Stink bugs (Hemiptera: Pentatomidae) are significant economic pests of many agricultural crops and are frequently one of the most difficult pests to control in crops such as soybeans [Glycine max (L.) Merr.], cotton (Gossypium hirsutum L.), tomatoes (Solanum lycopersicum L.), and many fruit crops. The green stink bug, Acrosternum hilare (Say) (Fig. 1), is native to North America and is a pest found throughout the United States. It is one of several important stink bug species that can cause feeding injury to fruit, vegetable, and field crops that may require preventative management. Many strategies are available for its control, which include multiple chemical, cultural, and biological options. Broad-spectrum insecticides such as pyrethroids and organophosphates, as well as the less toxic neonicotinoids, are efficacious against the green stink bug. Cultural options, including trap cropping and the planting of resistant varieties, have been documented as decreasing crop injury by stink bugs. In addition, there are multiple natural enemies that reduce population numbers.

Identification. The green stink bug is about 1.3–2.0 cm long and 0.8 cm wide. It is usually bright green and may have a yellow border around the margin of the abdomen, head, and thorax (Underhill 1934). Although rare, an orange color morph of this insect exists (Fig. 1b).

Green stink bug adults are similar in appearance to the southern green stink bug, Nezara viridula (L.), but can be differentiated by black bands on the antenna and a pointed abdominal spine, instead of red antennal bands with a rounded abdominal spine (Fig. 2) (Miner 1966, McPherson 1982, McPherson and McPherson 2000). The nymphs of the green stink bug are easily distinguishable from those of the southern green stink bug. Southern green stink bug nymphs have two rows of white dots on their abdomen, whereas the green stink bug nymphs do not. Color morphs are found in both species of nymphs, and both dark and light colorations are commonly exhibited by green stink bug nymphs (Figs. 3 and 4).

Taxonomy. The green stink bug first was described by Thomas Say as Pentatoma hilarii in 1832 (Say 1832). Its scientific name was changed several times, and eventually in 1915, it was changed to its current name, A. hilare (Parshley 1915). However, it has been suggested recently that the green stink bug is misnamed and should be classified as Chinavia hilaris (Say) (D. Rider, personal communication). According to their findings, the genus Acrosternum belongs to smaller Palearctic species of stink bugs that live in arid environments. However, because the Entomological Society of America has not officially changed the species name of the green stink bug, this paper will use the nomenclature A. hilare (ESA 2012).
to light pink before hatching in about 1 wk (Miner 1966). The duration of the egg stage depends on temperature. Shorter durations occur in warmer temperatures, and longer durations in cooler temperatures (Underhill 1934, Capinera 2001). Upon hatching, they undergo five instars before becoming adults (Underhill 1934, Miner 1966).

The first instars do not feed and remain clustered together around the egg mass. Second instars are less gregarious and begin to feed. Third instars behave in a similar manner to second instars, but are slightly larger in size. Feeding by the fourth and fifth instars can result in as much economic damage to the plants as from adults (Barbour et al. 1988). Development time of the nymphs can vary based on the host and temperature, and development of each instar occurs most rapidly at 27°C (Simmons and Yeargan 1988). Adulthood is reached in ≈36 d (Underhill 1934, Miner 1966). A complete description of each life stage is available by Miner (1966).

**Host Plants.** The green stink bug is polyphagous and feeds on a variety of plants, but prefers woody plant tissue (McPherson 1982). A comprehensive list of host plants is included in Schoene and Underhill (1933), Underhill (1934), and McPherson (1982). To complete its development, the green stink bug typically requires a series of plants with overlapping periods of seed and fruit production (Underhill 1934). It prefers woody hosts including basswood, *Tilia americana* L.; mulberry, *Morus* spp.; pear, *Pyrus* spp.; maple, *Acer* spp.; American elder, *Sambucus canadensis* L.; and black locust, *Robinia pseudoacacia* L.; yet it is a common pest of vegetable and field crops such as lima beans, *Phaseolus lunatus* L.; green beans, *Phaseolus vulgaris* L.; soybean, *Glycine max* (L.) Merr.; tomato, *Solanum lycopersicum* L.; cotton, *Gossypium hirsutum* L.; eggplant, *Solanum melongena* L.; and cucumber, *Cucumis sativus* L. (Capinera 2001). The green stink bug also has been recorded as feeding on the herbaceous weeds goldenrod, *Solidago* spp.; ironweed, *Vernonia* spp.; horseweed, *Conyza* spp.; and jimsonweed, *Datura stramonium* L. (McPherson 1982, Capinera 2001).

**Crop Damage.** The green stink bug is one of several species of agriculturally important stink bugs in the United States. Similar to other stink bugs, green stink bug populations reach their peak in late summer. Crop injury is accrued when the feeding stylet penetrates plant tissue. The economic injury potential of green stink bug feeding varies by crop.

**Tomato.** Several species of stink bugs, including green stink bug, are reported as economic pests of the tomato (Lye et al. 1988, Zalom et al. 1997, McPherson and McPherson 2000, Nault and Speese 2002). Stink bugs inject a toxin into the fruit when they feed, which can result in a spongy white area. This renders it unmarketable for processing and fresh market tomatoes (Fig. 6) (Kennedy et al. 1983). Stylet insertion also leads to premature ripening and smaller fruit (Lye et al. 1988). Nault and Speese (2002) reported stink bugs as causing more damage to spring tomatoes in Virginia than either thrips or lepidopterans. In addition, Kennedy et al. (1983) stated that the green stink bug is one of the most damaging pests of tomato in North Carolina.

**Peach.** Stink bug feeding on fruit trees can result in extensive damage, and feeding injury in the early developmental stage of the fruit results in the most damage (McPherson and McPherson 2000). In peaches, feeding injury results in blemishes on the skin, yield loss, misshapen fruit, or catfacing (Fig. 7) (Rings 1957, McPherson and McPherson 2000). Catfacing occurs because the site of the feeding puncture does not grow, although the areas around it continue to grow. This results in bumpy areas on the surface of the fruit, making it unmarketable (Rings 1957). This same dimpling and damage to the...
Historically, green stink bug was considered an economically important stink bug pest of peaches along with the brown stink bug, *Euschistus servus* (Say), and the dusky stink bug, *Euschistus tristigmatus* (Say), in the eastern United States (Hogmire 1995). More recently, the brown marmorated stink bug, *Halyomorpha halys* (Stål), has caused the greatest economic loss to peaches in the mid-Atlantic states (Leskey and Hamilton 2010).

Soybean. Stink bug feeding preference varies with the developmental progress of the crop. The insects typically move into a soybean field after flowering and remain through plant maturity. A survey of soybean and cotton in southeastern Virginia determined that brown and green stink bugs were the most common species in 2005 and 2006 (Kamminga 2008). More recently, the brown marmorated stink bug has become a dominant stink bug in many agricultural commodities in the mid-Atlantic, including areas of New Jersey, Maryland, Delaware, Pennsylvania, West Virginia, and Virginia. It was reported that the brown marmorated stink bug outnumbered all native species in soybean fields in Pennsylvania (Nielsen et al. 2011).

Stink bug feeding on soybean can cause green stem syndrome, a plant response that results in green stems past maturity. Feeding also results in reduced seed quality (Fig. 8); decreased yield (Underhill 1934, McPherson and McPherson 2000); and less oil than undamaged beans (Daugherty et al. 1964). Feeding punctures from green stink bug stylets may also increase the possibility of infection by a pathogen. The insect has been shown to transmit the causative agent of yeast-spot disease (McPherson and McPherson 2000). Importers may reject seeds if too much stink bug damage is present (Chyen et al. 1992), resulting in even greater economic loss.

Cotton. Stink bugs have been considered to be pests of cotton since the early 1900s (Morrill 1910). Historically, stink bugs were controlled by broad-spectrum insecticide sprays, intended to control other...
pests such as the boll weevil, *Anthonomus grandis grandis* Boheman (Coleoptera: Curculionidae), and the bollworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) (Greene et al. 1997). Recently, stink bug populations in cotton have increased. This is in part because of fewer insecticide sprays targeting boll weevil, resulting from a widely successful eradication program throughout most of the southern United States. In addition, *B. thuringiensis* Berline, crops have increased in acreage and provide control over many lepidopteran pests without the need to spray insecticides. These advancements have decreased the number of broad-spectrum insecticide sprays on cotton, resulting in an increase in stink bugs.

A complex consisting of the four primary stink bugs, the green, southern green, red banded, *Piezodorus guildinii* (Westwood), and brown stink bug are found in cotton throughout the southeast. Reay-Jones et al. (2009, 2010) reported the green stink bug as being the primary stink bug collected during sampling in cotton in South Carolina and Georgia in 2008 and 2007. In addition, surveys in Virginia also determined that the green stink bug is a prominent stink bug in the cotton system (Kamminga 2008).

Stink bugs feed on young, tender cotton bolls resulting in injured seeds and lint, and lower yield (Fig. 9) (Barbour et al. 1988, 1990). Researchers have investigated an association between external feeding punctures (sunken lesions) and internal injury; however, it is still difficult to accurately correlate the two (Blinka et al. 2010).

**Monitoring and Management Options**

*Sweep Nets and Beat Sheets.* Sampling of insects on crops is traditionally performed to assess the pest complex in relation to economic thresholds. Sweep net and beat sheet sampling methods are recommended for monitoring stink bugs in field crops (Todd and Herzog 1980). For fruits and vegetables, beat sheets are more common (Nielsen and Hamilton 2009).

Stink bug thresholds vary according to the crop. For example, the threshold for tomatoes is one stink bug per three beat sheet samples (Brust and Zalom 2005). For soybeans, recommendations for stink bug thresholds can also vary by state (Parker 2012). In many southern states, a beat sheet sample containing above one stink bug per 0.3-row meter may require an insecticide application (Parker 2012). However, thresholds can also vary by maturity (Parker 2012) and seed spacing (Herbert 2012). Current practices in cotton recommend a dynamic threshold based on the age of the boll and the percent internal damaged bolls per field. Moreover, Herbert (2012) indicates that one stink bug per 25 sweeps or one stink bug per two-row meters may be above economic threshold.

Establishing accuracy of the sampling methods is complex, as this can depend on the life stage and density of both crops and insects, as well as time of day (Reay-Jones et al. 2009). Sampling using sweep nets and beat sheets can help determine the seasonality and life stage of stink bugs, but they may drop to the ground or fly away when disturbed. Other monitoring methods, like pheromone and blacklight traps, may offer additional information as to the species, relative abundance, and flight activity of stink bugs on farms.

**Blacklight Trapping.** Many insects, including stink bugs, can be monitored using blacklight traps (Fig. 10). Blacklight trap catch may be useful for improving the timing of scouting and management methods for stink bugs (Kamminga et al. 2009a, Nielsen and Hamilton 2009). In addition, flight activity and distribution can be determined for native and possible invasive species.
and may occur because of the similarities in their chemical composi-

tion (Aldrich et al. 1989, 1993). However, synthesis of the aforementioned pheromone is expensive and currently inhibits widespread use of this technique.

**Chemical Control.** Broad-spectrum insecticides, such as organophosphates and pyrethroids, are the most frequently applied insecticides for stink bug management (Kuhar et al. 2006, Herbert 2012), and both classes provide efficacy against *Acrosternum* spp. (Willrich et al. 2003). Dicofol, an organophosphate, has been cited as having a high toxicity to various stink bug species (Tillman and Mullinix 2004, Snodgrass et al. 2005), and it is suggested that it provides consistent control of the green stink bug (Willrich et al. 2003, Snodgrass et al. 2005). In addition, Kamminga et al. (2009c) performed efficacy trials on stink bug nymphs and adults in southeastern Virginia, and found that the green stink bug was especially susceptible to all of the pyrethroids tested. Neonicotinoids also were effective against green stink bug adults. In particular, thiamethoxam, dinotefuran, and imidacloprid were found to be efficacious against green stink bug adults; whereas dinotefuran and clothianidin were efficacious against green stink bug nymphs. In a similar study, Tillman (2006b) reported that acetamiprid and thiamethoxam exhibited some residual contact and ingestion activity on nymphs, but not adults, of the southern green stink bug.

Differences in the susceptibility of stink bug life stages to insecticides are common (McPherson et al. 1979; Willrich et al. 2002, 2003; Kamminga et al. 2009c). Willrich et al. (2003) reported that brown stink bug nymphs were more susceptible to the pyrethroid lambda-cyhalothrin than the adults. Conversely, southern green stink bug nymphs were less susceptible to the pyrethroids cypermethrin and lambda-cyhalothrin than the adults. McPherson et al. (1979) and Willrich et al. (2002) reported that the LD$_{50}$ (lethal dose required to kill 50% of the insects tested) of methyl parathion on late instars of brown, green, and southern green stink bugs was higher than the LD$_{50}$ during the adult stage.

Very little research has been done to test the efficacy of Organic Materials Review Institute-certified (organic) insecticides against stink bugs. The research that has been published primarily investigates the effects of the extract azadirachtin from the neem tree, *Azadirachta indica* (A. Juss), on stink bug nymphs. Azadirachtin acts as an antifeedant (Seymour et al. 1995, Abudulai et al. 2003, Kamminga et al. 2009b), but mixed results have been reported in its efficacy against stink bugs (Kamminga et al. 2009b). Azadirachtin also is an insect growth regulator and has been reported as disrupting the molting of stink bug nymphs (Abudulai et al. 2003, Riba et al. 2003), but research also has indicated that it is not always efficacious against stink bug nymphs that were fed an azadirachtin-treated food source (Overall 2008, Kamminga et al. 2009b).

Pyrethrins and an organic formulation of spinosad have been found to be effective against stink bug nymphs (Overall 2008, Kamminga et al. 2009b). Pyrethrins were reported as repelling stink bugs, whereas spinosad attracted them (Kamminga et al. 2009b). Spinosad also was determined to have a lower LC$_{50}$ on harlequin bug nymphs, *Morgania histrionica* (Hahn), than either pyrethrins or azadirachtin (Overall 2008). In addition, in behavioral bioassays, stink bugs were found to feed more on spinosad-treated tomatoes than untreated-, azadirachtin-, and pyrethrin-treated tomatoes. Spinosad caused high mortality when green and brown stink bug adults were fed treated green beans, but mixed results were obtained when tested against nymphs (Kamminga et al. 2009b).

**Cultural Control.** Trap crops are designed to intercept and allow for the removal of a pest before it moves into a cash crop by providing a preferred food source. This method has been found to be an effective management technique for stink bugs (Todd and Schumann 1988, Hokkanen 1991). For example, sorghum, *Sorghum bicolor* L. Mo-

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**Fig. 11.** Yellow pyramid trap with pheromone for monitoring stink bugs (Photo by K. Kamminga).

**Fig. 12.** Tachinid fly, *T. pennipes* (F.) (Photo by Russ Ottens, University of Georgia, Bugwood.org).

**Pheromone Trapping.** Pheromone traps have been used to monitor green stink bug populations in peach, *Prunus persica* (L.) Batsch; apple, *Malus domestica* Borkh. (Leskey and Hogmire 2005); and pecan, *Carya illinoinensis* (Wangenh.) K. Koch, orchards (Mizell and Tedders 1995). A yellow base pyramid trap with a pheromone lure is commonly used to monitor green stink bug populations (Fig. 11) (Leskey and Hogmire 2005, Hogmire and Leskey 2006). The aggregation pheromone blend for the green stink bug has been identified as a 95:5 cis:trans blend of (4S)-cis-Z-bisabolene epoxide and (4S)-trans-Z-bisabolene epoxide (Aldrich et al. 1989, 1993; McBrien et al. 2001). Cross attractiveness of the green stink bug to the southern green stink bug has been identified as a 95:5 cis:trans blend of (4S)-cis-Z-bisabolene epoxide and (4S)-trans-Z-bisabolene epoxide (Leskey and Hogmire 2005, Hogmire and Leskey 2006). The aggregation pheromone blend for the green stink bug has been identified as a 95:5 cis:trans blend of (4S)-cis-Z-bisabolene epoxide and (4S)-trans-Z-bisabolene epoxide (Leskey and Hogmire 2005, Hogmire and Leskey 2006).
**Host Plant Resistance.** Stink bug resistant varieties of soybean have been shown to have a lower population of pentatomids than other varieties (Gilman et al. 1982, Jones and Sullivan 1982). More recent studies have indicated that certain breeding lines of soybean may be possible genetic material for stink bug resistant soybeans (McPherson et al. 2007, Campos et al. 2010). These resistant lines may decrease damage caused by stink bug feeding and insecticide applications for stink bug control in soybeans.

**Biological Control.** Biological control, which relies upon natural enemies of the pest to manage the pest population and reduce commodity damage, is a part of stink bug pest management. Stink bugs are vulnerable to multiple predators, parasitoids, and parasites. Mermithid nematodes have been reported as infesting stink bug adults and nymphs (Fuxa et al. 2000, Riberiro and Castiglioni 2008). Lacewing larva; spined soldier bugs, *Podisus maculiventris* (Say); and birds are common predators of stink bugs (Underhill 1934, McPherson 1982, McPherson and McPherson 2000). Most stink bug parasitoids are tachinid flies that oviposit on the abdomen of the host. A common example is *Trichopoda pennipes* (F.) (*Diptera: Tachinidae*) (Fig. 12) (Capanera 2001). The female fly deposits one or multiple small grayish eggs on the abdomen of adults or nymphs. The eggs hatch in ~30 h and the larvae then burrow into the body of the host. After ~16 d, a single larva will emerge as a maggot from the host. This maggot pupates and an adult fly emerges in 2–4 wk (Worthley 1924). Overwintering larvae remain in their host throughout the winter and emerge in the spring.

Other egg parasitoids include wasps of the genera *Trissolcus*, *Anastatus*, and *Telenomus* (Fig. 13). *Trissolcus basalis* Wollaston (*Hymenoptera: Scelionidae*) (Fig. 14) has shown potential against southern green stink bugs in soybean (Ehler 2002). Inoculative releases of 15,000 *T. basalis* adults per hectare in a trap crop of early maturing soybean reduced the stink bug density an average of 58% in the main crop of late planted soybeans (Corrêa-Ferreira and Moscardi 1996), maintaining it below economic threshold. Koppel et al. (2009) reported 47% green stink bug egg parasitism during a survey of crops in the mid-Atlantic United States. Orr et al. (1986) reported an egg parasitization rate of 14–22% in Louisiana soybeans. The Louisiana and Virginia egg parasitoid surveys determined that green stink bug eggs were parasitized by *Trissolcus euschisti* Ashmead, *T. basils*, *Trissolcus edessae* Fouts, and *Telenomus podisi* Ashmead (Orr et al. 1986, Koppel et al. 2009). An additional parasitoid species, *Telenomus cristatus* Johnson, also was identified as parasitizing green stink bug eggs in Louisiana (Orr et al. 1986).

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