Predation of *Anasa tristis* (Hemiptera: Coreidae) by *Geocoris punctipes* (Hemiptera: Geocoridae)[1]

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Abstract Thesquash bug, *Anasa tristis* (DeGeer), is an indigenous pest of squash, *Cucurbita pepo* L., and other cucurbits. *Geocoris punctipes* (Say) adults were collected from stands of mixed grasses in Spalding County, GA, held without food for 24 h, and presented *A. tristis* eggs, first instars, or second instars in no-choice tests. Consumption of first and second instars was significantly greater by females than by males. Egg consumption was very low with no difference between males and females ($P > 0.05$). Male *G. punctipes* consumed a range of 0 to 3 first-instar squash bugs, 0 to 6 second-instar squash bugs, and 0 eggs during the 72-h exposure. Females consumed a range of 0 to 10 first-instar squash bugs, 0 to 10 second-instar squash bugs, and a range of 0 to 1 eggs. Male *G. punctipes* consumed on average 1.08 ± 0.24 first-instar squash bugs, 1.68 ± 0.41 second-instar squash bugs, and 0 eggs during the 72-h exposure. Females consumed on average 4.12 ± 0.56 first-instar squash bugs, 4.28 ± 0.56 second-instar squash bugs, and 0.12 ± 0.06 eggs. Background mortality for first and second instars was similar and exceeded that for eggs in control, male, and female trials. Previous research demonstrated seasonal overlap in squash bug nymphs and *G. punctipes* occurrence. These data suggest that *G. punctipes* can contribute to the suppression of early-season squash bug populations.

Key Words *Anasa tristis*, *Geocoris punctipes*, natural enemies, squash, beneficial insects

In 2014, the United States harvested 38,530 acres (15,592.5 ha), or \$191,532,000 worth, of squash, *Cucurbita pepo* L. (USDA 2015). As preferences shift toward locally grown foods, a substantial number of consumers are willing to pay premiums, especially for certain types of produce (Wolf et al. 2005). In 2011, Georgia had 23 organic-certified vegetable farms that produced \$2,761,182, while in 2016, there were 83 farms with Certified Naturally Grown certification that produced \$48,233,000 in Georgia (USDA NASS 2017). According to the latest Census of Agriculture, direct sales of food products from farmers to individual consumers increased by nearly 50% between 2002 and 2007 (Farm Futures Magazine Online 2013). This organic production market is growing, although production and harvesting expenses remain as limiting factors (e.g., Biermacher et al. 2007). One of the major pests for squash (especially nonconventional) production is the squash bug, *Anasa tristis* (DeGeer).

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Anasa tristis feeds on the leaves, stems, and vines of the squash plant, consuming nutrients and reducing photosynthetic capacity due to leaf chlorosis and necrosis (Beard 1935). Significant loss of yield may also occur due to cucurbit yellow vine disease caused by the bacterial pathogen *Serratia marcescens* Bizio. The disease was observed in 1988 when farms in Texas and Oklahoma experienced significant yield loss due to the yellowing and wilting of their squash and pumpkin plants (Bruton et al. 2003), and Pair et al. (2004) conclusively demonstrated that *A. tristis* was a competent vector of *S. marcescens*.

While chemical control is an option, especially for conventional farmers, small-scale growers and organic farmers may opt for other means to suppress squash bugs. Resistant cultivars, row covers, mulch, trap crops, and biological control have been assessed (Cartwright et al. 1990, Chalfant et al. 1977, Kring 1964, Margolies et al. 1998, Natwick and Durazo 1985, Pair 1997). The most prevalent squash bug predators are reported to be spiders (Lycosidae and Linyphiidae), Hemiptera (*Geocoris punctipes* [Say], *Geocoris uliginosus* [Say]), and Coleoptera, especially lady beetles (*Coccinella septempunctata* [L.], *Coleomegilla maculata* [DeGeer], and *Hippodamia convergens* [Guérin-Méneville]), and species of Carabidae and Staphylinidae (Decker and Yeargan 2008, Rondon et al. 2003, Schmidt et al. 2014). Squash bug nymphs and adults spend much of their time on the ground beneath the plants and would, therefore, be subject to many ground-dwelling predators (Britton 1919, Palumbo et al. 1991). *Geocoris punctipes* predation potential on *A. tristis* and other economically important insect pests has received attention (e.g., Joseph and Braman 2009, Rondon et al. 2003); however, further information is needed to refine management strategies.

Geocoris punctipes are common generalist omnivores found throughout the southern United States (Tamaki and Weeks 1972). Previous research has shown that they significantly reduce fall armyworm, *Spodoptera frugiperda* (J.E. Smith), numbers in turf grass (Braman et al. 2003), and prey on spider mites, plant bugs, leafhoppers, aphids, chinch bugs, and various lepidopteran larvae (Dunbar 1971). *Geocoris punctipes* is also known to feed on plant material, but Hunter (2009) assessed the tritrophic interaction, and determined that the net effect is usually in favor of the plant. Rondon et al. (2003) determined that *G. punctipes* third instars and adults consumed *A. tristis* first-instar nymphs, and this study sought to expand on that finding by determining the difference in predation by male and female *G. punctipes*, and if the prey range of *G. punctipes* includes eggs and later instars of *A. tristis*.

Materials and Methods

Geocoris punctipes were field collected using a sweep net in Spalding County, GA, during August through October of 2015. *Anasa tristis* were maintained in a greenhouse colony in rearing cages (61 $\times$ 61 $\times$ 61 cm; BugDorms, Bioquip Products, Compton, CA). Cages were supplied with the straightneck squash, *C. pepo* var. ‘Zephyr’ (Johnny’s Selected Seeds, Waterville, ME).

Field-collected *G. punctipes* were placed in a petri dishes with moist filter paper and kept in a growth chamber at 25°C and 14:10 (light:dark) photoperiod. Food was withheld for 24 h prior to challenge with 10 eggs or first- or second-instar squash

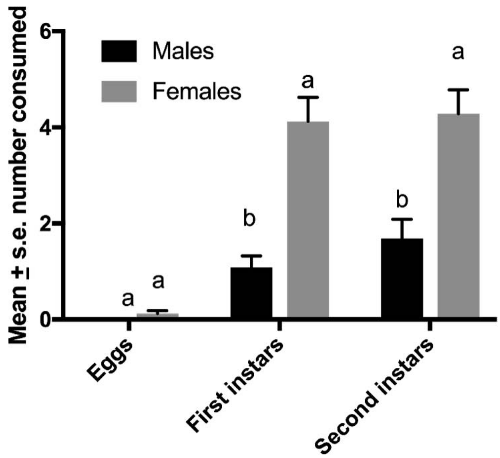

Fig. 1. Mean ± SE number of *Anasa tristis* eggs or first or second instars consumed by *Geocoris punctipes* during 72 h of exposure. Means with different letters are significantly different ($P < 0.05$).

bugs with each individual male or female *G. punctipes*. *Geocoris punctipes* had access to their potential food item for 72 h, after which the number of consumed *A. tristis* individuals (either first instar, second instar, or eggs) was recorded. Controls for first instars, second instars, and eggs (without *G. punctipes*) were included. Each challenge was replicated 25 times ($n = 25$) for each group (male, female, and control) for a total of 75 challenges. After 72 h of exposure to *G. punctipes*, number of live versus dead squash bugs was recorded. Probed and vacant eggs and desiccated nymphs were recorded as preyed upon. Background mortality (unconsumed squash bug eggs and nymphs) also was determined.

A generalized linear mixed model was applied to determine the influence of *G. punctipes* gender and the food source (*A. tristis* egg, first or second instar) on *G. punctipes* predation of *A. tristis* as well as the *A. tristis* background mortality data. The data collected were subjected to analysis of variance using a generalized linear mixed model (PROC GLIMMIX, SAS Institute Inc. 2013). Predation data were modeled as the outcome of 10 Bernoulli trials using a binomial distribution and logit transformation. Differences in least square means were determined by pairwise *t* tests (alpha = 0.05) as the multiple comparisons *post hoc* test to determine significant differences between levels of all factors.

Results and Discussion

Consumption of first and second instars was significantly greater by females than by males (Fig. 1; $F_{1,48} = 53.11$ and 38.16, respectively; $P < 0.0001$). Egg consumption was very low with no difference between males and females ($P > 0.05$). Male *G. punctipes* consumed a range of 0 to 3 first-instar squash bugs, 0 to 6 second-instar squash bugs, and 0 eggs during the 72-h exposure. Females consumed a range of 0 to 10 first instars, 0 to 10 second instars, and a range of 0 to

Table 1. Background *Anasa tristis* mortality. Mean ± SE nonpredation mortality of squash bugs that occurred for each group: control with no predator, and male and female *Geocoris punctipes* added to each arena of 10 squash bugs ($n = 25$).

Developmental Stage	Mean ± SE
Male	
Egg	0.20 ± 0.08a
First	0.68 ± 0.30b
Second	0.88 ± 0.34b
Female	
Egg	0.20 ± 0.1 a
First	0.72 ± 0.33b
Second	0.80 ± 0.25b
Control	
Egg	0.12 ± 0.08a
First	1.48 ± 0.38b
Second	1.48 ± 0.42b

1 eggs. Male *G. punctipes* consumed, on average, 1.08 ± 0.24 first instars, 1.68 ± 0.41 second instars, and 0 eggs during the 72-h exposure. Females consumed, on average, 4.12 ± 0.56 first instars, 4.28 ± 0.56 second instars, and 0.12 ± 0.06 eggs. Background mortality for first and second instars was similar and exceeded that for eggs in control, male, and female trials (Table 1) ($F = 5.61$; $df = 2{,}72$; $P = 0.0054$).

Previous literature has shown that the big-eyed bug, *G. punctipes,* is a generalist predator that consumes a variety of insects, including the squash bug, *A. tristis* (e.g., Braman et al. 2003, Rondon et al. 2003). Fair and Braman (2017) demonstrated seasonal overlap in squash bug nymphs and big-eyed bug occurrence (Fig. 2). This seasonal synchrony is consistent throughout a typical squash production season. Rondon et al. (2003) demonstrated the ability of *G. punctipes* to consume first-instar *A. tristis,* and our results extend the prey range to include both eggs and second instars. The likelihood of *G. punctipes* consuming third or later squash bug instars is small due to size constraints.

We demonstrated a difference in predation between genders of *G. punctipes*. Female *G. punctipes* consumed almost four times more first- and second-instar nymphs of *A. tristis* than males. Nutritional requirements of females are likely larger than that of males due to requirements for egg nutrient production (vitellogenin). Additionally, there is the possibility that predation-related mortality of *A. tristis* eggs could be underestimated. There were many instances where eggs were probed and punctured by a *G. punctipes*, and had then hatched while kept in the petri dish in the

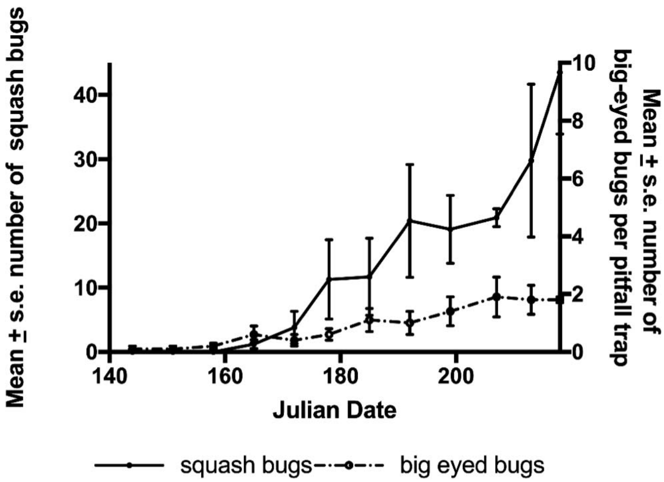

Fig. 2. Mean ± SE number of *Anasa tristis* nymphs per plant or *Geocoris punctipes* adults per pitfall trap in field plots in 2014 (adapted from Fair and Braman 2017, Supplemental Data Tables S1 and S5).

growth chamber. It is possible that had those probed or punctured eggs experienced the variable temperature and potential pathogens found in the field, they might not have hatched. The potential prey range of *G. punctipes* does include eggs as well as the first two instars of *A. tristis*. These data suggest that *G. punctipes* can contribute to the suppression of early-season squash bug populations.

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