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Trap Cropping System to Suppress Stink Bugs in the Southern Coastal Plain

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A trap cropping system was developed to manage the stink and leaffooted bug pests in the southern coastal plain and perhaps other areas. The biologically based strategy can be customized for any planting season from spring to fall. Plantings are established in small plots adjacent to the cash crop using standard cultural practices. A mixture of species and continuous management is required to ensure optimum food availability in the trap crop to out compete the cash crop for stink bug feeding. Triticale, sorghum, millet, buckwheat, and sunflower are the main species recommended. Small-acreage growers may wish to plant trap crops in large containers for portability. Millet, sorghum, and buckwheat may be ratooned (new growth after mowing) to extend the life of the trap crops relative to the cash crop. Augmentation of insect pollinators, generalist predators and parasites including those of stink bugs is an emergent property of these plantings. Stink bugs can be killed in the relatively smaller areas of the trap crop by hand, with sweep nets, or with insecticide applications.

Stink bugs (Pentatomidae) and leaffooted bugs (Coreidae) are an overarching pest management issue in all types of agriculture in the southeastern U.S. Stink bugs, primarily the brown stink bug [*Euschistus servus* (Say)], the dusky stink bug [*E. tristigmus* (Say)], the green stink bug [*Acrosternum hilare* (Say)], the southern green stink bug [*Nezara viridula* (L.)], and the leaffooted bug [*Leptoglossus phyllopus* (L.)], are direct primary pests of vegetable, fruit, seed, and grain crops in the Southeast, irrespective of the production system (Schaefer and Panizzi, 2000). McPherson and McPherson (2000) reported that 21 important commodities in the U.S. were damaged by stink bugs. In Georgia, during some years, stink bug damage in soybeans alone was estimated to cost producers more than $13 million in damage and control costs (Douce and McPherson, 1991).

Stink bugs are naturally tolerant of many pesticides; therefore, few efficacious insecticides are available to manage these difficult pests. Mizell and Tedders (1995) described a trap for monitoring *Euschistus* spp. stink bugs that works very well against both sexes and also captures nymphs in close proximity to the trap when used in combination with the aggregation pheromone (Aldrich et al., 1991). This trap does not efficiently monitor the other bug genera mentioned above, although some presence–absence data is garnered from the visual attraction of the yellow-colored trap. Virtually no other biologically based strategies and tactics of practical use are available for suppression of stink bugs in small farm, organic, or homeowner production.

Stink bugs are also major pests in commercial agronomic, fruit, and vegetable crops: including beans, peas, okra, small grains, soybean, cotton, peach, and pecan, etc. The boll weevil eradication program and the use of genetically modified cotton for suppression of lepidopteran pests have greatly reduced the pesticide load in cotton. As a result, stink bugs have recently become major pests in cotton. Based on the large acreage of cotton planted across the Southeast, the vagility of stinkbugs and the temporal and spatial population dynamics at the landscape level of these pests (Mizell, unpublished GIS data), it is logical to assume that losses from stink bugs will continue to increase in susceptible crops.

Stink bug species overwinter as adults often in grass clumps, litter (Jones and Sullivan 1981), and under tree bark (Jones and Sullivan, 1981; Mizell and Schiffhauer, 1987). Adults emerge in early spring and as the season progresses, the vagile adults move from crop to crop (Jones and Sullivan, 1982; Mizell et al., 2008; Todd, 1989). All stink bugs use a sequence of crops as their populations increase throughout the year (Mizell et al., 2008), and the host plants of nymphs and adults may vary considerably (Jones and Sullivan, 1982). Stink bugs are extremely polyphagous and this behavior appears to be partially explained by their preference for feeding on specific parts of plants, primarily the seeds (usually in the milk stage) (Figs. 1–3) and certain other succulent areas that are present on individual plants for a limited amount of time during the season (Jones and Sullivan, 1982; Panizzi, 1997; Mizell, unpublished data). These behaviors help explain the landscape-level aggregated distribution.

Trap crops have been evaluated for some time as a tactic to reduce stink bug damage in soybean [*Glycine max* (L.)] (McPherson and Newsom, 1984; Newsom and Herzog, 1977; Todd and Schumann ,1988), and in a variety of other crops (Hokkanen, 1991; Javaid and Joshi, 1995; Ludwig and Kok, 1998; Rea et al., 2002). In brief, a series of preferred host plants attract and concentrate stink bugs and their natural enemies into the trap crop instead of the cash crop, enable population suppression by mechanical removal or other means in smaller plots, and thereby reduce the damage in the cash crop. Besides soybeans, many other plant species have also been tested as trap crops (Hokkanen, 1991; Javaid and Joshi, 1995). Boucher and Durgy (2004) reported that commercial pepper grower profits increased by $153/acre using a perimeter planting of a more preferred pepper cultivar for pepper maggot. Shuster (2004) used a trap crop of squash adjacent to a tomato planting to reduce the impact of the whitefly-vectored disease tomato yellow leaf curl. Tillman (2006) reported that sorghum was an effective trap crop for *N. viridula* in cotton in

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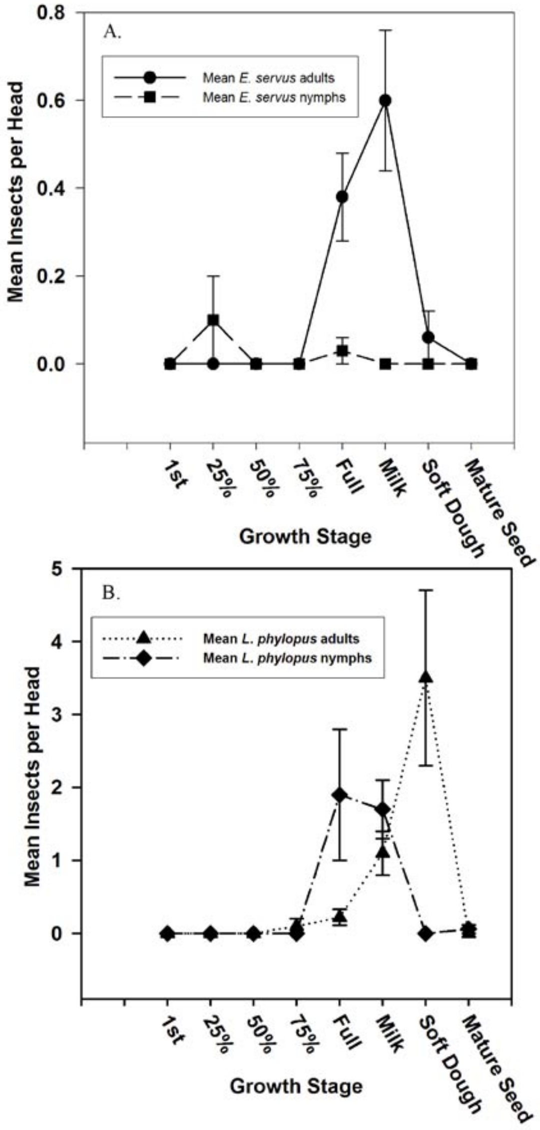

Fig. 1. Responses of the adults and nymphs of the stink bug *Euschistus servus* and the leaffooted bug *Leptoglossus phyllopus* to the growth stages of sorghum. Growth stage percentage refers to the seed head. Values are mean ± SEM.

the southern United States. Rae et al. (2002) evaluated and recommended white mustard [*Sinapis alba* (L.)] with pea [*Pisum sativum* (L.)] as trap crops for *N. viridula* in sweet corn.

The primary objective of this project was to develop a practical trap cropping system to manage the three major stink bug pests, *E. servus*, *A. hilare*, and *N. viridula*, as well as other minor stink bug species (in the genera *Euschistus, Banasa, Thyanta)* and the leaffooted bug (*L. phyllopus*) in vegetable and fruit production in the southern coastal plain. The biologically based, integrated strategy can be customized for the spring to fall planting seasons and is farmer-philosophy and farm-scale neutral.

Materials and Methods

Plantings of the test trap crop species were developed and evaluated in a number of ways over the course of this study at the University of Florida–IFAS NFREC–Quincy. The original plan was to use long-juvenile soybeans [*Glycine max* (L.)] combined with buckwheat [*Fagopyrum sagittatum* Gilib] and sunflower

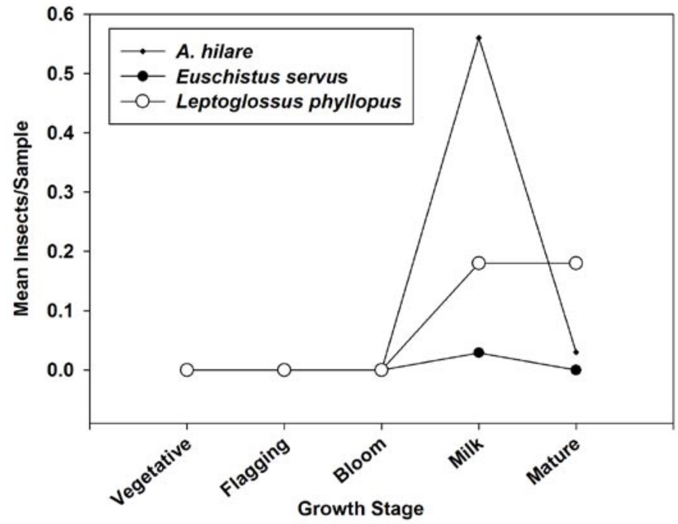

Fig. 2. Responses of the adults of three bug species to different growth stages of millet.

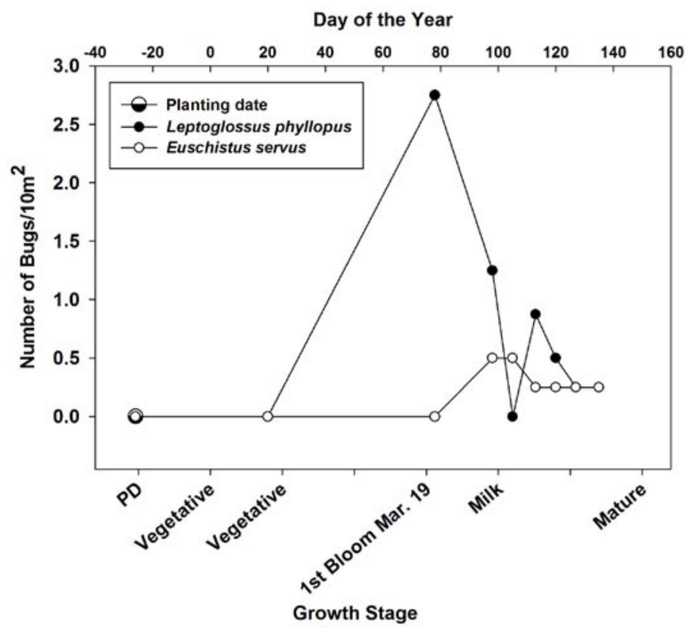

Fig. 3. Responses of the adults of two bug species to triticale growth stages.

(*Helianthus annus* L.). However, the soybeans were destroyed quickly in early testing either by deer or by defoliating lepidoptera. Therefore, we changed plans by incorporating plant species that would be less attractive or more tolerant to deer, have seed commercially available to producers, are easily cultured and managed, and serve as host plants to as many of the major stink and leaffooted pest species as possible.

Four types of plot evaluations were undertaken: 1 and 2). In 2006 and 2007, we set up late spring plantings and also a midsummer planting in 2007 of the test trap crops with four replications in a randomized complete-block design. Plot size was 2 × 10 m. Plant species were established using standard agronomic culture and management practices along with overhead irrigation as needed. Treatments for evaluation consisted of buckwheat

(‘Mancan’), grain sorghum (‘9200Y’), *Sorghum bicolor* (L.), pearl millet (‘Tiftleaf III’), *Pennisetum glaucum* (L.), sunflower (‘Perodovic’), okra (‘Clemson Spineless’), *Abelmoschus esculentum* Moench, and hemp sesbania [*Sesbania exaltata* (Raf.) ‘Cory’] (cv. from Adams-Briscoe Seed Co.), along with an unplanted weedy control plot. The plots were visually inspected 2–3 times per week for the plant growth stage present and one time per week by sweep net (three sweeps/plot) for stink/leaffooted bugs and beneficial insects. Once seed heads began to form and stink or leaffooted bugs appeared, we gathered separate data to establish the relationship of plant growth stage to stink bug feeding for each plant growth stage. This was accomplished by observing 100 insects per stink bug species and available bug life stage (Figs. 1–3). The phenology of the plants in the plots was followed until maturity of each species and the entire plot. Following maturity, each plot was ratooned (mowing) to 0.5 m in height and the plant and insect observations continued until plants either died or no longer attracted bugs. This experimental design was followed in both 2006 and 2007. However, several late March frosts and accompanying lower soil temperatures in 2007 killed or substantially impacted (leaf damage or retarded growth) the spring plots, necessitating replanting.

3). Occurrence of the frosts prompted us to search for plant species more suitable for early spring weather. Serendipitously, we examined a large triticale cultivar selection trial at NFREC–Quincy for its phenology and attraction to stink and leaffooted bugs. During the course of these observations, triticale was found to attract all four of the target bug species in early spring (March–April) long before any of the other test species could be available. Therefore, in Fall 2007, we established three plantings (staggered in time by 2 weeks beginning on 2 Oct. 2007) in 2 × 10 m plots of triticale (*Triticale hexaploide* Lart. cvs. Monark and #342, Foundation Seed, Marianna, FL). These two cultivars vary in maturity by ~10 d (‘Monark’ follows #342). The triticale plots were established in a mixture with crimson clover (*Trifolium incarnatum* L.) and hairy vetch (*Vicia villosa* Roth), two plant species well known and used as cover crops for green manure (Anonymous, 1998) and to enhance beneficial insects in spring (Tedders, 1983; Anonymous, 1998). In Spring 2008, we sampled the plots beginning in mid February as described above. Again, late frosts in northern Florida destroyed the heads of the triticale from the two earliest plantings, however, the last October planting developed heads (first bloom stage) naturally and began attracting leaffooted bugs on 10 Mar. and other stink bug species later as they emerged from overwintering.

4). On 21 July 2006, we planted additional plots of the test species as described under planting one above in replicated plots (n=3) on the east perimeter of a 0.35-ha (100 × 35m east–west) planting of Hinson soybeans in an organic production trial. Field peas *Phaseolus vulgaris* L. were also included in this planting trial. Beginning when the plants were ~ 0.23m in height, the plots were sampled once each week as described above. The soybeans were also sampled using a sweep net (n=3 sweeps) at 1 and 3 m away from the trap crops adjacent to each plot replicate. Stink bugs present in the soybean sweep samples were recorded by life stage (Figs. 1–2).

Results and Discussion

Buckwheat, triticale, sunflower, millet, field pea, and sorghum all served as host plants for the four major stink bug and leaffooted species discussed above during some period of their growth (Figs. 1–5). In addition, these plants also attracted other minor stink bug species. The plant species that produced blooms (sunflower and buckwheat), pollen (triticale, millet, sorghum, buckwheat, and sunflower), or served as hosts to other herbivores (aphids and whiteflies) (millet, sorghum, sunflower, and triticale) were highly attractive to a number of pollinating bees and parasitic Tachinidae (adult *Trissolcus* spp.) of stink bugs, and other generalists predators including numerous ladybeetle species, lacewings, etc., commonly found in augmentation crops (Bugg and Dutcher, 1993; Tedders, 1983).

Hemp sesbania did not attract any major stink bug pest species well enough to recommend, although large numbers of the rice

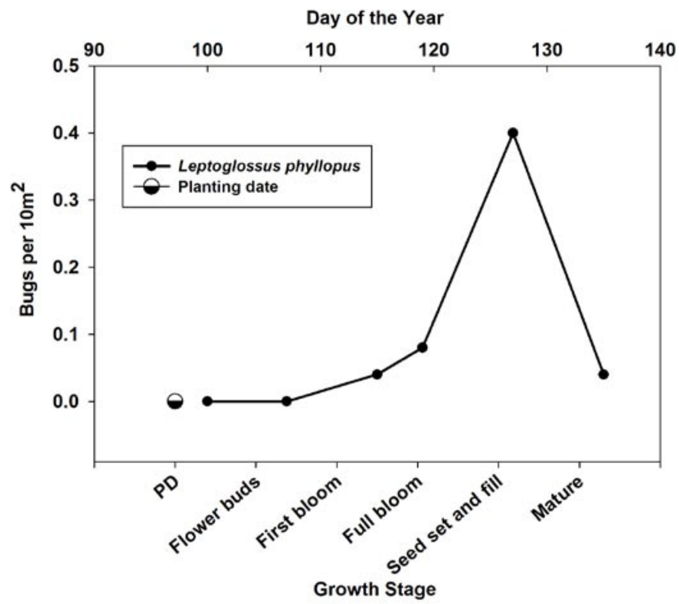

Fig. 4. Responses of *Leptoglossus phyllopus* adults to the growth stages of buckwheat.

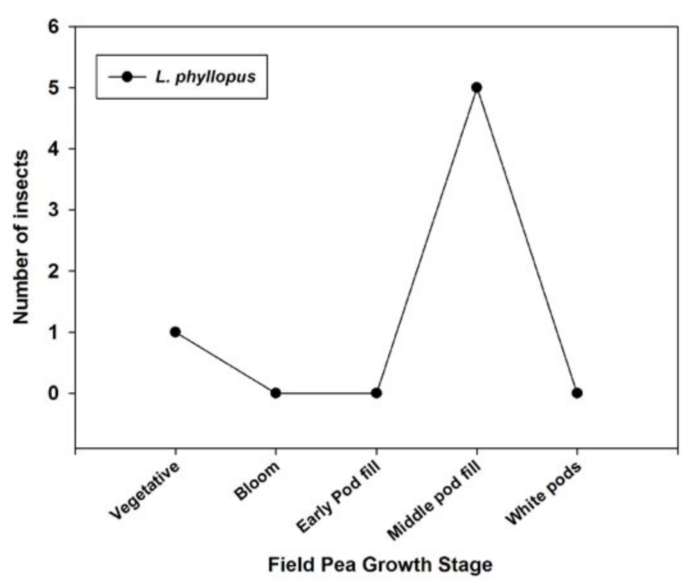

Fig. 5. Response of *Leptoglossus phyllopus* adults to the growth stages of field pea.

stink bug [*Oebalus pugnax* (F.)] and low numbers of a *Thyanta* sp. were observed on the seed heads. Moreover, once planted and allowed to go to seed, it will return the following year very vigorously. Okra did attract stink bugs and consistently was infested with aphids and occasionally whiteflies that attracted large numbers of syrphid flies, ladybeetles, and other generalist beneficial species. We do not highly recommend okra as an integral part of a stink bug trap cropping system because it matures slowly, is difficult to manage due to the need for continuous pod removal to maintain attractive pods, and it may support phytophagous soil nematodes. However, it can be ratooned. Field pea did attract stink bugs and has the added beneficial attraction of extrafloral nectaries, but slow growth and low vine-like growth characteristics require some support to provide a higher and more prominent visual cue to stink bugs.

Stink bugs are highly polyphagous feeders and move through the landscape in search of food and oviposition plants whose qualities vary over time and space. Polyphagy is an apparent manifestation of the stringent requirements the stink bugs have for their food quality (Patel et al., 2006) (Figs. 1–5). All four of the major stink bugs and likely all species are very finicky with respect to plant growth stage as it relates to the quality of their food. Preference for hosts varies with both plant stage of development and stink bug life stage; thus these variables were included in this study (Figs. 1–5). Because of this food quality issue, a narrow window exists for each trap crop plant to serve as food for stink bugs. This is critically important because it is necessary to provide a continuous source of high quality food in the trap crop to prevent the buildup of stink bugs in the cash crop which at some time also will be very favorable for stink bug feeding. Thus, the reason why trap crops require multiple plant species is to maintain a continuously competitive food source to out compete the cash crop for stink bug feeding (Fig. 6).

When the trap crops were planted adjacent to the perimeter of a plot of organically grown Hinson soybeans, the total number of stink bugs remained much higher in the trap crop than in the soybeans (Fig. 7). While the trap crop plots were managed by ratooning to maintain efficacy, the stink bugs were not removed from the trap crops and destroyed as they would be under commercial conditions. Therefore, this conservative test of the trap crop methodology provided very positive results and strong support for further testing and use by producers, but requires additional study. Stink bugs can be killed in the relatively smaller area of the trap crop by hand, with sweep nets, or with insecticide applications.

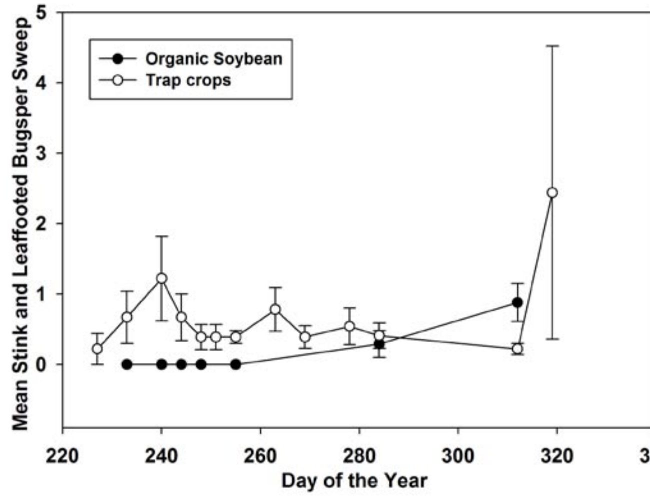

Fig. 7. Mean (±SEM) number of total stink bugs found in trap crop and an adjacent organic soybean field.

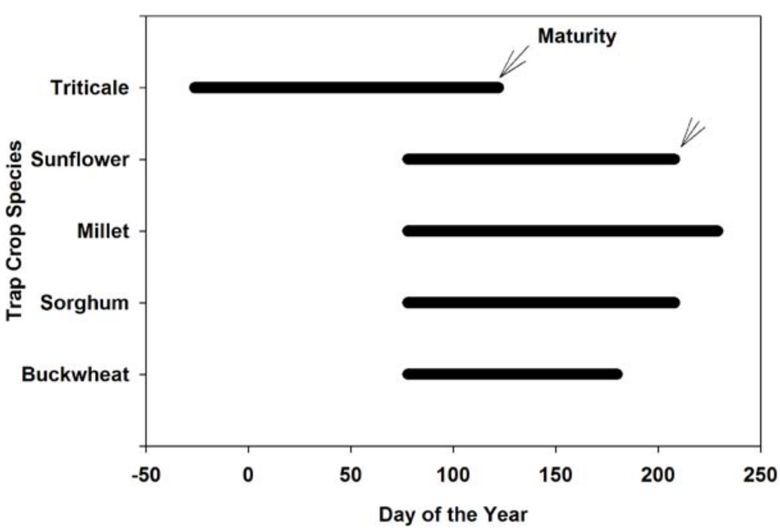

Fig. 6. Timeline indicating appropriate earliest planting times (left end) and relative maturity times (right end) for trap crops species.

Trap crop spatial and temporal considerations. Stink bugs move through the landscape in search of food and oviposition hosts and they exhibit a pronounced "edge effect" during these movements, i.e., they tend to congregate their populations in the border rows of vegetation blocks. This observation suggests that they respond to natural corridors in the vegetation that provide pathways, but they likely do not move within the corridors per se as they prefer plant cover for protection. Thus, the landscape may be described from the stink bug perspective as a series of corridors and barriers (matrix is the ecological term for the vegetation block, (Tewksbury et al., 2002)) which the vegetation represents.

Placement of trap crops relative to the cash crop should exploit these stink bug behavioral tendencies. Trap crops attract stink bugs by vision and odor. Stink bug attraction and movement merit further investigation, but we offer the following advice to growers in making decisions about trap crop placement. The vegetation species (source), structure, size and location outside the target cash crop is important in attracting and retaining stink bugs that may emigrate to the trap and cash crop. Trap crops should be placed between the suspected sources of stink bugs and the cash crop borders to intercept moving stink bugs. With smaller acreages, it may be best to plant the trap crop around the entire cash crop perimeter, but this is likely not necessary if there are large areas of open space around the cash crop. It may only be necessary to place the trap crop on the cash crop's perimeter that is closest to the nearest vegetation. These areas will likely be the location from which the stink bug originates and leaves to move toward the cash crop.

The plot size of the trap crop necessary to insure efficacy has yet to be accurately determined. The key attribute is the quality of the food available relative to the food quality of the cash crop. Due to the tendency of stink bugs to respond to vegetation barriers and concentrate on the borders, the "edge effect," plot size does not have to be very wide. If plots are established using machinery, then the width of one tractor pass is sufficient. We used a plot size of 3 × 10 m but only enough plants are needed to provide management flexibility in maintaining continuous optimum food availability. This can be achieved by planting larger plots and ratooning part of the plot at different times if sorghum and millet are used. Long narrow plots should be used in most cases given the discussion above of the factors affecting trap crop placement.

Description of the trap cropping procedure. All species used in the trap cropping system are established using standard culture and management practices. To minimize the number of plant species used in a trap crop, it is also necessary to identify species that are attractive, acceptable hosts to as many stink bug species as possible. Prior to this study, host plants that were attractive to both the major stink bug species and to the leaffooted bugs were not well known. In addition, it is necessary to have the trap crop plants available in a high quality state prior, during, and after the cash crop is most susceptible to bug feeding and damage. Lastly, plant species, and their cultivars in the case of food or grain crops, have individual growth characteristics such as maturity date, plant height, and seed head structure, as well as specific requirements for and tolerances to soil, moisture and other habitat factors. These not only determine culture and management practices, but they also may affect stink bug behavior either positively or negatively. For example, sorghum and millet do not germinate and grow well under cool soil conditions, whereas cool conditions are ideal for triticale. Buckwheat matures seed in 28–42 d, whereas sorghum and millet may require 60–90 d. Stink bugs appear to respond better to (arrest in the plots) taller plant species and prefer relatively open seed heads.

Presented with the requirements of food quality, multiple target pest species, optimum timing and practicality, the inherent limitations of insect behavior and the growth and management of each plant species, the following recommendations are suggested. These recommendations cover the entire growing season from spring to fall, attract all major and most minor stink bug pest species and present a workable plan to suppress stink bugs under any farming philosophy and farm size. The plants recommended for trap crops from this study are also very useful for augmentation of beneficial insects, e.g., parasites and predators of stink bugs, as well as many generalist feeders, and for augmentation of pollinating bees and wasps. These factors are attributable to the presence of flowers with their nectar and pollen and the occurrence of aphids and other phytophagous insects on the trap crop plants which may produce honeydew or serve as alternate hosts for beneficials.

For early spring cash crops, plantings of triticale should be made in fall by staggering several planting dates in October to early November (should be customized to location); earlier plantings may be more effective in more northern locations. Several cultivars may be established to provide a range in plant height and maturity dates. We believe that taller varieties better attract the stink bugs (Potting et al., 2005). Crimson clover and hairy vetch may also be planted at the same time within the plots to augment beneficials in spring. Triticale surmounts the limitations of cool spring soil conditions that prohibit growth of sorghum and millet and the staggered plantings will provide a hedge against total loss of the trap crop from unpredictable spring freezes. The range in maturity dates provided through use of multiple cultivars will prolong the efficacy of the trap crop and insure timely competition with the cash crop relative to food quality. Because sunflower and buckwheat can withstand cooler soil temperatures, these two species can be added to the spring trap crop in early spring. Note that neither buckwheat nor sunflower is totally tolerant of spring frosts. However, buckwheat is highly important due to its rapid seed formation within 4 to 6 weeks from planting. Because of this, if planted repeatedly, buckwheat may serve as a "relay" crop between the maturation dates of the other species.

For the summer to fall period, sunflower, buckwheat, sorghum and millet are recommended for the trap crop. Okra or field pea may also be added to further attract stink bugs and enhance the augmentation of beneficial insects; however, all of the other plant species recommended along with augmentation of pollinators perform the same functions. For sorghum and millet, we recommend planting several commercially available cultivars with a range in maturity dates. Sorghum and millet also are amenable to ratooning to increase their temporal efficacy. Sunflower can develop problems with root knot nematodes.

Sorghum seed heads remain in the optimum growth stage that is most attractive to stink bugs for a period of two–four weeks depending on the weather, cultivar and cumulative bug feeding damage. Ratooning of sorghum works best if the plants are mowed (bush hogged) to a height between 0.5 and 0.75 m after the initially formed, mature seed heads are no longer attractive to stink bugs. The plants will tiller (develop multiple stalks—ratoon) and will set new heads in about 3–4 weeks. However, the plants will be shorter in height and out of synchrony with respect to seed formation; unlike the synchronized seed set derived from the initial seed plot establishment. This is an important and unexpected "emergent property" that is very useful to extend the temporal efficacy of the trap crop. Millet may also be ratooned, but it does not return seed set as well nor grow as tall as sorghum. Sunflower is not amenable to ratooning while buckwheat is. However, buckwheat is so easily planted and quick to form seed heads that ratooning may be the less desirable management choice. Okra is also amenable to ratooning but requires longer time periods to mature.

All of the recommended species may be cultivated in large containers individually or in multiple species groups for portability and moved around to small plantings in a strategic approach by small-acreage producers or homeowners. Container plants can be ratooned as well.

A trap cropping system has been developed that is applicable to plantings varying in size and cultural practices and thus is neutral with respect to farm scale and farmer philosophy. Although, the exact size and placement of trap cropping plots around larger acreage blocks remains unclear. The recommended procedure is usable by conventional growers as well as homeowners, organic and other types of small-acreage producers. Small-acreage producers and home owners also have the option of growing the trap crops in large portable containers to reduce establishment costs and increase the efficacy of the tactic by strategic placement of the trap plants adjacent to a sequence of cash crops.

Areas needing additional study. The location for placement and size of plots relative to the cash crop, especially for larger acreage blocks, remains to be definitively determined. This limitation in part is dependent upon developing a better understanding of the relationship of stink bug movement to vegetation patterns and alternative food sources at the landscape level. This is an area that is receiving much research attention. Additionally, the crop phenology will change with location by latitude from year to year and the required presence of the preferred trap crop stage timed to the most susceptible cash crop stages must be managed for the trap crops to function properly. Semiochemical attractants for the southern green and green stink bugs and the leaffooted bugs are not available or presently remain too expensive to synthesize for practical use. This will likely change in the future, and when attractants become available, they can be incorporated into trap crops to make them more effective at attracting stink bugs to them along with the natural enemies. Meanwhile, the Florida stink bug trap and the attractant for *Euschistus* spp. can also be incorporated into a trap crop to enhance the attraction and suppression of these species. With present knowledge, growers of any type should test the trap crops as described herein to suppress stink and leaffooted pests.

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