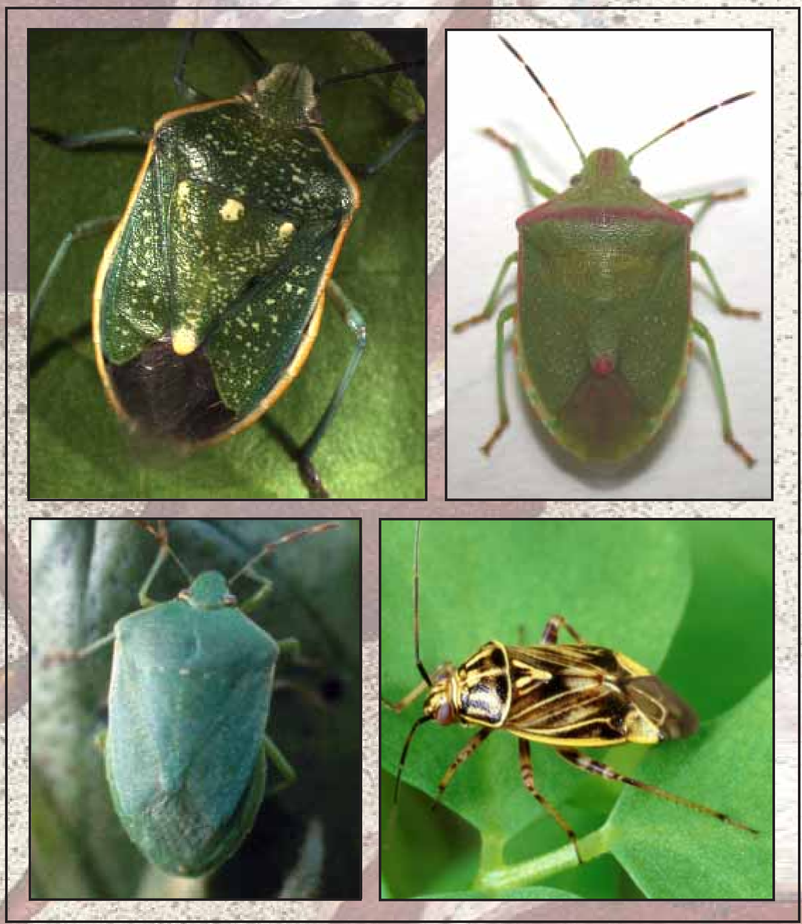
EB 158
August 2006

Identification and Management of Common Boll-Feeding Bugs in Cotton

Jeremy K. Greene, C. Scott Bundy, Phillip M. Roberts and B. Roger Leonard



Clemson University in cooperation with Louisiana State University, New Mexico State University and the University of Georgia. Funding by Cotton Incorporated.

Identification and Management of Common Boll-Feeding Bugs in Cotton

Jeremy K. Greene, C. Scott Bundy, Phillip M. Roberts and B. Roger Leonard

Introduction

This publication was developed to provide a summary of information about common boll-feeding bugs (heteropteran pests), stress proper identification of these pests, and acquaint the reader with the recommended strategies for management of boll-feeding bugs in cotton. The first section of this publication emphasizes the recent importance of boll-feeding bugs in cotton and provides a brief discussion of the biology of these pests. The second section offers a general guide to identification of the common boll-feeding bug pests in cotton. The final section presents an overview of current management strategies for boll-feeding bugs and suggests implications for their future control in cotton.

Increased Importance of Boll-Feeding Bugs in Cotton

Boll-feeding insects with piercing/sucking mouthparts, such as stink bugs (Pentatomidae) and plant bugs (Miridae), have become more common cotton pests during recent years for one major reason — a reduction in the frequency of foliar, broad-spectrum insecticide applications. The reduced use of conventional insecticides for major pests has resulted in less coincidental control of those cotton pests that traditionally have been considered of minor importance. For example, successful eradication of the boll weevil, *Anthonomus grandis grandis*, in most states has had a tremendous impact on broad-spectrum insecticide inputs in cotton (Duffy and Hishamunda 2001). Also, recent developments in insecticide chemistry for cotton insects have produced target-specific or "selective" compounds having enhanced specificity for caterpillar insect (Lepidoptera) pests. These narrow-spectrum insecticides offer little or no control of insect pests with sucking mouthparts.

The increased adoption of transgenic cotton varieties expressing *Bacillus thuringiensis* (Bt) insecticidal proteins has allowed further reductions in foliar insecticide use by providing effective control of important lepidopteran pests such as tobacco budworm (TBW), *Heliothis virescens*, and bollworm (BW), *Helicoverpa zea*. However, the Bt proteins provide no control of sucking pests. Second-generation Bt cotton varieties, such as those with dual Bt proteins, have enhanced the efficacy and spectrum of caterpillar pest control in cotton, further reducing the need for broad-spectrum insecticides. Insect pests, such as those included in the boll-feeding bug complex, that are not susceptible to Bt toxins and are no longer subjected to repeated applications of broad spectrum insecticide chemistry have exploited the recent changes in technology.

Another factor that has increased the occurrence of boll-feeding pests, especially stink bugs, in cotton and other crops is a shift in soybean production systems, especially in the Mid-Southern states. In recent years, growers in the Mid-South have planted earlier in the spring and assigned more acreage to maturity group IV soybeans. This shift has dramatically changed the interval when soybeans are a suitable host for stink bugs. The shift to maturity group IV soybeans and earlier planting dates has resulted in the majority of soybeans being harvested while cotton is still susceptible to stink bugs. Therefore, when soybeans are mature and no longer a preferred host, stink bugs and other bug pests may migrate to cotton fields. Consequently, the higher numbers of insecticide applications for boll-feeding bugs in cotton have primarily been during the flowering period. There has been a steady increase in the number of insecticide applications targeting stink bugs and plant bugs in the US during recent years (Figure 1).

Cotton yield losses from boll-feeding bug pests have also increased in recent years, especially in the Southeast. The number of bales lost from stink bug injury tends to be higher in the Southeast compared with other production regions (Figure 2). This may be due, in part, to low populations of plant bugs in that region. Few insecticide applications target plant bugs in the Southeast compared with the multiple treatments applied for control of high populations of plant bugs in the Mid-South. Insecticide sprays targeting plant bugs often suppress populations of stink bugs below damaging levels. As with stink bugs, cotton bale losses attributed to plant bug injury has also increased in the US, especially in the Mid-South during recent years (Figure 3). Cotton yield losses from boll-feeding bugs

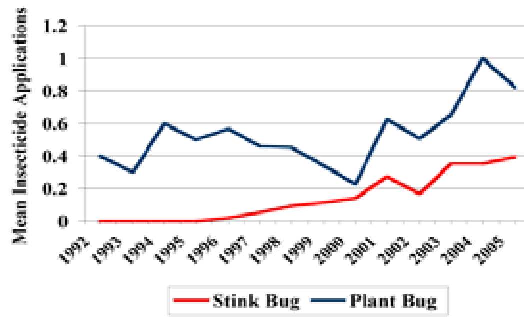


Figure 1. Frequency of insecticide applications per acre for stink bugs and plant bugs, US Cotton 1992-2005 (Beltwide Cotton Conferences).

Figure 2. Estimates of cotton bale losses due to stink bug damage, US and Southeast Regions 1992-2005 (Beltwide Cotton Conferences).

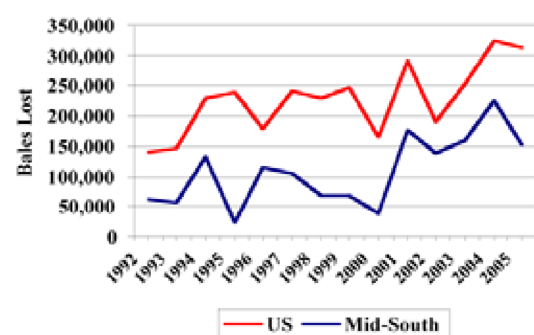


Figure 3. Estimates of cotton bale losses due to plant bug damage, US and Mid-South Regions 1992-2005 (Beltwide Cotton Conferences).

vary depending on time and location. This variation greatly influences the detection and management of these pests. Several factors contribute to this variation but are based primarily on (a) initial pest bug population densities, (b) environmental conditions that result in preferred wild host plants becoming unattractive, and (c) efficacy and timing of recommended insecticides.

Biology and Ecology of Selected Boll-Feeding Bugs in Cotton

The predominant species of pentatomids (stink bugs) infesting cotton in the Southeast and Mid-South include the southern green stink bug, *Nezara viridula*, the green stink bug, *Acrosternum hilare*, and the brown stink bug, *Euschistus servus*. In recent years, the brown stink bug has become a more common pest than in previous reports. The brown stink bug has a wider range of native hosts than the southern green stink bug (Jones and Sullivan 1982, McPherson and McPherson 2000). The recent increase in this pest might be related to its ability to use a wide range of hosts. In western production regions, the brown stink bug has been reported to cause significant losses in Texas and Arizona. A related species, E. *conspersus*, impacts cotton in California. Stink bugs are primarily a pest during the flowering stages of cotton development, feeding on bolls. Additional pentatomids, including other *Euschistus spp.*, *Piezodorus guildinii*, *Thyanta spp.* and others, are occasional cotton pests. Still other species of stink bugs present in cotton are "transient" species. These species have not been recorded as pests, but are present in some fields for various reasons. For example, *Edessa spp.*, a plant-feeding stink bug, feeds on non-crop plants and can be observed in cotton fields on morningglory plants. Although this species does not feed on cotton, it can be confused with the brown stink bug. The spined soldier bug, *Podisus maculiventris*, is a common predatory stink bug that typically feeds on cotton insect pests. This species can also be confused with the brown stink bug, and proper identification of these insects is crucial. *Proxys punctulatus* is a species that congregates on tropical spiderwort, a weed in Georgia cotton-growing areas, but is not considered to be a cotton pest at this time. Other species of true bugs (Heteroptera) that were once considered transient species have become more frequent and feed on cotton plants. Leaffooted bugs, *Leptoglossus spp.*, are examples of infrequent pests that are becoming more common in the boll-feeding bug complex. Although many stink bugs feed on plants, a few species are considered beneficial insects.

There are several species of mirids that are important in cotton production systems including the tarnished plant bug, *Lygus lineolaris*, the western tarnished plant bug, *Lygus hesperus*, the clouded plant bug, *Neurocolpus nubilus*, and the cotton fleahopper, *Pseudatomoscelis seriatus*. Plant bugs have been perennial early-season pests in cotton, feeding habitually in plant terminals and on pre-floral buds (squares) (Tugwell et al. 1976). However, the changing "low-spray" environment has allowed them to become significant mid- to late-season problems (Leonard and Emfinger 2002, Gore and Catchot 2005). Currently, square and boll injury can be attributed to plant bugs during the flowering stages of cotton, especially in areas of the Mid-South. Other species of plant bugs, such as *Ceratocapsus punctulatus* and *Lygus elisus* may be infrequent, but problematic pests.

Both stink bugs and plant bugs feed on and use a variety of plant hosts. The diverse host range of stink bugs includes over 200 documented species of host plants. Stink bugs are key pests of soybeans, field corn and vegetables in the Mid-South, but have been relatively unimportant in cotton until recently. Over 120 economically important plants in the families Amaranthaceae, Asteraceae, Chenopodiaceae, Euphorbiaceae, Leguminaceae, Lythraceae, Malvaceae, Onagraceae, Portulacaceae, Solanaceae and Verbenaceae have been recorded as host plants for tarnished plant bug, including 21 of the 30 most important crops in the United States (Young 1986, Cleveland 1982, Snodgrass et al. 1984). Plant bugs most commonly use these host plants for food and reproduction when flower buds and fruit are formed or opening. Nymphs are found on hosts that have a flower bud, are flowering or have recently flowered (Snodgrass et al. 1984, Fleisher and Gaylor 1988). Host availability and sequence of occurrence are important for population development during the seasonal cycle. Mass migrations from host plants (cultivated crops and/or wild host) may occur with both stink bugs and plant bugs.

Life cycles of stink bugs and plant bugs are very similar in that there are five nymphal instars, requiring about three to four weeks for development into adults. Stink bug eggs are barrel-shaped and usually deposited on the lower surface of leaves in masses of 20 to 100 eggs, depending on species. First instar stink bugs do not feed on plant tissue and are gregarious, tending to remain clustered around the egg mass unless disturbed. Second instars also remain clustered near the egg mass, but begin to feed on plant tissues. Third, fourth, and fifth instars disperse to neighboring plants and feed on bolls. Late instars (fourth-fifth) and adults are the most destructive life stages to developing cotton bolls (Greene et al. 1999). Plant bugs, such as the tarnished plant bug, oviposit elongated and slightly curved eggs on flowers, squares, bracts, and stems of plants. Each egg is partially inserted into plant tissue and hatches in about ten days.

Typically, these pests overwinter as adults beneath leaf litter, bark, wood piles, and within other objects that offer protection from environmental extremes (Todd and Herzog 1980, Todd 1989, McPherson et al. 1994). During winters with above-average rainfall, bugs concentrate in well-drained elevated areas, whereas in winters with low rainfall, they are more widely dispersed (Cleveland 1982). Temperature is a critical factor for over-wintering populations of stink bugs. In the United States, distribution of the southern green stink bug is affected by its susceptibility to low temperatures, although it has reproduced at least as far north as southern Illinois (McPherson 1982). Green and brown stink bugs are more tolerant of cold temperatures, and their distributions include the southern states and extend into northern states where they can successfully overwinter. Adults emerge from overwintering sites in the spring and can be found on numerous wild and crop host plants (Rolston and Kendrick 1961, Todd and Herzog 1980, McPherson et al. 1994). Subsequent generations of stink bugs migrate to cultivated hosts such as wheat, field corn, soybean, and cotton. Movement from wild host plants to cultivated field crops coincides with spring wild host senescence and development stages of crop hosts (Rolston and Kendrick 1961, Todd and Herzog 1980, Panizzi and Meneguim 1989). Recently, high numbers of tarnished plant bug have been recorded on reproductive-stage ryegrass and field corn. These plant species may serve as alternate hosts before immigration to cotton fields.

The agricultural landscape in many cotton production regions provides suitable cultivated and non-cultivated hosts, both temporally and spatially, for many of these bug pests. Stink bugs, for example, can use a sequence of crop hosts during the summer. Infestations are usually observed in field corn followed by populations in grain sorghum and early-maturing soybean (Group IV) and finally migrations to cotton and late-maturing soybean (Groups V and VI). In some instances these species use rice and grain sorghum as hosts during the mid-to-late summer. Frequently, stink bug and plant bug populations exceed action thresholds on crop plants near field borders that are adjacent to the plant hosts from which they are emigrating.

Stink bugs and plant bugs are common on vegetative- and reproductive-stage plants in cotton fields. Most data show no significant effects of stink bugs on plant growth and fruiting-form development until the plants begin to flower (Willrich 2004). Historically, plant bug feeding on bolls was considered to be a relatively unimportant source of yield loss (Scales and Furr 1968, Tugwell et al. 1976). Plant bugs preferentially feed on squares during pre-flowering and flowering stages. However, infestations during the flowering period can injure bolls, induce boll abscission, and reduce cotton yields (Horn et al. 1999, Russell 1999). These pests pierce the boll wall with their piercing-sucking mouthparts and feed on developing seeds and surrounding tissues (Wene and Sheets 1964). When bolls are small, excessive feeding may cause them to shed. However when larger bolls are fed upon, they often remain on the plant and form rough cellular growths on the inner surface of the carpel wall (Wene and Sheets 1964). Stink bugs can damage bolls from anthesis to 25 days of age (Willrich 2004, Greene et al. 2005). Stink bugs preferentially feed on bolls that are approximately the diameter of a quarter but will feed on other boll cohorts in their absence. The period of boll susceptibility to plant bug induced abscission is only about 10 days after anthesis (Russell 1999).

Direct and indirect damage to cotton bolls occurs from these pests. Bugs may physically damage the seed during feeding which impacts fiber development and maturity. In addition to yield loss, preliminary studies indicate that fiber quality is also negatively impacted when excessive damage occurs (Turnipseed et al. 2004, Roberts et al. 2005) Indirect effects of stink bug feeding occur through the introduction of boll-rot pathogens during feeding, or rot organisms entering the boll through feeding, causing individual locks or entire bolls to rot (Kirkpatrick and Rothrock 2001, Willrich 2004). Damaged bolls at harvest range from localized discoloration on individual locks, which fail to fluff (hard-locked bolls), to one or more locks or the entire boll rotting (Halloin 1986, Wene and Sheets 1964, Barbour et al. 1990, Turnipseed et al. 1995). Penetration of bolls that do not abscise can result in discolored and yellowed lint. There is some evidence suggesting that humid environments (multiple rainfall events) exacerbate hard-locked bolls that have been damaged by stink bugs (Willrich 2004).

Natural enemies of stink bugs and plant bugs are limited, but include selected predators and parasitoids. While beneficial organisms can provide limited assistance with populations of boll-feeding bugs, proper identification to select the appropriate control procedures is a necessity for adequate management of boll-feeding bugs in cotton.

Identification

The plant-feeding insect pest complexes that damage cotton, commonly referred to as "bugs," are characterized by having piercing-sucking mouthparts and wings that are half-leathery and half-membranous (Hemiptera). Considered here are the common bugs on cotton. This list is not comprehensive and is designed as a user-friendly guide for growers and consultants. For more comprehensive work and keys, refer to McPherson and McPherson (2000) and McPherson (1982) for stink bugs and to Mueller et al. (2003), Schwartz and Foottit (1998), or the University of California at http://anrcatalog.ucdavis.edu/pdf/8104.pdf for plant bugs.

PHYTOPHAGOUS STINK BUGS

Phytophagous (plant-feeding) stink bugs are distinguished from predaceous species by the shape of the proboscis (beak) (*Figure 4*). Plant-feeding species (*Figure 5*) have a more narrow proboscis (about the same diameter as an antenna), and the first beak segment is attached to the head for most of its length. Predaceous stink bugs (*Figure 6*) have a broad proboscis (about twice the width of an antenna), with the first beak segment free from the body. Predatory stink bugs are often observed feeding with their proboscis directed away from the head (Figure 7).

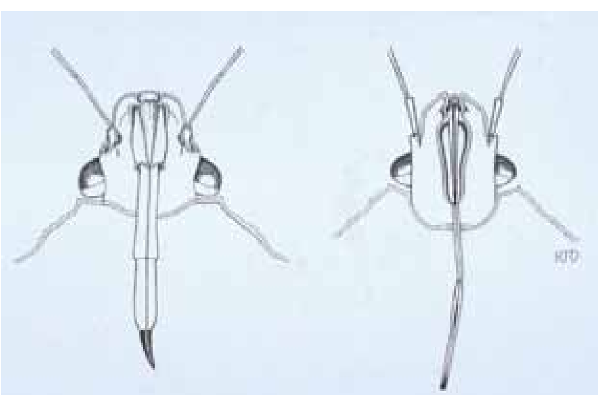


Figure 4. Illustration of beak (proboscis) structures of predaceous (left) and plant-feeding (right) stink bugs.

Figure 5. Ventral (left) and lateral (right) views of proboscis of plant-feeding stink bug. Arrow indicates attached first segment of proboscis.

Figure 6. Ventral (left) and lateral (right) views of proboscis of predaceous stink bug. Arrow indicates detached first segment of proboscis.

Figure 7. Predaceous stink bug with prey.

Figure 8. Adult of the southern green stink bug, *Nezara viridula*.

Southern Green Stink Bug,
Nezara viridula (L.)

Adults: Body color green, length 0.5 - 0.7 inch (Figure 8). The southern green stink bug is sometimes confused with the green stink bug. However, the southern green stink bug is distinguished by a short, rounded ventral abdominal spine (Figure 9); antennae with reddish-brown bands (Figure 10); and ostiolar canal (scent-gland opening) (Figure 11) extending less than halfway to margin of thorax.

Nymphs: Body color of 1st instars reddish-brown, becoming black in 2nd and 3rd instars, 4th and 5th instars mostly green – margins of abdomen and thorax often tinged with orange, yellow, or red. White abdominal spots visible for 3rd through 5th instars (Figure 12).

Eggs: Deposited in large clusters (~150 eggs possible per cluster) in many tightly aligned rows (Figure 13). The egg surface appears relatively smooth with 28-40 short, tear-shaped micropyles.

Distribution: Commonly found from Virginia south to Florida and west to Texas and Oklahoma.

Figure 9. Ventral view of rounded abdominal spine of southern green stink bug.

Figure 10. Red-striped antennal pattern of southern green stink bug.

Figure 11. Scent-gland opening of southern green stink bug. Arrow indicates extension of scent-gland opening less than halfway to the margin of thorax.

Figure 12. Immature (5th instar) of southern green stink bug.

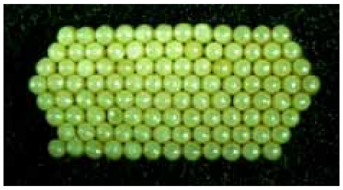


Figure 13. Egg mass of southern green stink bug.

Green Stink Bug, *Acrosternum hilare* (Say)

Adults: Body color green, length 0.5 – 0.75 inches (Figure 14). The green stink bug is often confused with the southern green stink bug. However, the green stink bug is distinguished by a pointed ventral abdominal spine facing toward the head (Figure 15); antennae with black bands (Figure 16); ostiolar canal (scent-gland opening) extending more than halfway to margin of thorax (Figure 17).

Nymphs: Head and thorax of early instars typically black, becoming mostly green in 4th and 5th instars. Light forms may be present in 3rd through 5th instars that are almost entirely green. Dark forms with margins of abdomen and thorax tinged with orange. Abdomen white or green with alternating dark green to purplish-black lines, giving it a striped appearance. Abdomen never with spots (Figure 18).

Eggs: Deposited in large clusters (~70 eggs possible per cluster) in many loosely aligned rows (Figure 19). The egg surface appears porous with 47-64 slightly curved, thumb-shaped micropyles.

Distribution: Commonly found from eastern Canada south to Florida and west to California.

Figure 14. Adult of green stink bug, *Acrosternum hilare*.

Figure 15. Ventral view of pointed spine of green stink bug.

Figure 16. Black-striped antennal pattern of green stink bug.

Figure 17. Scent-gland opening of green stink bug. Arrow indicates extension of scent-gland opening more than halfway to margin of thorax.

Figure 18. Immature (5th instar) of green stink bug.

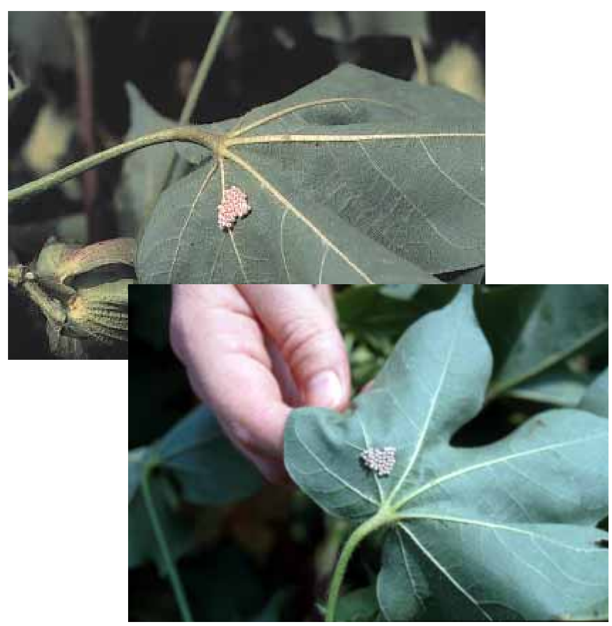


Figure 19. Egg masses of green stink bug.

Brown Stink Bug,
Euschistus servus (Say)

Adults: Body color brown, length 0.4 – 0.6 inch (Figure 20). Humeral angles ("shoulders") of pronotum variable, but not with the sharp, prominent spines observed on predatory stink bugs; Membranous part of wings not extending beyond tip of abdomen.

Nymphs: Body color greenish-brown or yellowish tan. Dark brown plates down middle of abdomen becoming more obvious in later instars, giving the appearance of two to three large, dark spots (Figure 21).

Eggs: Deposited in medium-sized clusters (~55 eggs possible per cluster) in loosely aligned rows (Figure 22). The egg surface appears rough to spiny with 26-39 rod-shaped micropyles.

Distribution: Commonly found from eastern Canada south to Florida and west to California.

NOTE: The shape of the humeral angles of the pronotum may be variable within and among species of "brown" stink bugs. The most reliable characteristic to use in comparing these plant feeders to the predatory species (particularly the spined soldier bug) is the width and orientation of the beak. See beginning of Identification section for characteristics of mouthparts (Figure 4).

Other species:
- Consperse stink bug (*E. conspersus*) (Figure 23)
- Dusky stink bug (*E. tristigmus*) (Figure 24)
- Onespotted stink bug (*E. variolarius*) (Figure 25)
- *E. quadrator* (Figure 26)

Figure 20. Adult of brown stink bug, *Euschistus servus*. Note rounded humeral angles (shoulders)

Figure 21. Immatures (nymphs) of brown stink bug.

Figure 22. Egg mass of brown stink bug.

Figure 23. Adult of *Euschistus conspersus*.

Figure 24. Adult of dusky stink bug, *Euschistus tristigmus*.

Figure 25. Adult of onespotted stink bug, *Euschistus variolarius*.

Figure 26. Adult of *Euschistus quadrator.*

Figure 27. Adult of red-shouldered stink bug, *Thyanta accerra*.

Redshouldered Stink Bug, *Thyanta accerra* McAtee

Adults: Body color green, often with a red stripe running across widest region of pronotum (Figure 27), length 0.35 – 0.5 inch. Abdominal spine absent; ostiolar canal (scent-gland opening) extending more than halfway to margin of thorax (as in Figure 17).

Nymphs: Body dark reddish-brown to black, white spots present on thorax, margins of thorax often tinged with red. Abdomen black with white stripes (Figure 28).

Eggs: Deposited in moderate to large clusters (~70 eggs possible per cluster) in loosely aligned rows (Figure 29). The egg surface has a rough texture with 18-25 tiny, rod-shaped micropyles. Mature eggs often greenish to brown with cream colored rings and a cream colored spot in the center of the operculum.

Distribution: Commonly found from eastern Canada south to Florida and west to Utah.

Redbanded Stink Bug, *Piezodorus guildinii* (Westwood)

Adults: Body color green to yellowish with a red stripe across pronotum, length 0.3 – 0.45 inch (Figure 30). A long ventral abdominal spine present, reaching middle pair of legs (Figure 31).

Nymphs: Body color reddish-brown for 1st through 3rd instars, turning yellowish-brown

Figure 28. Immature (nymph) of redshouldered stink bug.

Figure 29. Egg mass of redshouldered stink bug.

Figure 30. Adult of redbanded stink bug, *Piezodorus guildinii*.

Figure 31. Long abdominal spine of redbanded stink bug.

Figure 32. Immatures (nymphs) of redbanded stink bug.

Figure 33. Egg mass of redbanded stink bug.

in later instars. Fourth and fifth instars often with reddish-brown longitudinal stripes on the head and thorax (Figure 32).

Eggs: Laid in ~30 eggs per cluster; deposited in two distinct rows (Figure 33). Egg surface is spiny with a flat operculum and 31-44 long, spindle-shaped micropyles. Eggs are typically dark reddish-brown with a white medial stripe and a white spot often present on the operculum.

Distribution: This is a Central and South American species that recently has become a problem in the southern US. It has been collected in many southern states including Florida, Georgia, and Louisiana.

Conchuela,
Chlorochroa ligata (Say)
Adults: Body color green or black* with red to orange body margins and a white (or red) spot at tip of scutellum, length 0.5 – 0.65 inch (Figure 34). Abdominal spine absent; ostiolar canal not extending more than halfway to margin of thorax.

Nymphs: Head and thorax dark brown to black in early instars (remaining so in later instars of the black form), turning dark green in later instars. Margins of thorax often tinged yellow or orange-red. Abdomen gray to pale violet with black abdominal plates (Figure 35).

Eggs: Deposited in large clusters (~20-50 eggs per cluster) in many loosely aligned rows (Figure 36). The egg surface appears porous with ~22 tiny, club-shaped micropyles. Eggs cream with two tan rings and a spot around operculum, resembling a bull's-eye.

Distribution: Missouri and Arkansas south to Texas and west to California.

Figure 34. Adult of conchuela, *Chlorochroa ligata*.

Figure 35. Immature (nymph) of conchuela.

Figure 36. Egg mass of Conchuela.

Figure 37. Adult of Say stink bug, *Chlorochroa sayi*.

Other species:
-Say stink bug, *Chlorochroa sayi* (Stål) (Figure 37)

* In New Mexico and west Texas the conchuela is black (or gray). In these regions, a green *Chlorochroa* likely will be *C. sayi*.

Figure 38. Adult of rice stink bug, *Oebalus pugnax*. Arrow indicates spine projecting anteriorly.

Figure 39. Immature (nymph) of rice stink bug.

Phytophagous Stink Bugs of Lesser Importance in Cotton

Rice Stink Bug,
Oebalus pugnax (F.)

Adults: Body color yellowish-brown, length 0.3 – 0.5 inch. Body narrow with humeral angles of pronotum directed anteriorly (Figure 38).

Nymphs: Early instars with black head and thorax gradually turning off-white to brown in later instars. Abdomen red with black spots (Figure 39).

Eggs: Eggs laid in clusters of ~45 eggs; deposited in two distinct rows (Figure 40). The egg surface smooth with 50-79 tiny, mushroom-shaped micropyles. Eggs are green when first deposited, appearing red at maturity.

Distribution: Commonly found from the Northeast south to Florida and west to Arizona.

Proxys punctulatus (Palisot de Beauvois)

Adults: Body color black with black and cream legs; head and humeral angles of pronotum pointed (Figure 41).

Distribution: Commonly found from North Carolina south to Florida and west to Arizona.

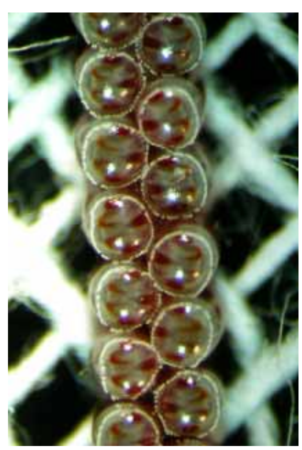


Figure 40. Egg mass of rice stink bug.

Figure 41. Adult of *Proxys punctulatus*.

PREDATORY STINK BUGS

See beginning of Identification section for characteristics of this group (Figures 4 - 7).

Spined Soldier Bug,
Podisus maculiventris (Say)

Adults: Body color brown, length 0.3 – 0.5 inches. Humeral angles (shoulders) of pronotum pointed (Figure 42). Membranous part of wing with dark spots, extending well beyond tip of abdomen.

Nymphs: Early instars with reddish-brown to black head and thorax and a bright red abdomen. Later instars with straw-colored patterns becoming evident on head and thorax, abdomen orange to white with reddish-brown to black lateral and medial plates (Figure 43).

Eggs: Deposited in small- to medium-sized clusters (~57 eggs possible per cluster) in loosely aligned rows (Figure 44). The egg surface is metallic in color and spiny with 12-19 extremely long, curved micropyles.

Distribution: Commonly found from eastern Canada south to Florida and west to California.

Other Common Predaceous Stink Bugs
-*Stiretrus anchorago* (F.) (Figure 45)
-Twospotted Stink Bug, *Perillus bioculatus* (F.) (Figure 46)
-*Euthyrhynchus floridanus* (L.) (Figure 47)

Figure 42. Adult of spined soldier bug, *Podisus maculiventris*.

Figure 43. Immature (nymph) of spined soldier bug with prey.

Figure 44. Egg mass of spined soldier bug.

Figure 45. Adult of *Stiretrus anchorago*.

Figure 46. Adult of twospotted stink bug, *Perillus bioculatus*.

Figure 47. Adults (female- left and male- right) of *Euthyrhynchus floridanus*.

PHYTOPHAGOUS PLANT BUGS

Tarnished Plant Bug, *Lygus lineolaris* (Palisot de Beauvois)

Adults: Body color yellowish-brown, with variable amounts of brown or black mottling on the body, length 0.15 – 0.20 inch. Scutellum with conspicuous yellow Y-shaped marking and pronotum with several longitudinal dark and light rays (Figure 48).

Figure 48. Adult of tarnished plant bug, *Lygus lineolaris*.

Nymphs: Early instars mostly green. Late instars green/yellow with five black spots on the dorsum prominent on last (5^{th}) instar (Figure 49).

Eggs: Laid individually partially in plant tissue. The egg is elongate and slightly curved (Figure 50).

Distribution: Ranges over most of the eastern and central United States.

Western Tarnished Plant Bug, *Lygus hesperus* Knight

Adults: Body generally characterized by reddish-tinge, particularly on hind legs, length 0.17 – 0.20 inch (Figure 51).

Nymphs: Nymphs are similar to those of tarnished plant bug but have a longer second antennal segment. Immatures are difficult to

Figure 49. Nymph (5^{th} instar) of tarnished plant bug.

Figure 50. Egg of tarnished plant bug.

identify and will likely need to be sent to a specialist for confirmation. (Figure 52).

Eggs: Similar to those of tarnished plant bug.

Distribution: Ranges from west Texas to California.

Clouded Plant Bug, *Neurocolpus nubilus* (Say)

Adults: Body reddish-brown, length 0.26-0.3 inch, second antennal segment conspicuously thickened, hind legs large (Figure 53).

Nymphs: Body green, late instars have legs and antennae with brown and white bands (Figure 54).

Figure 51. Adult of western tarnished plant bug, *Lygus hesperus*.

Figure 52. Nymph (5th instar) of western tarnished plant bug.

Eggs: Similar to other plant bugs, deposited into plant tissue.

Distribution: Ranges over most of the eastern and central United States.

Cotton Fleahopper,
Pseudatomoscelis seriatus (Reuter)

Adults: Body pale, greenish-white, speckled with brownish-black spots, dorsum with frosted appearance, length 0.11-0.12 inch, second antennal segment with 4 or 5 conspicuous black spots or bands, numerous short bristles on legs and body (Figure 55).

Nymphs: Bright green and considerably smaller than other plant bug nymphs. Resembles an aphid but without cornicles.

Figure 53. Adult of clouded plant bug, *Neurocolpus nubilus*.

Figure 54. Nymph of clouded plant bug, *Neurocolpus nubilus*.

Eggs: Similar to other plant bugs (elongate and slightly curved), deposited into plant tissue.

Distribution: Ranges throughout the southern United States but most common in the Southwest. Prevalent on weed hosts until senescence.

Figures 55. Adults of cotton fleahopper, *Pseudatomoscelis seriatus*.

OTHER PHYTOPHAGOUS BOLL-FEEDING BUGS

Leaffooted Bug, *Leptoglossus phyllopus* (L.) (Figure 56).

Description: Body of adult bright brown with white band across wings, length 0.7-0.8 inch, leaf-like expansions of hind tibiae (Figure 56).

Distribution: Ranges over much of the south-eastern United States. Other species range over most of the United States.

Figure 56. Adult of leaffooted bug, *Leptoglossus phyllopus*.

Selected Species of True Bugs (Heteroptera: Hemiptera) Found in Cotton:

Acrosternum hilare (Say) (green stink bug)
Apateticus cynicus (Say)*
Chlorochroa ligata (Say) (Conchuela)
Chlorochroa sayi (Stal) (Say stink bug)
Edessa spp.
Euschistus servus (Say) (brown stink bug)
- *E. tristigmus* (Say) (dusky stink bug)
- *E. quadrator* Rolston
- *E. variolarius* (Palisot de Beauvois) (onespotted stink bug)
- *E. conspersus Uhler*

Euthyrhynchus floridanus (L.)*
Leptoglossus phyllopus (L.) (leaffooted bug)
Lygus lineolaris (Palisot de Beauvois) (tarnished plant bug)
Lygus hesperus Knight (western plant bug)
Nezara viridula (L.) (southern green stink bug)
Neurocolpus nubilus (Say) (clouded plant bug)
Perillus bioculatus (F.) (twospotted stink bug)*
Piezodorus guildinii (Westwood) (redbanded stink bug)
Podisus maculiventris (Say) (spined soldier bug)*
Proxys punctulatus (Palisot de Beauvois)
Pseudatomoscelis seriatus (Reuter) (cotton fleahopper)
Stiretrus anchorago (F.)*
Thyanta accerra McAtee (redshouldered stink bug)
- *T. custator* (F.)
- *T. calceata* (Say)

*Denotes predatory species

Monitoring Boll-Feeding Bug Populations in Cotton and Action Levels to Initiate Treatment

The increased importance of boll-feeding bug pests in cotton fields has created the need to refine management strategies for these pests. An effective sampling system is the basis for all reactive IPM strategies. Sampling protocols should be dynamic and flexible during the production season and provide ample data to support action thresholds and subsequent control measures. Thresholds for initiating insecticide applications should only be considered guidelines. Each cotton producer's production system for input costs and yield goals are unique; therefore, IPM recommendations and thresholds can vary considerably among fields, farms, and regions. The variation among action thresholds for different states does not indicate lack of agreement among entomologists, rather the difficulty in establishing a single protocol and action level that consistently provides the necessary data across a wide variety of situations. The agricultural consultant, extension agent, or producer must use their recent and historical knowledge of the field to complement the prescribed thresholds and make an informed decision.

Many of the early-season (pre-flowering stages) sampling systems for tarnished plant bugs and other cotton pests that feed on squares and terminals are well-understood and used to guide insecticide treatments. Less information is available for establishing action levels to initiate treatments for boll-feeding pests during the latter stages of cotton development. The typical methods used to sample these pests in cotton include visual observation of plants (whole-plants, vegetative parts, or reproductive forms), and samples with sweep nets or shake sheets (i.e. drop cloths). In addition, each state or production region may use the sampling data collected with these methods in a different manner to establish thresholds for triggering a treatment. There are advantages and disadvantages to each of these methods, but all can be effectively used in specific situations.

In cotton, estimating stink bug densities and injury levels is difficult (Greene and Herzog 1999). The drop cloth procedure provides the most practical means of detecting stink bug populations in cotton. However, sampling bolls for presence of injury is probably the most effective and repeatable monitoring tool (Greene and Herzog 2000; Greene et al. 2001a, 2001b). Injured bolls that remain on the plant may display symptoms on the exocarp and internally on the endocarp or seed lint. The external injury includes dark, circular indentations on the boll wall (Figure 57). The presence of external symptoms is an inaccurate estimate of internal boll injury because approximately 20% of injured bolls with internal warts lack external symptoms of feeding (Bundy et al. 2000). Dark feeding

Figure 57. External symptoms of feeding injury from boll-feeding bug.

punctures or wart-like cellular growths (callous tissue) are found on the internal carpel wall (Figure 58) (Wene and Sheets 1964, Greene and Herzog 1999). Internal warts and signs of feeding on the exocarp are evident within 48 h (Bundy et al. 2000).

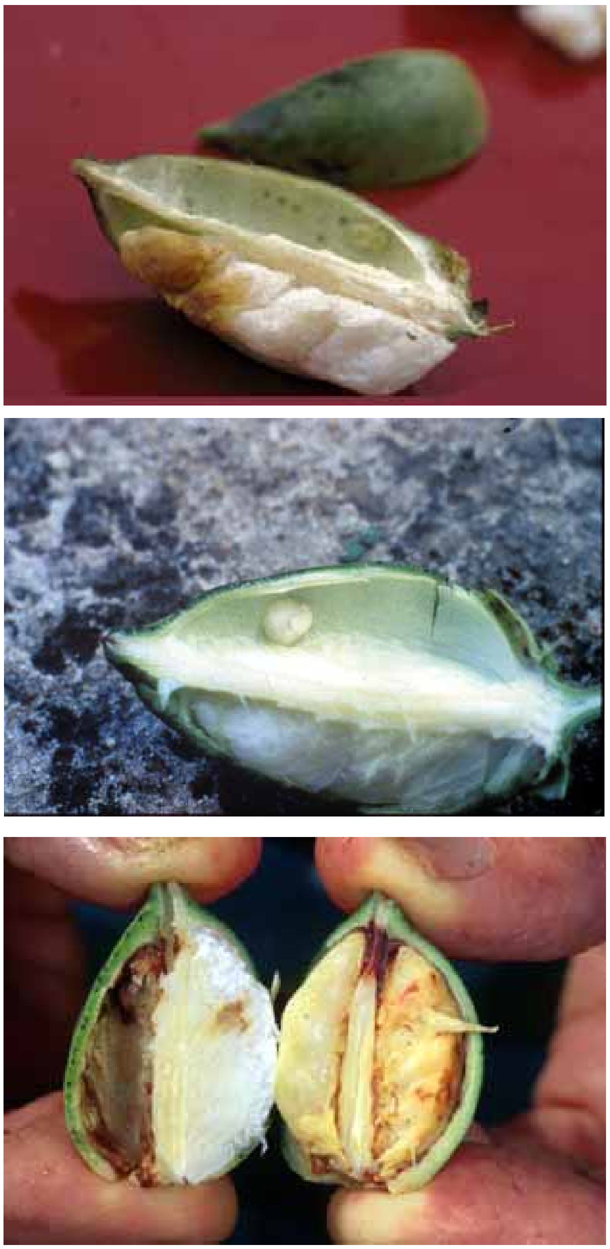


Figure 58. Internal symptoms of feeding injury from boll-feeding bug.

Defining stink bugs as the primary causal agent of boll abscission and injury can be problematic because tarnished plant bugs cause similar effects. Both pests cause young bolls to abscise (Wene and Sheets 1964, Burris et al. 1997). On older bolls, the internal warts formed by tarnished plant bug are indistinguishable from those of stink bug nymphs (Greene et al. 1999).

Thresholds for initiating insecticide applications against stink bugs in cotton have been established using various sampling methods (Table 1). Although action thresholds vary among cotton-producing states in the mid-southern and southeastern states, these recommendations are more consistent than those for tarnished plant bug. The primary problem with stink bug control in cotton is the non-acceptance of these scouting methods among agricultural consultants and producers. There are perceived time constraints associated with drop cloth samples and opening green bolls, and most consultants trigger insecticide applications on visual observations and presence of insects on plants.

Action thresholds for tarnished plant bug in flowering cotton are mostly qualitative and based on experience of the pest manager rather than quantitative scientific data (Russell 1999). This is compounded by the difficulty in sampling for tarnished plant bugs in flowering cotton. In general, sweep nets are the preferred method for sampling tarnished plant bugs in pre-flowering cotton. However, it remains uncertain if sweep net samples provide an accurate estimate of tarnished plant bug population densities during the flowering period of cotton plant development. One accurate method for estimating tarnished plant bug densities in flowering cotton is the shake sheet (Stewart et al. 2001). While shake sheet samples

Table 1. Recommended timing of application for control of stink bugs in mid-southern and southeastern cotton-producing states, 2004-05.

State	Timing of Application	Reference
Alabama	1 stink bug/20 row-feet or 10% of small bolls (1/3 size) display damage	Anonymous (2002)
Arkansas	1 bug/6 row-feet or 20% of medium sized bolls display internal signs of feeding and stink bugs are present	Johnson et al. (2002) Greene (2005)
Florida	4 stink bugs/100 sweeps or 1 stink bug/6 row-feet	Sprenkel (2002)
Georgia	1 bug/6 row-feet or 20% of medium-sized bolls (the diameter of a quarter) display internal signs of stink bug feeding and stink bugs are observed	Roberts and Ruberson (2005)
Louisiana	1 adult or nymph/6 row feet, 5 adults or nymphs/100 sweeps, or 20% internal injury in 12- to 16-d-old bolls	Bagwell et al. (2004)
Mississippi	5 adults or nymphs (1/4 inch or greater) /100 plants or 1 bug/6 row-feet (1/4 inch or greater)	Layton (2002)
North Carolina	1 adult or large nymph/6 row-feet or 1 adult or large nymph/25 sweeps or 10 stink bug damaged (internal feeding) thumb-sized bolls/100	Bachelor and Van Duyn (2003)
South Carolina	1 adult or large nymph/6 row-feet or 20% boll damage in quarter-sized bolls	Roof and Arnette (2000)
Tennessee	1 stink bug/6 row-feet	Patrick and Lentz (2001)
Virginia	1 stink bug/25 sweeps or 5% damaged thumb-sized bolls	Herbert and Chappell (2003)

provide a good tool for estimating populations, they are not viewed as time efficient for practical application by agricultural consultants and farm managers. Many consultants are currently using thresholds that are conservatively based on the visual observation of tarnished plant bugs at any level or on visible damage to fruiting forms (squares and bolls). Recommended action levels are listed for selected states on when to initiate insecticide treatments for control of tarnished plant bug (Table 2).

Boll Tolerance and Termination of Late-Season Management Strategies

Numerous studies have documented the last effective boll population that is susceptible to direct yield losses from boll-feeding pests. These data can be used to guide the termination of insecticide use strategies during the boll maturation of cotton development. Stink bugs can cause relatively high levels of boll abscission (Wene and Sheets 1964, Barbour et al. 1990, Willrich 2004). Boll abscission

Table 2. Recommended timing of application for control of tarnished plant bugs in mid-southern and southeastern cotton producing states, 2004-05.

State	Timing of Application	Reference
Alabama	Pre-flower: Pinhead square damage reaches 20% Post-flower: 15% dirty blooms or 10% damaged bolls	Freeman (1999)
Arkansas	Pre-flower: Treat for one bug per row foot on normal squaring plants or 1 bug per 3 foot of row on abnormal squaring plants; Post-flower: 15% of squares display internal signs of feeding	Johnson et al. (2002) Greene (2005)
Florida	Pre-flower: 6-7 tarnished plant bugs per 100 sweeps or if square retention is less than 80-85% and tarnished plant bugs are present in the field	Sprenkel (2002)
Georgia	Pre-flower: Plant is not retaining 80% of pinhead squares and numerous plant bugs are observed	Roberts and Ruberson (2005)
Louisiana	Pre-flower: 10 to 25 per 100 sweeps. Adjust treatment to hold 70% - 85% first position square retention; Post-flower: 10% internal injury	Bagwell et al. (2004)
Mississippi	First 2 weeks of squaring: Drop Cloth: 1 bug per 6 row feet, Visual: 5 bugs per 100 terminals, or Sweep Net: 8 bugs per 100 sweeps; Third week of squaring to first bloom: Drop Cloth: 2 bugs per 6 row feet, Visual: 10 bugs per 100 terminals, or Sweep Net: 15 bugs per 100 sweeps; Post-flower: 3 bugs per 6 row feet, Visual: 15 bugs per 100 terminals, 20 bugs per 100 sweeps	Anonymous, Delta Ag Digest (2004)
North Carolina	Pre-flower: 80% of first position are not retained	Bacheler (2004)
South Carolina	Pre-flower: An average of one plant bug per row foot using a beat cloth, and 25% or more of pinhead squares have been lost; Post-flower: 15% internal injury to quarter-sized bolls	Anonymous (2001)
Tennessee	Pre-flower: First two weeks: one or more per 6 row feet or 8 per 100 sweeps and square damage; Third week until bloom: two or more per 6 row feet or 15 per 100 sweeps and square damage; Post-flower: Four or more per 6 row feet, 30 per 100 sweeps, or 15 per 100 plants	Anonymous, Delta Ag Digest (2004)
Virginia	Square retention is below 80% and bugs are active Post-flower: 15% dirty blooms, 10% internal boll damage in quarter-size bolls	Herbert (2004)

induced by stink bugs can occur until bolls have accumulated at least 350 heat units beyond anthesis (Willrich 2004). However, the proportion of hardlocked carpels, seedcotton yield, and seed germination was significantly lower for stink bug infested bolls that had accumulated 400, 550, and 600 heat units beyond anthesis, respectively (Fromme 2000, Willrich 2004). Tarnished plant bugs successfully injured bolls and induced abscission until bolls had accumulated $\geq$ 245 heat units after anthesis (Russell 1999, Horn et al. 1999). Seedcotton yields were significantly reduced by tarnished plant bugs until bolls had accumulated at least 330 heat units after anthesis.

Preliminary results indicate boll-feeding bugs cause detrimental effects on fiber quality and indirect economic losses. Additional research is needed to determine the levels of boll maturity that are tolerant to boll-feeding bug injury and reductions in fiber quality.

Insecticide Use Strategies

Insecticides and acaricides are required in IPM systems when other control measures (biological, cultural, host-plant resistance, physical, regulatory, etc.) fail to keep pest populations below economic thresholds, and thus it is critical that effective chemicals be available for successful production of cotton. Considerable research efforts have attempted to improve non-chemical strategies for managing stink bugs and plant bugs, but insecticides remain the primary pest management tool.

There is an extensive list of commercial insecticides (primarily organophosphates and pyrethroids) recommended against boll-feeding bug pests that consistently provide satisfactory control. Products recommended by a number of the States' Cooperative Extension Service for control of green and southern green stink bugs include the organophosphates (acephate, dicrotophos, and methyl parathion), carbamate (oxamyl), and the pyrethroids (bifenthrin, cyfluthrin, deltamethrin, *gamma*-cyhalothrin, *lambda*-cyhalothrin, tralomethrin, and *zeta*-cypermethrin). In general pyrethroids have not provided effective control of brown stink bug at rates that are commonly used in cotton. Therefore, these insecticides are currently not recommended for control of brown stink bugs. Insecticides representing the neonicotinoid class (imidacloprid, thiamethoxam, acetamiprid) have been evaluated against stink bugs but are generally not recommended. Thiamethoxam has demonstrated promise in controlling adults and nymphs of both southern green stink bug and brown stink bug (Willrich et al. 2000). Co-application of imidacloprid and cyfluthrin has been effective against stink bugs, however, with less efficacy against brown stink bug as compared with southern green stink bug (Young and Brown 2001). Selected organophosphates (acephate, dicrotophos, and dimethoate), a carbamate (oxamyl), neonicotinoids (imidacloprid and thiamethoxam) and an IGR (novaluron) are relied upon for effective control of tarnished plant bug. The organophosphates (e.g., acephate and dicrotophos) are the most common treatments used against species and life-stage complexes, due to their broad-spectrum efficacy. Unfortunately, there are no new insecticides registered in recent years, that perform as well as the organophosphates.

Initiating control measures against boll-feeding bugs in cotton requires more than detecting the pest and estimating infestation levels. Proper identification of species and developmental stages is necessary because of variation in insecticide susceptibility among species and life stages. There are significant differences in the insecticide susceptibility among the three common species of stink bugs. For many states, insecticide recommendations in cotton are separated for brown stink bug and the green/southern green stink bug complex. Greene et al. (2001a) and Willrich (2004) demonstrated that pyrethroids (*zeta*-cypermethrin, cypermethrin, and cyfluthrin), with the exception of bifenthrin, used at equivalent rates produced lower levels of mortality for brown stink bug compared with those for southern green stink bug. Those same studies showed no significant differences in susceptibility to acephate and dicrotophos among stink bug species. Developmental stages must be characterized because of potential variation in insecticide susceptibility between nymphs and adults. Mortality levels for fifth instars of southern green stink bug, green stink bug, and brown stink bug are lower than for their corresponding adults when exposed to a range of insecticides (Greene and Capps 2002). Willrich (2004) reported the order of susceptibility of stink bug species and development stages to insecticides from least to most susceptible as adult *Euschistus* spp. < late-instar nymphs < southern green stink bug adults.

In addition, insecticide efficacy against boll-feeding bugs may vary during the season. Plant bugs are more difficult to control in flowering cotton. During the flowering period, cotton plants are much larger than during the pre-flowering stages and adequate coverage with insecticide sprays is difficult to obtain (Scott et al. 1985, Smith and Luttrell 1997). Also boll-feeding bugs often feed enclosed within the bracts of squares and bolls (Tugwell et al. 1976), escaping some direct exposure to insecticide. Nymphs appear to be more difficult to control with insecticides, partially because nymphs are less mobile than adults, remaining within the bracts of fruiting forms and not readily exposed to insecticides (Hollingsworth et al. 1997). Finally, insecticide tolerances increase during the season, making those applications during the final weeks of flowering and boll maturity less effective (Snodgrass 1996, Snodgrass and Scott 2000).

References

Anonymous. 2001. Pest Management handbook. Clemson University. (2004). http://cufan.clemson.edu/pestmgmtguide/.

Anonymous. 2002. Cotton insect, disease, nematode, and weed control recommendations for 2002. Alabama Cooperative Extension Service. http://www.aces.edu/dept/extcomm/ publications/anr/2002IPM/COTTON.02.PDF.

Anonymous. 2004. Cotton, pp. 9-85. *In* 2004 Delta Agricultural Digest. Primedia Business Magazines and Media. Clarksdale, MS.

Bacheler, J. S. 2004. Managing insects on Cotton. North Carolina State University. (2004) http://ipm.ncsu.edu/cotton/insectcorner/CHAP11.htm.

Bachelor, J.S. and J.W. Van Duyn. 2003. 2003 North Carolina agricultural chemical manual: insect control on cotton. http://ipm.ncsu.edu/agchem/chptr5/505.pdf.

Bagwell, R.D., Stewart, S., B.R. Leonard, G. Burris, S. Stewart, C. Pinnell-Alison, T. Erwin, M. Farris, and S. Micinski. 2004. Cotton Insect Control, 2004. Louisiana Cooperative Extension Service. Pub. No. 1083. 6 pp.

Barbour, K.S., J.R. Bradley, and J.S. Bacheler. 1990. Reduction in yield and quality of cotton damaged by green stink bug (Hemiptera: Pentatomidae). J. Econ. Entomol. 83: 842-845.

Bundy, C. S., R. M. McPherson, and G. A. Herzog. 2000. An examination of the external and internal signs of cotton boll damage by stink bugs (Heteroptera: Pentatomidae). J. Econ. Entomol. 35: 402-410.

Burris, E., J. H. Pankey, B. R. Leonard, and J. B. Graves. 1997. Tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois), in cotton. Louisiana Agric. Exp. Stn. Res. Info. Sheet 101. 6 pp.

Cleveland, T. C. 1982. Hibernation and host plant sequence studies of tarnished plant bugs, *Lygus lineolaris*, in the Mississippi Delta. Environ. Entomol. 11: 1049-1052.

Duffy, P. A. and N. Hishamunda. 2001. Economic impacts of boll weevil eradication, pp. 157-174. *In* Dickerson et al. [eds.] Boll Weevil Eradication in the United States Through 1999. Cotton Foundation Ref. Book Series No. 6, Memphis, TN.

Fleischer, S. J. and M. J. Gaylor. 1988. *Lygus lineolaris* (Heteroptera: Miridae) population dynamics: nymphal development, life tables, and Leslie matrices on selected weeds and cotton. Environ. Entomol. 17(2): 246-253.

Freeman, B. 1999. Tarnished plant bugs. Auburn University. (2004) www.agrisk.umn.edu/cache/ARL01668.html.

Fromme, D.D. 2000. The effect of boll age on stink bug feeding, boll damage and yield loss, p. 10. Cotton Incorporated Research Summary. Raleigh, NC.

Gore, J. and A. Catchot. 2005. Tarnished plant bug sampling and management in the Mississippi Delta. In Proc. 2005 Beltwide Cotton Conf. National Cotton Council, Memphis, TN, pp. 1234-1238.

Greene, J. K., S. G. Turnipseed, M. J. Sullivan, and G. A. Herzog. 1999. Boll damage by southern green stink bug (Hemiptera: Pentatomidae) and tarnished plant bug (Hemiptera: Miridae) caged on transgenic *Bacillus thuringiensis* cotton. J. Econ. Entomol. 92(4): 941-944.

Greene, J.K. and G.A. Herzog. 1999. Management of stink bugs using symptoms of boll injury as a monitoring tool, pp. 1041-1044. *In* Proc. 1999 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Greene, J.K. and G.A. Herzog. 2000. Monitoring for and management of stink bugs, pp. 1120-1121. *In* Proc. 2000 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Greene, J.K., G.A. Herzog, and P.M. Roberts. 2001a. Management decisions for stink bugs, pp. 913-917. *In* Proc. 2001 Beltwide Cotton Conf., National Cotton Council. Memphis, TN.

Greene, J.K., S.G. Turnipseed, M.J. Sullivan, and O.L. May. 2001b. Treatment thresholds for stink bugs (Hemiptera: Pentatomidae) in cotton. J. Econ. Entomol. 94: 403-409.

Greene, J. K. and C. Capps. 2002. Efficacy of insecticides for control of stink bugs. *In* Proc. 2002 Beltwide Cotton Conf., National Cotton Council. Memphis, TN.

Greene, J. K. (Editor). 2005. Insecticide Recommendations for Arkansas. University of Arkansas Cooperative Extension service. http://www.uaex.edu/Other_Areas/publications/HTML/MP-144.asp and http://www.uaex.edu/Other_Areas/publications/PDF/MP144/C_61-69_Cotton.pdf.

Greene, J.K., C. Capps, G. Lorenz, G. Studebaker, J. Smith, R. Luttrell, S. Kelley, and W. Kirkpatrick. 2005. Management considerations for stink bugs – 2004, pp. 1527-1538. *In* Proc. 2005 Beltwide Cotton Conf., National Cotton Council. Memphis, TN.

Halloin, J.M. 1986. Weathering: changes in planting seed quality between ripening and harvest, pp. 475-481. *In* J.R. Mauney and J. McStewart [eds.], Cotton Physiology. The Cotton Foundation, Memphis, TN.

Herbert, D. A., Jr. 2004. Insect Control. Virginia Tech University. (2004) http:/www.ext.vt.edu/pubs/cotton/424-200/insectcontrol.pdf.

Herbert, D.A. and G.F. Chappell. 2003. 2003 Virginia cotton insect control. Virginia Cooperative Extension. http://www.ext.vt.edu/pubs/pmg/fc4d.pdf.

Hollingsworth, R. G., D. C. Steinkraus, and N. P. Tugwell. 1997. Response of Arkansas populations of tarnished plant bugs (Heteroptera: Miridae) to insecticides, and tolerance differences between nymphs and adults. J. Econ. Entomol. 90: 21-26.

Horn, T. O., F. A. Harris, J. T. Robbins, and R. E. Furr, Jr. 1999. Influence of boll age on susceptibility to tarnished plant bug injury, pp. 1044-1045. *In* Proc. 1999 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Johnson, D.R., G.E. Studebaker, G. Lorenz, and J.K. Greene. 2002. Cotton insect management. University of Arkansas Cooperative Extension Service. http://www.uaex.edu/Other_Areas/publications/HTML/FSA-2065.asp.

Jones, W.A. and M.J. Sullivan. 1982. Role of host plants in population dynamics of stink bug pests of soybean in South Carolina. Environ. Entomol. 10: 409-414.

Kirkpatrick, T. L. and C. S. Rothrock. 2001. Compendium of Cotton Diseases, 2nd [ed.]. American Phytopath. Soc., St. Paul, MN. 77 pp.

Layton, M.B. 2002. Cotton insect control guide, 2002. Mississippi State University Extension Service. Pub No. 343. http://msucares.com/pubs/pub343.htm.

Leonard, B.R. and K. Emfinger. 2002. Insects in low spray environments and modified cotton ecosystems, CD-ROM A010.pdf. *In* Proc. 2002 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

McPherson, J.E. 1982. <u>The Pentatomoidea (Hemiptera) of Northeastern North America with Emphasis on the Fauna of Illinois</u>. Southern Illinois University Press, IL. 240 pp.

McPherson, J.E. and R.M. McPherson. 2000. <u>Stink Bugs of Economic Importance in America North of Mexico</u>. CRC Press, Boca Raton, FL. 253 pp.

McPherson, R.M., J.W. Todd, and K.V. Yeargan. 1994. Stink bugs, pp. 87-90. *In* L.G. Higley and D.J. Boethel [eds.], <u>Handbook of Soybean Insect Pests</u>. Entomological Society of America, Lanham, MD.

Mueller, S. C., C. G. Summers, and P. B. Goodell. 2003. A field key to the most common *Lygus* species found in agronomic crop of the central San Joaquin Valley of California. Calif. Agri. and Natural Resources, Pub. 8104, 12 pp.

Panizzi, A.R. and A.M. Meneguim. 1989. Performance of nymphal and adult *Nezara viridula* on selected alternate host plants. Entomol. Exp. Appl. 50: 215-223.

Patrick, C.R. and G.L. Lentz. 2001. 2001 Cotton insect control guide. University of Tennessee Agricultural Extension Service. Pub. PB387-1M-1/01.

Roberts, P.M. and J. Ruberson. 2005. 2005 Georgia pest management handbook. http://www.ent.uga.edu/pmh/Agronomic/Agronomic_Crops.htm.

Roberts, P., C. Bednarz, and J. Greene. 2005. Impact of boll feeding bugs on lint yield and fiber quality, pp.1718-1724. *In* Proc. 2005 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Rolston, L.H. and R.L. Kendrick. 1961. Biology of the brown stink bug, *Euschistus servus* Say. J. Kansas. Entomol. Soc. 34: 151-157.

Roof, M.E. and F. Arnette. 2000. Monitoring stink bugs in cotton in South Carolina, pp. 1122-1123. *In* Proc. 2000 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Russell, J.S. 1999. Effects of tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), feeding on cotton boll abscission and yield. M.S. thesis, Louisiana State University, Baton Rouge, LA. 47 pp.

Scales, A. L. and R. E. Furr. 1968. Relationship between the tarnished plant bug and deformed cotton plants. J. Econ. Entomol. 61: 114 118.

Schwartz, M. D. and R. G. Foottit. 1998. Revision of the Nearctic species of the genus *Lygus* Hahn, with a review of the Palearctic species (Heteroptera: Miridae). Mem. Entomol. Int. Vol. 10. Associated Publishers, Gainesville, FL.

Scott, W. P., J. W. Smith, and G. L. Snodgrass. 1985. The tarnished plant bug (Hemiptera: Miridae) a key pest of cotton in the Mississippi Delta, pp. 164-167. *In* Proc. 1985 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Smith, D. B. and R. G. Luttrell. 1997. Application technology, pp. 379 404. *In* E. G. King, J. R. Phillips, and R. J. Coleman [eds.], <u>Cotton Insects and Mites: Characterization and Management.</u> Cotton Foundation Ref. Book Series No. 3, Memphis, TN.

Snodgrass, G.L. 1996. Insecticide resistance in field populations of the tarnished plant bug (Heteroptera: Miridae) in cotton in the Mississippi delta. J. Econ. Entomol. 89:783-790.

Snodgrass, G. L., W. P. Scott, and J. W. Smith. 1984. Host plants and seasonal distribution of the tarnished plant bug (Hemiptera: Miridae) in the delta of Arkansas, Louisiana, and Mississippi. Environ. Entomol. 13:110-116.

Snodgrass, G. L and W. P. Scott. 2000. Seasonal changes in pyrethroid resistance in tarnished plant bug (Heteroptera: Miridae) populations during a three-year period in the delta are of Arkansas, Louisiana, and Mississippi. J. Econ. Entomol. 93: 441-446.

Sprenkel, R.K. 2002. Insect management in cotton. University of Florida Cooperative Extension Service, Pub no. ENY400. http://edis.ifas.ufl.edu/BODY_IG059.

Stewart, S. D., J. Smith, J. Reed, R. Luttrell, C. D. Parker, and F. A. Harris. 2001. Comparing drop cloth, sweep net, and suction sampling methods for arthropods in cotton, pp. 951-954. *In* Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Todd, J.W. 1989. Ecology and behavior of *Nezara viridula.* Annu. Rev. Entomol. 34: 273-292.

Todd, J.W. and D.C. Herzog. 1980. Sampling phytophagous pentatomidae on soybean. *In* M. Kogan and D.C. Herzog [eds.], Sampling Methods in Soybean Entomology. Springer-Verlag, New York, NY.

Tugwell, P., S. C. Young, Jr., B. A. Dumas, and J. R. Phillips. 1976. Plant bugs in cotton, importance of infestation time, types of cotton injury, and significance of wild hosts near cotton. Univ. of Ark. Agri. Exp. Sta. Report Series 227.

Turnipseed, S.G., M.J. Sullivan, J.E. Mann, and M.E. Roof. 1995. Secondary pests in transgenic Bt cotton in South Carolina, pp. 768-769. *In* Proc. 1995 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Turnipseed, S., M. Sullivan, A. Khalilian, P. Roberts, and G. Rains. 2004. Optional management tactics for the sucking bug complex in advanced Bt cotton, pp. 1534-1537. *In* Proc. 2004 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Wene, G.P. and L.W. Sheets. 1964. Notes on control of stink bugs affecting cotton in Arizona. J. Econ. Entomol. 57: 60-62.

Willrich, M. M. 2004. Evaluation of injury and management strategies for stink bugs (Heteroptera: Pentatomidae) on cotton, *Gossypium hirsutum* L. Ph.D. Dissertation. Louisiana State University, Baton Rouge, LA. 145 pp.

Willrich, M.M., C.G. Clemens, M.E. Baur, B.J. Fitzpatrick, and D.J. Boethel. 2000. Evaluation of insecticides for southern green and brown stink bug control on soybean, 1999. Arthropod Management Tests 25: 314.

Young, O. P. 1986. Host plants of the tarnished plant bug, *Lygus lineolaris* (Heteroptera: Miridae). Ann. Entomol. Soc. Am. 79: 747-762.

Young, H.S. and S.N. Brown. 2001. Performance of leverage in the southeast, pp. 798-799. *In* Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Photo Credits

8, 10, 12, 14, 16, 18, 19, 20, 21, 27, 28, 41, 42, 44, 47
Jeremy Greene, Clemson University

5, 6, 9, 11, 13, 15, 17, 22, 23, 24, 25, 26, 29, 31, 32 (top), 33, 34, 35, 36, 37, 38, 39, 40, 45, 51, 52
Scott Bundy, New Mexico State University

7, 43, *50, 53, 54
Scott Stewart, University of Tennessee

4, *32 (bottom), *56
Russ Ottens, The University of Georgia

30
Ralph Bagwell, LSU AgCenter

*57, *58
Phillip Roberts, The University of Georgia

*55
Ronald Smith, Auburn University

*48, *49
Scott Bauer, USDA Agricultural Research Service

*46
Louis Tedders, USDA Agricultural Research Service

*www.ipmimages.org

Reviewers

Dr. Peter H. Adler, Professor, Department of Entomology, Soils and Plant Sciences, Clemson University, Clemson, SC.

Dr. John Andrae, Assistant Professor, Department of Entomology, Soils and Plant Sciences, Clemson University, Clemson, SC.

Dr. Bob Bellinger, Professor, Department of Entomology, Soils and Plant Sciences, Clemson University, Clemson, SC.

Dr. David Thompson, Associate Professor, Department of Entomology, Plant Pathology and Weed Science, New Mexico State University, Las Cruces, NM.

Jeremy K. Greene, Ph.D.
Department of Entomology, Soils & Plant Sciences
Clemson University
Edisto Research & Education Center
64 Research Road
Blackville, SC 29817

Phillip M. Roberts, Ph.D.
Department of Entomology
University of Georgia
15 RDC Road
Tifton, GA 31794

C. Scott Bundy, Ph.D.
Department of Entomology, Plant Pathology, & Weed Science
New Mexico State University
Skeen Hall, Rm. N141
Las Cruces, NM 88003

B. Roger Leonard, Ph.D.
LSU AgCenter
Dept of Entomology/NERS
212 Macon Ridge Rd
Winnsboro, LA 71295

COTTON INCORPORATED

Funding for this publication provided by Cotton Incorporated.