (Saber Extra insecticide ear tags; Jeffers, Dothan, AL) and then to the steel mesh of the lid. The steel mesh provided a strong base of attachment for the ear tag. With this length of floral wire, approximately three-quarters of the ear tag laid alongside the interior screen funnel. When an insect-collecting device was seated atop a 1.22-m-tall pyramid base, the tip end of the pyramid trap fit snugly into the 5-cm-diameter opening with $\approx$ 3 cm of the tip protruding past the opening so the crawl space for stink bug entry is approximately a quarter of the size of the internal opening of the funnel (Fig. 2A). This modified

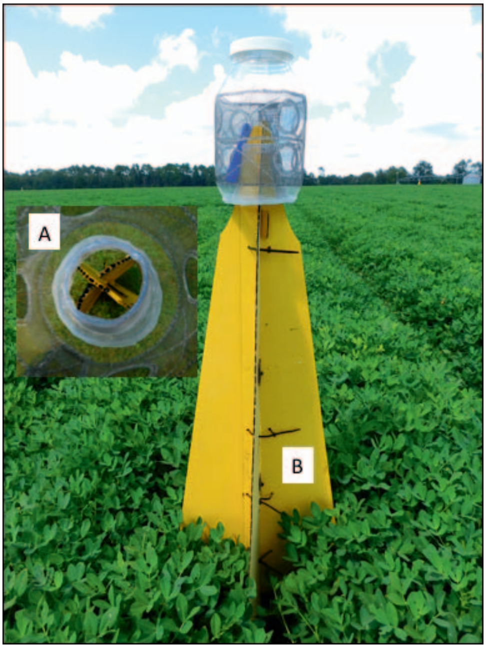

Fig. 2. The crawl space for entrance of stink bugs into the insect-collecting top (A) atop a yellow pyramid base (B).

top effectively captured *E. servus*, *E. tristigmus*, and *C. hilaris* in cotton, *Gossypium hirsutum* L. (Tillman and Cottrell 2016b), and peanut, *Arachia hypogaea* L. (Tillman, unpublished data).

The 3.8-L clear plastic PET top was constructed based on the design of the smaller top. The cap size was the same for both jars. Regarding assembly, the three major differences for the larger top were eight larger side holes instead of six holes, the longer length (53.3 cm) of the fiberglass screen wire placed around the circumference of the jar, and the longer length (22.9 cm) of the floral wire used to hang the ear tag (because this jar is taller).

A yellow-painted chloroplast base (plum curculio trap base; Great Lakes IPM) was used with each experimental insect-collecting device (Fig. 2B). Each device was baited with a *Euschistus* spp. pheromone (MDD) lure. The pheromone for the lure was purchased from Bedoukian Research Inc. (Danbury, CT). Lures were produced by pipetting 40 μL of the *Euschistus* spp. pheromone into the opening of rubber septa (11-mm natural, rubber sleeve stoppers; Wheaton, Millville, NJ), holding septa upright in a laboratory rack, and allowing septa to absorb the pheromone at room temperature (Cottrell and Horton 2011). The two treatments were set up as a randomized complete block design by using six blocks (i.e., replicates). Lures were changed and nymphs (2nd through 5th instars) and adults (males and females) collected on a weekly basis. Traps were established on 30

Table 1. Mean (SE) total number of *E. servus* nymphs and adults and *E. tristigmus* adults per trap for two types of insect-collecting tops on yellow pyramid traps.

Top	Number of *E. servus* Adults*	Number of *E. servus* Nymphs*	Number of *E. tristigmus* Adults*
2.8-L	5.79 (0.88)a	0.42 (0.1)a	0.44 (0.1)a
3.8-L	5.55 (0.82)a	0.28 (0.08)a	0.40 (0.1)a

* Means within a column followed by the same letter are not significantly different by top type, Tukey's HSD ($P > 0.05$).

June 2017 and then insects were collected for 8 weeks from 7 July through 25 August. Voucher specimens of stink bug species were deposited in the USDA-Agricultural Research Service, Crop Protection & Management Research Laboratory in Tifton, GA.

Stink bug count data were modeled using a Poisson distribution. The analysis was conducted using PROC GLIMMIX (SAS Institute, Inc. 2010). The LINK=LOGIT function was used in the model statement. Model fit was evaluated by use of the chi-square and df statistic provided by PROC GLIMMIX (Littell et al. 2006). For *E. servus* adults, fixed effects were treatment, week, and treatment by week. Random effects were replicate and residual error. Because total numbers *E. servus* nymphs and *E. tristigmus* adults were low, fixed effects were treatment and week for these two groups. Random effects were replicate and residual error. Means were back transformed using the ILINK option in the LSMEANS statement and compared using Tukey's honestly significant difference (HSD).

Results

Euschistus servus was the predominant stink bug species captured (92.9%) in pheromone-baited yellow pyramid traps in peanuts ($\chi^2 = 4{,}046.6$; df=5; $P < 0.0001$), followed by *E. tristigmus* (4.5%), *E. quadrator* (2.3%), *E. ictericus* (1%), *C. hilaris* (1%), and *N. viridula* (1%). Total trap capture for *E. servus* adults was not significantly affected by top type ($F = 0.17$; df = 1, 75; $P < 0.6777$) (Table 1) but was significantly influenced by week ($F = 68.39$; df = 7, 75; $P < 0.0001$), and the interaction between week and top type was significant ($F = 2.3$; df = 7,75; $P < 0.0356$) (Table 2). Trap capture was higher for traps with the 3.8-L top than for traps with the smaller top for 2 weeks and higher for traps with the 2.8-L top than for traps using the larger top for 1 week. The number of *E. servus* nymphs per trap was not significantly affected by top type ($F = 1.97$; df = 1,82; $P < 0.1639$) (Table 1) but was significantly influenced by week ($F = 3.72$; df = 7, 82; $P < 0.0015$) (Table 3). The highest number of *E. servus* nymphs per trap was captured on week 6. Trap capture for *E. tristigmus* adults was not significantly affected by top type ($F = 0.09$; df = 1, 82; $P < 0.7639$) (Table 1) or week ($F = 0.72$; df = 7, 82; $P < 0.6551$) (Table 3).

Table 2. Mean (SE) number of *E. servus* adults per trap per week for the two types of insect-collecting tops on yellow pyramid traps.

	Number of *E. servus* Adults*							
Top	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**
2.8-L	3.53 (0.88)a2	1.6 (0.55)a1	1.28 (0.48)b1	2.73 (0.75)a2	6.09 (1.27)a3	28.73 (4.31)a5	19.9 (3.15)a4	18.29 (2.94)a4
3.8-L	2.57 (0.72)a1	1.77 (0.55)a1	3.21 (0.83)a1	3.37 (0.86)a1	5.46 (1.18)a1	18.13 (2.91)b3	12.36 (2.14)b2	14.93 (2.48)a2

* Means within a column followed by the same letter are not significantly different by top type, and means within a row followed by the same number are not significantly different by week, Tukey's HSD ($P > 0.05$).

Table 3. Mean (SE) number of *E. servus* nymphs and *E. tristigmus* adults per trap per week for both types of insect-collecting tops on yellow pyramid traps.

Week	Number of *E. servus* Nymphs*	Number of *E. tristigmus* Adults*
1	0.08 (0.08)c	0.33 (0.17)a
2	0.24 (0.14)bc	0.58 (0.22)a
3	0.08 (0.08)c	0.58 (0.22)a
4	0.33 (0.16)bc	0.66 (0.24)a
5	0.57 (0.22)bc	0.33 (0.17)a
6	1.47 (0.35)a	0.42 (0.19)a
7	0.82 (0.26)ab	0.58 (0.22)a
8	0.49 (0.2)bc	0.17 (0.12)a

* Means within a column followed by the same letter are not significantly different by week, Tukey's HSD ($P > 0.05$).

Discussion

Euschistus servus is one of the predominate stink bug species detected on peanut (Tillman 2008). Thus, the dominance of *E. servus* captured in the MDD-baited yellow pyramid traps is consistent with population data in peanut. Total trap capture was similar when traps were topped with either a 2.8-L or 3.8-L insect-collecting device. The capture of *E. servus* in apple orchards with yellow pyramid traps baited with a MDD lure was significantly higher when traps were topped with a 3.8-L top with a 1.6-cm-diameter opening than with a 1.9-L top with a 5-cm-diameter opening (Hogmire and Leskey 2006). Increased stink bug capture in the 3.8-L top compared to the 1.9-L top was attributed to reduced escape of stink bugs through the smaller internal opening of the larger top compared to the smaller top and not to differences in top volume. Except for the difference in height of the 3.8-L versus 2.8-L jars in the current test, both are the same when sitting atop the pyramidal base. The connection of the jar top with the pyramidal base is a critical point affecting trap capture. This connection point was designed the same for the 3.8-L jar top as previously designed for the 2.8-L jar top. For example, with both sizes of tops used in the current test, the tip of the pyramid base extended through the internal opening of the top. So, the crawl space for entrance of stink bugs into the top was basically quartered and, thus, smaller than the 5-cm-diameter opening of the 1.9-L top described above by Hogmire and Leskey (2006). Also, because stink bugs tend to crawl upward, extension of the tip of the trap into the jar may help bugs move higher into the jar than when it does not extend into the device. We conclude that a 3.8-L top can be substituted for a 2.8-L top, as described here, on a pyramid trap to capture *Euschistus* spp. We are currently conducting experiments to compare these two top types for capturing the invasive brown marmorated stink bug *Halyomorpha halys* (Stål).

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