BIOLOGICAL CONTROL OF STINK BUGS IN COTTON

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Abstract

Stink bugs have long been recognized as cotton pests in the southeastern United States. They were noted as cotton pests in the region as early as 1855 (Glover 1855). Even at that time, Glover suspected that stink bug feeding was involved in boll rot, indicating the understanding that the overall effects of stink bug damage possibly extended beyond simply the direct effect of feeding. Stink bugs continued to be intermittent pests for some decades afterwards (e.g., Morrill 1910), but ceased to be of significant concern for a time, apparently with the advent of synthetic insecticides. However, stink bugs emerged as pests once again in the region with the elimination of the boll weevil and the widespread adoption of Bt cotton. These significant changes in the cotton cropping system led to substantive reductions in insecticide use, creating an environment in which insects that were previously excluded from cotton by heavy insecticide use are now able to survive.

Emergence of stink bugs in the Bt cotton system threatens to at least reduce the benefits that have been gained through adoption of the Bt technology by requiring additional insecticide use to manage the emergent stink bugs. To further complicate management, detection of stinkbugs in cotton can be very difficult due to the cryptic habits of stink bug nymphs and adults, and the stink bugs are made up of a species complex (Fig. 1) that differs in biology and susceptibility to insecticides, depending on the species constitution of the complex. Therefore, most management decisions rely on detection of injured bolls rather than on detection of the insects themselves. Under such circumstances, use of natural enemies (e.g., well-timed releases of egg parasitoids and conservation of predators) has the potential to be a valuable tool, as natural enemies can actively seek out the pests on their own, and suppress stink bug populations without relying on scouts to find the pests and plant injury. But how effective might we expect biological control to be against stink bugs in cotton?

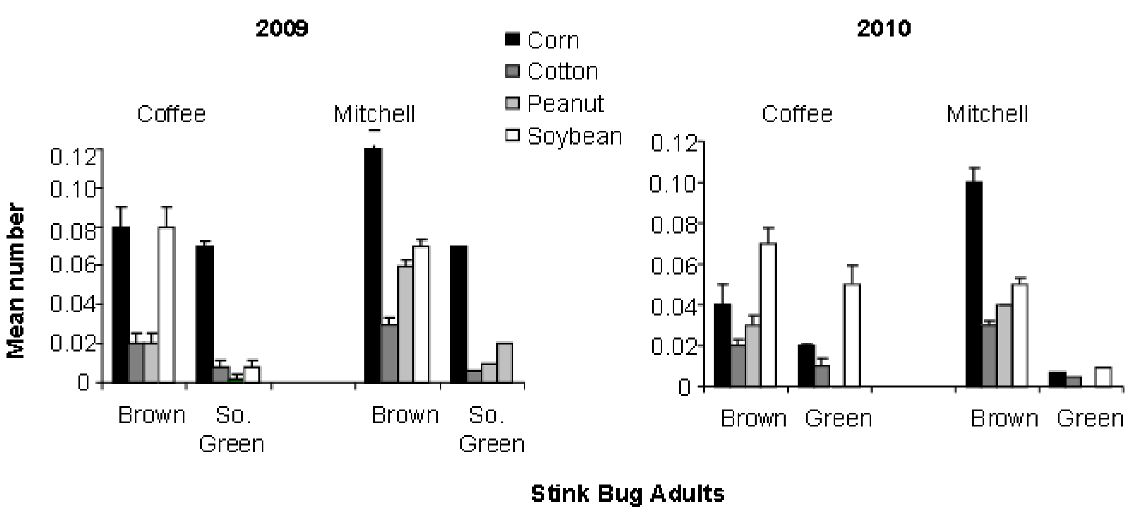

Figure 1. Relative species composition of stink bug communities in corn, cotton, peanut, and soybean in fields at two locations (Coffee and Mitchell Counties, Georgia) in 2009 and 2010 (Olson and Ruberson, unpubl.). All stink

bug species present were recorded. Note the variability in species composition (absence of GSB in 2009 and of SGSB in 2010) and abundance across crops, years, and locations.

Stink bugs are attacked by a suite of natural enemies that differs in response to the stink bug species and plant system (Table 1). Most studies of natural enemies of stink bugs have focused on the Southern green stink bug, *Nezara viridula*, and much less is known about the effectiveness of natural enemies of other important stink bugs, such as the brown stink bug *Euschistus servus* or the Green stink bug *Chinavia hilaris*. Nevertheless, the studies of *N. viridula* provide valuable insights into the role of natural enemies in managing the complex of stink bug species.

Table 1. Selected natural enemies of stink bugs in the southeastern United States (from unpublished observations by Ruberson, Olson, Athey and Harwood). Stink bug species are Southern green stink bug (SGSB), Brown stink bug (BSB), and Green stink bug (GSB). LN = Late nymphal instars.

Enemy type	Enemy species	Stage(s) attacked	Stink bug species		
			SGSB	BSB	GSB
Parasitoid	*Trissolcus basalis*	Egg	X	X	
	Telenomus podisi	Egg	X	X	X
	Trissolcus euschisti	Egg		X	X
	Aridelus rufotestaceus	Nymphs	X	X?	
	Trichopoda pennipes	LN/Adult	X	X	X
	Cylindromyia binotata	LN/Adult		X	
	Euthera tentatrix	LN/Adult	X	X	
	Gymnosoma fuliginosum	LN/Adult		X	
Predator	Fire ants - *Solenopsis invicta*	Egg, nymphs?	X	X	X
	Long-horned grasshoppers/katydids - Tettigoniidae	Egg	X	X	?
	Big-eyed bugs - *Geocoris* spp.	Egg, nymphs?	X	X?	X?
	Other Pentatomidae	Egg, nymphs, adults	X	X	X
	Astatidae	LN/Adults	X?	X	X
	Green lacewing – *Chrysoperla rufilabris*	Egg	X		
	Various spiders	Nymphs, adults	X	X	X

Among the parasitoids of stink bugs, the most commonly observed are wasps that attack the eggs, and flies that attack the adults, although the efficacy of the various parasitoid species varies considerably among plant systems and stink bug species. Of these, the egg parasitoids offer the obvious advantage of killing the stink bugs before they hatch and can do any damage to the crop. Parasitoids have been reared from all three stink bug species, particularly in the egg stage. The efficacy of egg parasitoids of *N. viridula* has been demonstrated in multiple systems and has led to re-distribution of selected parasitoid species around the world for suppression of this, and several other, stink bug species (cf. Clausen 1978). A variety of adult parasitoids also have been reared from stink bugs, parasitizing bugs at high levels in some cases. Some adult parasitoids (e.g., the tachinids *Trichopoda giacomelli* and *T. pennipes*) also have been moved to other countries because of their potential to suppress stink bug populations (Clausen 1978, Coombs and Khan 1998). However, the impact of adult parasitoids differs considerably among stink bug species: in surveys of stink bug parasitism in southern Georgia, parasitism of nymphs and adults of *E. servus* and *C. hilaris* was much less frequent than was the case for *N. viridula* (Ruberson and Olson, unpubl.; Fig. 2).

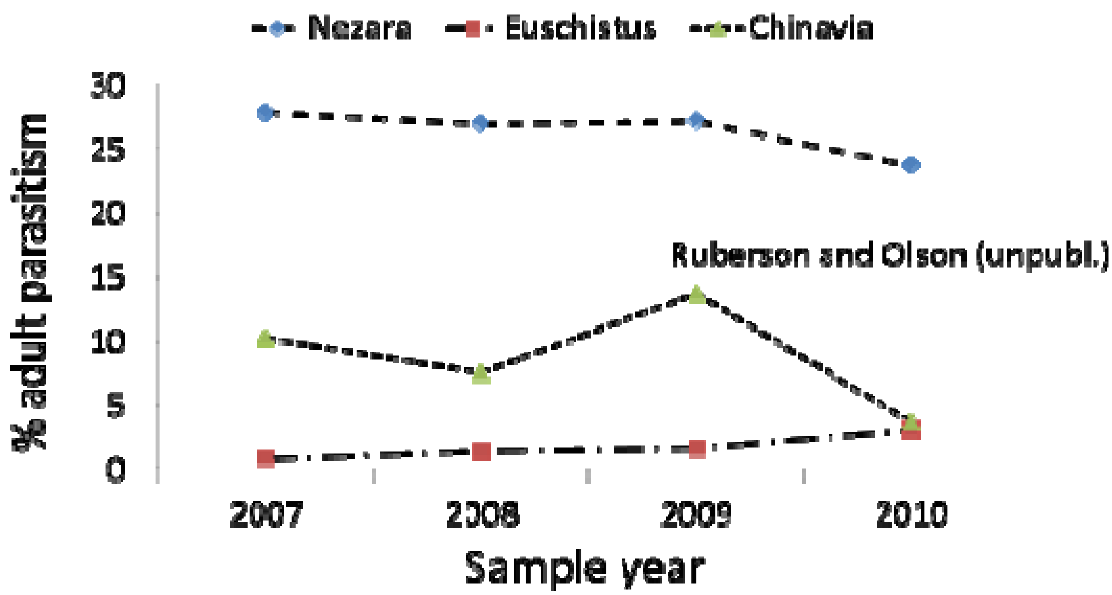

Figure 2. Average annual parasitism of adult stink bugs in the field sampled in southern Georgia (various crops) from 2007 to 2009. Species were the Southern green stink bug (*Nezara viridula*), Brown stink bug (*Euschistus servus*), and Green stink bug (*Chinavia hilaris*). Sample sizes by species and year: 2007 – *Nezara*, 499, *Euschistus* 104, *Chinavia* 39; 2008 - *Nezara*, 403, *Euschistus* 131, *Chinavia* 118; 2009 - *Nezara*, 757, *Euschistus* 345, *Chinavia* 109; 2010 - *Nezara*, 21, *Euschistus* 569, *Chinavia* 107 (Ruberson and Olson, unpubl.).

The activity of predators in suppressing stink bug populations is less well understood, but a number of predators are known to feed on stink bugs, especially ants and spiders (Kiritani 1964, Nishida 1966, Stam et al. 1987, Ehler 2002), and at least one study found that egg predators were more important than egg parasitoids in suppressing stink bug populations in macadamia nut orchards. Most predation is known from stink bug eggs, but there are also some observations of predation on nymphs and adults by arthropods and vertebrates (see relationships listed in McPherson 1982). Kiritani (1964), Nishida (1966), and Singh (1973) all demonstrated that the activity of predators was most significant in the egg and early nymphal stages for *N. viridula*, with much less mortality occurring in the later nymphal stages (4th and 5th instars). Similarly, Liljesthröm and Bernstein (1990) observed that the key agents of within-generation mortality of *N. viridula* in Argentina were egg parasitism and egg and early nymphal predation, and the chief biotic regulator between generations was adult parasitism. Therefore, the greatest efficacy of natural enemies appears to be concentrated in the egg and early nymphal stages, with later stages experiencing little mortality from enemies.

Results

Pest stink bugs have broad host plant ranges and, as a result, can be distributed widely across the landscape (McPherson and McPherson 2000). However, not all plants are equally used for reproduction and feeding, which affects the development of stink bug populations at the landscape level (Panizzi and Meneguim 1989, Velasco and Walter 1992, Panizzi 1997). Recent studies have demonstrated that stink bug species have a strong tendency to use cotton as a feeding rather than a reproductive host (Herbert and Toews 2011, Olson et al. 2011). This finding has significant ramifications for management of stink bugs in cotton. If reproduction in cotton is low, then adult stink bugs will dominate in the cotton crop, and the adult stage should therefore be the target of management tactics. Further, given the rapidity with which significant injury can be inflicted, and the mobility of the adult stink bugs in the crop, the tactic chosen to manage the stink bug adults must be capable of rapid activity to incapacitate the bugs relatively quickly, and must be able to cope with spatially shifting populations. Finally, these findings indicate that the origins of the stink bug populations, or in other words the reproductive hosts, are plants other than cotton. These factors present challenges to the use of biological control for stink bugs in cotton, as will be discussed below.

Predominance of adults: As noted above, the greatest impact of stink bug natural enemies appears to be on the eggs and young nymphs according to studies conducted to date (Liljesthröm and Bernstein 1990, Singh 1974); therefore, if adult stink bugs predominate, then the impact of natural enemies will likely be significantly reduced relative to what might occur if the bug populations reproduced *in situ*. Adult stink bugs are susceptible to parasitism by tachinid flies, as noted above, but bugs tend to live for 2-3 weeks after being parasitized, and can continue to feed, reproduce, and damage the crop after parasitism (Harris and Todd 1982, Coombs and Khan 1998). Adult parasitoids can have significant effects on stink bug populations, but their impact tends to extend across rather than within generations (Liljesthröm and Bernstein 1990), so that they will likely have little impact within the 4-5 week timeframe of greatest concern to cotton growers. In other words, adult parasitoids may reduce adult populations over time by reducing longevity of stink bugs, but the timeframe is likely too long to provide satisfactory results for cotton producers in a single, limited period of the season. Predators of adult stink bugs are known to include a variety of invertebrates and vertebrates, but their impact is very poorly understood, and appears to be low. Therefore, biological control of predominantly adult stink bugs within the critical time window to protect cotton bolls would appear to be highly limited in value.

Complex of adult stink bug species: Adult parasitoid efficacy is highly variable across stink bug species. For example, parasitism of *N. viridula* by *Trichopoda pennipes* can be very high at times, but parasitism of *Euschistus servus* adults by any parasitoid species is consistently quite low (Fig. 2). Therefore, if the stink bug adult complex is dominated by *E.* servus, then adult parasitoids will likely have little impact at any temporal scale during the growing season. The relative action of predators against adults of the various species is unknown.

Stink bug mobility: The value of natural enemies against adult stink bugs is further dependent on whether the stink bugs comprise a resident and relatively closed population, or if they are a shifting pool of itinerant migrants. If the former is the case, then removal of adults from the population will reduce the impact of bugs and the action of natural enemies may be valuable. However, the evidence to date suggests that the bugs use cotton as a transient host (Herbert and Toews 2011, Olson et al. 2011), and given the strong flight capacity of stink bugs, there is likely frequent replacement for mortality and emigration via immigrants. If this is the case, then the value of biological control for adult stink bugs within cotton itself will be further reduced than discussed in the previous paragraphs due to replacement of losses through immigration.

Biological control of stink bug populations within the cotton crop appears to be of limited value because of the life stage and species composition of bugs in the crop, as well as the high mobility of bugs across the landscape. However, biological control certainly has a place in management of stink bugs. We must think beyond the cotton system, both in space and time, to effectively manage pests that utilize broad panoramas of the landscape, but to do so we must better understand the biology of the pest in relation to the landscape. Stink bugs move through a series of host plants before adults colonize cotton, and it may be possible to target key “fatal funnels” in the season – periods and places where stink bug populations are relatively small and/or concentrated in limited areas of reproductive host plants or pre-overwintering hosts. Releases of efficacious enemies into these host plant systems at the appropriate times may significantly reduce the number of nymphs surviving to reproduce, thereby significantly slowing population growth. For example, releases of egg parasitoids in the spring targeting initial reproduction of overwintering stink bugs in a limited area of reproductive plant hosts may greatly reduce subsequent population size and growth. Similarly, the release of large numbers of adult parasitoids in concentrations of pre-overwintering stink bug adults in the fall may provide critical mortality during the winter that significantly reduces success of the overwintering population. If sufficient mortality is inflicted during the winter or early in the season, the growth of the stink bug populations may be significantly reduced well in advance of colonization of the cotton crop. Knipling (1992) proposed such an approach for managing insect pests by use of inoculative releases of host-specific parasitoids early in the season when the parasitoid:host ratio can be inflated with relatively low numbers of parasitoids. He modeled several pest/parasitoid systems involving lepidopteran and dipteran pests to evaluate the possible efficacy of a “fatal funnel” approach to parasitoid releases, and demonstrated that the concept has considerable potential. The question is whether it can be made to work economically for stink bugs. More detailed life history and natural history information on stink bugs and their natural enemies is critical for the success of such an approach. Nevertheless, given the broad range of crops attacked by stink bugs, such an approach may be valuable for producers of multiple crops in addition to cotton.

Summary

Although natural enemies of stink bugs undoubtedly play important roles in limiting overall pest population growth, their short-term efficacy for biological control of stink bugs in cotton is likely hampered by several factors: (1) the preponderance of stink bug adults and their limited reproduction in cotton, (2) the shifting complex of stink bug species that varies in susceptibility of adults to natural enemies, and the (3) the high mobility of the stink bugs. Instead, the use of biological control must be applied on a larger spatial scale, and during a "fatal funnel" period in the seasonal history of the stink bugs, when populations are concentrated in spatially limited plant patches (cf. Knipling 1992). During these periods it may be highly effective to release stink bug-specific natural enemies to significantly increase stink bug mortality and significantly reduce population growth before they are capable of colonizing cotton.

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