Stink Bugs (Hemiptera: Pentatomidae) in Primocane-bearing Raspberries in Southwestern Virginia[1]

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Abstract Raspberries (*Rubus* species) are widely grown in Virginia, and stink bugs (Hemiptera: Pentatomidae) have become significant pests of this crop in recent years. To understand which species are attacking the crop, we sampled a well-established primocane-bearing raspberry planting near Blacksburg, VA in 2008 - 2009 and in 2011, 2012, and 2013. Altogether, 16 species of stink bugs were found on the raspberries. The brown stink bug, *Euschistus servus* (Say), was consistently a major species through 2012. The invasive species, *Halyomorpha halys* (Stål), was not found on the raspberries in 2008 or 2009, but was detected in 2011 and 2012, and became the most abundant stink bug species on these plantings in 2013. The Shannon-Weaver diversity index and Shannon's equitability in 2012/2013 were higher than in 2008/2009. The increase in diversity and equitability revealed that *H. halys* may be displacing *E. servus* populations in Virginia raspberry plantings. Similar trends have occurred on other crops in the MidAtlantic USA where *H. halys* has become well established. Stink bugs were found on plants from midJuly to September, which corresponds to the presence of fruit. Both nymphal and adult stink bugs were feeding on the fruiting structures of raspberry. Most of the stink bugs found were adults, and no egg masses were collected from raspberry plants. Thus, there is no evidence that stink bugs commonly use raspberry as a reproductive host for nymphal development.

Key Words stink bug, raspberry, *H. halys*, diversity indices, invasive species

The raspberry industry has flourished in the eastern United States in the recent years, and there is a great demand for this fruit in Virginia (Stiles et al. 2009). Phytophagous stink bugs (Hemiptera: Pentatomidae) are important pests of raspberry (Kieffer et al. 1983). Stink bugs include both phytophagous and predaceous species, with several of the phytophagous species considered serious agricultural pests (McPherson and McPherson 2000). In the MidAtlantic USA, including Virginia, the most common predaceous stink bugs are the spined soldier bug, *Podisus maculiventris* (Say) and the twospotted stink bug, *Perillus bioculatus* (F.), that attack cutworms and other lepidopteran larvae, as well as the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Westich and Hough-Goldstein 2001).

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Phytophagous stink bugs are more diverse and abundant than predatory species. Most species prefer to feed on seeds and immature fruits of an array of plants (Panizzi and Corrêa-Ferreira 1997) and also are found feeding in stems, petioles, foliage, and flowers (McPherson et al. 1994). Hoffman (1971) reported 26 genera of stink bugs in Virginia. Historically, the important stink bug species in the state have been the brown stink bug, *Euschistus servus* (Say), and the green stink bug, *Chinavia* (*Acrosternum*) *hilaris* (Say) (Hoffman 1971, Kamminga et al. 2009a, b, Koppel et al. 2009, Day et al. 2011). Both of these species are polyphagous and attack a range of crops including soybeans, cotton, corn, fruiting vegetables, and tree fruit (McPherson and McPherson 2000). The harlequin bug, *Murgantia histrionica* (Hahn), is also a significant pest in Virginia but feeds predominately on brassicaceous vegetables (Wallingford et al. 2011). The species complex of the stink bugs varies greatly with respect to geographical location and cropping systems (Hoffman 1971, McPherson and McPherson 2000, Kamminga et al. 2009c, Temple et al. 2013). Very little is known about the stink bug species present on or their pest significance to raspberries. The invasive brown marmorated stink bug, *Halyomorpha halys* (Stål), that was first established around Allentown, PA in the late 1990s (Hoebeke and Carter 2003), has become established in Virginia (Day et al. 2011). However, its abundance in raspberry plantings and impact on native stink bug species has not been studied. Herein, we report the results of a multiyear survey of stink bugs on an established primocane-bearing raspberry plantings near Blacksburg, VA.

Materials and Methods

Study site. Research was conducted in primocane-bearing raspberry plots that were planted in 2000 at the Virginia Tech Kentland Agricultural Research Farm, near Blacksburg, VA. The raspberry plots were situated on an elevated site above the New River in southwestern Virginia (37°12.417' N, 80°35.513' W, 616 m elev.). The raspberry plantings consisted of 6 raised-bed rows and continued with a blackberry plot on one end. The primocane-bearing raspberry cultivars included 'Anne', 'Autumn Bliss', 'Autumn Britten', 'Caroline', 'Dinkum', 'Fall Gold', 'Heritage', 'Himbo Top', 'Josephine', 'Nova' and 'Prelude'. These included both early-bearing and late-bearing varieties. Each cultivar plot was 6.2 m long and 1.0 m wide; rows were 3.0 m apart. An apple orchard on the west, woods on the north, and the pasture on the east and south bordered the raspberry and blackberry plot.

Species composition. In each year, stink bugs were sampled by gently shaking the plants over a 71 cm^2 beat sheet (Bioquip, Rancho Dominguez, CA). In 2008 and 2009, sampling was conducted in 8 randomly-selected 6.2 m^2 cultivar plots. In 2008, stink bugs were collected on 6, 16, 21, 31 August and 14 and 19 September. In 2009, stink bugs were collected on 7 and 21 July and 5, 10 and 17 August. In 2011, 2012, and 2013, we decreased the sampling time interval and area. Sampling was conducted in 1.4 m^2 sections of 24 randomly-selected raspberry plots. In 2011, stink bugs were sampled on 27 and 30 July; 5, 19, 23, and 26 August and 2, 9, 16, and 26 September. In 2012 and 2013, raspberry was sampled from 30 June to 14 September on a weekly basis. Since the area sampled and the total number of samples collected in each year was different, we calculated the mean abundance of stink bugs per m^2. Raspberry plantings were also surveyed for stink bug egg masses in 2011 - 2013. The stink bugs found on each date were collected into a vial containing alcohol and taken to the laboratory for identification using the taxonomic key in McPherson and McPherson (2000). Specimens are retained in the Department of Entomology at Virginia Tech in Blacksburg.

Statistical analysis. Student *t*-tests ($\alpha = 0.05$) were used to compare the mean number of adults and nymphs using JMP 10 (SAS Institute, Inc. Cary, NC). Diversity indices measure the composition of species in a community, their relative abundance and richness. Shannon-Weaver diversity index (*H*') and Shannon's equitability (E_H) are the most commonly used method for measuring species diversity in ecology (Spellerberg and Fedor 2003). Shannon-Weaver diversity index (*H*') studies the species diversity in a community. Shannon's equitability (E_H) measures the evenness of the species in a community. The diversity index and the equitability of stink bug species for each year were calculated.

Results and Discussion

In 2008, 2009, 2011 - 2013, a total of 16 species of stink bugs were collected (Table 1). Only 4 species *E. servus, C. hilaris*, *Cosmopepla lintneriana* (Kirkaldy) and *E. tristigmus* (Say), were found in all years sampled. *Euschistus servus* is listed as the most common stink bug in agricultural crops in Virginia (Hoffman 1971, Kamminga et al. 2009b, Koppel et al. 2009). The survey showed that *Euschistus* species constituted more than half of the overall stink bug composition before the introduction of *H. halys. H. halys* was not detected in 2008 or 2009, but was found in low numbers in 2011 and 2012, and became the most abundant stink bug species on raspberry in 2013. *Chinavia hilaris* is a common significant pest of fruits, vegetables and field crops in the MidAtlantic States, including Virginia (McPherson and McPherson 2000). Counts of *C. lintneriana* varied annually. *C. lintneriana* was described as an insect of minor impact in agriculture by Kamminga et al. (2009b) and not mentioned by McPherson and McPherson (2000). Some factors for *C. lintneriana* being considered a less economically important species of stink bug are its relatively small size, early season activity, and high abundance only in some years. Three species of stink bugs - *H. halys*, *Podisus maculiventris* (Say) (a predator), and *M. histrionica*, were collected in 2011, 2012, and 2013, but not in 2008 or 2009. The harlequin bug, *M. histrionica,* is a pest of crucifers (Wallingford et al. 2011). Although it had not been reported previously in raspberry plantings, a few individuals were detected from our sampling. Cruciferous plants were grown within 1 km of the sampling location, and *M. histrionica* may have originated from those plantings.

The Shannon-Weaver diversity index of the stink bug species was higher in 2012 or 2013 than in 2008 or 2009. There was a gradual increase in Shannon's equitability through 2012 after which it dropped slightly in 2013 (Table 2). The species in the community were more evenly distributed as the *H. halys* population increased. The sharp decline of *E. servus* and the increase in *H. halys* led to the increase in evenness in the population. Therefore, the invasive *H. halys* has made a prominent impact on the native stink bug community in raspberry.

The species richness of stink bugs and the predominant species varies with crops and geographical area. Kamminga et al. (2009a) listed 11 economically important stink bug species in the upper southern and MidAtlantic USA including *C. hilaris*, *E. quadrator* (Rolston), *E. servus*, *E. tristigmus*, *H. halys*, *M. histrionica*, *N. viridula* (L.), the rice stink bug, *Oebalus pugnax* (F.), the redbanded stink bug, *Piezodorus guildinii* (Westwood), the redshouldered stink bug, *Thyanta accerra* (McAtee), and *Thyanta custator* (F.). In southern Arkansas, Smith et al. (2009) reported 5 species of stink bugs in soybean, of which *N. viridula* was the dominant one. In Louisiana soybeans, *P. guildinii* has risen to a greater dominance in that cropping system since its

Table 1. Species composition (%) of stink bugs in raspberry plantings in southwestern Virginia in 2008, 2009, 2011 - 2013.

Species	Common Name	2008	2009	2011	2012	2013
Halyomorpha halys	Brown marmorated stink bug	0.0	0.0	22.3	12.8	49.3
Euschistus servus	Brown stink bug	30.8	58.3	50.0	27.5	18.3
Cosmopepla lintneriana	Twicestabbed stink bug	3.8	37.5	14.6	32.1	10.6
Euschistus tristigmus	Dusky stink bug	56.1	1.3	1.5	5.3	5.3
Chinavia hilaris	Green stink bug	2.5	0.7	3.4	18.9	9.3
Murgantia histrionica	Harlequin bug	0.0	0.0	3.4	3.4	5.3
Podisus maculiventris	Spined soldier bug	0.0	0.0	4.9	0.0	0.0
Euschistus variolaris	Onespotted stink bug	3.4	0.0	0.0	0.0	0.0
Thyanta custator accerra	Redshouldered stink bug	2.2	0.0	0.0	0.0	0.0
Banasa euchlora	Juniper stink bug	0.4	0.0	0.0	0.0	0.0
Thyanta calceata	NA	0.2	0.0	0.0	0.0	0.0
Coenus delius	NA	0.4	0.0	0.0	0.0	0.0
Banasa calva	NA	0.0	0.5	0.0	0.0	0.0
Dendrocoris humeralis	NA	0.0	0.5	0.0	0.0	0.0
Brochymena quadripustulata	Rough stink bug	0.0	0.5	0.0	0.0	1.9
Hymenarcys nervosa	NA	0.0	0.5	0.0	0.0	0.0

Table 2. Shannon-Weaver diversity index and Shannon equitability of the stink bug species in raspberry plantings in southwestern Virginia in 2008, 2009, 2011, 2012 and 2013.

Year	Shannon-Weaver diversity index (*H'*)	Shannon equitability (E_H)
2008	1.34	0.58
2009	1.35	0.65
2011	1.18	0.66
2012	1.52	0.85
2013	1.50	0.77

introduction (Temple et al. 2013), although without data on community diversity before and after, it is difficult to determine its impact on the rest of the community. Four species of stink bugs were found in rice fields in Florida, and *O. pugnax* was the predominant species (Jones and Cherry 1986). Brennan et al. (2013) reported 6 species of stink bugs on blackberries in Florida; *E. quadrator* was the major one. In Brazil, at least 54 stink bug species have been recorded in soybean (Panizzi and Slansky 1985), but only a few are economically important. Compared with other crops, the number of stink bug species found on raspberries in the present was relatively high. The higher species richness in the study was possibly due to multiple crops being grown on the research farm, including raspberry, apple, pear, plum, and cherry that are common feeding hosts of many stink bugs. Both raspberry and blackberry are the hosts of stink bugs (Kieffer et al. 1983).

Halyomorpha halys has become well-established in Virginia (Leskey et al. 2012). After the severe outbreak of this pest in 2010 in Virginia, it has become the dominant stink bug species in many cropping systems with possible displacement of native stink bugs. The establishment of an invasive species is always a threat to the native ecosystem and biodiversity because there is competition for space and food. This displacement of native species can disrupt ecological communities and have an adverse impact on the ecosystem (Elton 2000, Mack et al. 2000). Invasive species often arrive without natural enemies. If an invasive species establishes in a new area, it can have adverse ecological and economic effects (Paini et al. 2008). For establishment, an invasive species should have superior competitive ability compared with the native species (Paini and Roberts 2005). Some of the factors enabling *H. halys* to become established in a new habitat are lack of natural enemies, high abundance, wide host range, climatic factors, and potential to spread quickly.

Seasonality of stink bugs in raspberry. In the early part of the cropping cycle of primocane-bearing raspberries, the Japanese beetle, *Popillia japonica* (Newman), and green June beetle, *Cotinus nitida* (L.), were observed with stink bugs feeding on the berries. Stink bugs were found throughout the sampling period. The population of both adults and nymphs peaked early in the season and decreased gradually in the latter months in 2011 and 2012, but increased in 2013 due to the higher late-season activity of *H. halys* (Fig. 1). Adults were significantly more abundant than nymphs (t = -6.07; df = 12.1; P = 0.0001) (Fig. 2).

Use of raspberry as a host by stink bugs. Both adult and nymph stink bugs were observed feeding on the ripening and ripe berries. Maxey (2011) reported that stink bugs feed on the berries by inserting their stylets between the drupelets. Coombs (2000) reported that the green stink bug from Australia, *Plautia affinis* (Dallas), feeds on green, ripening, and ripe raspberry. Information on raspberry plantings as a reproductive host is limited. Roy et al. (1999) pointed out that the presence of trichomes on the stem, leaves, and petioles of raspberry may hinder oviposition. Presence of a significantly higher population of adults as compared with nymphs, and absence of egg masses on the raspberry leaves strongly suggests that raspberry is not a common reproductive host. Other plants that grow within the raspberry plots or surrounding vegetation may be overwintering sites, and adults and nymphs may move to, and develop on raspberry fruits. Stink bug nymphs are highly mobile and can move to preferred host plants (Nielsen and Hamilton 2009). The study raspberry plot is bordered by apple and peach orchards and the movement of stink bug across these crops is possible. Pome fruits provide nutrients for reproductive development in early season and fat to be stored for diapause in the late season. However, Funayama (2004) found that *H. halys* that fed on apples produce fewer eggs.

In the area of introduction (Pennsylvania and New Jersey), *H. halys* has become the predominant species of stink bug and its phenology closely follows soybean development (Nielsen et al. 2011). Laboratory studies have shown that *H. halys* requires 538 DD (50°F base temperature) to complete development from egg to adult and climate data suggest that *H. halys* can have multiple generations per year in the warmer parts of the United States (Nielsen and Hamilton 2009). As *H. halys* expands its range and becomes

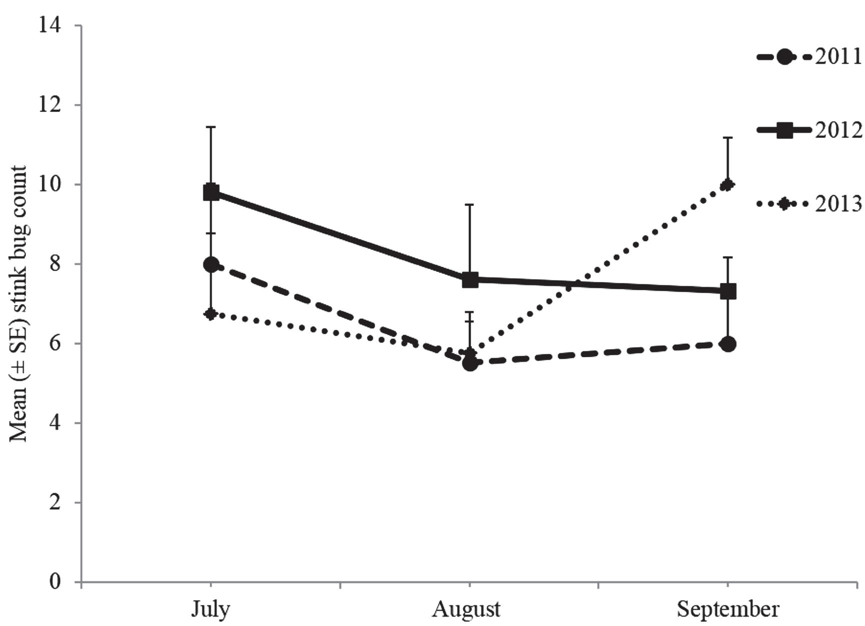

Fig. 1. Seasonal occurrence of stink bugs in southwestern Virginia collected in raspberry plantings in 2011, 2012, and 2013.

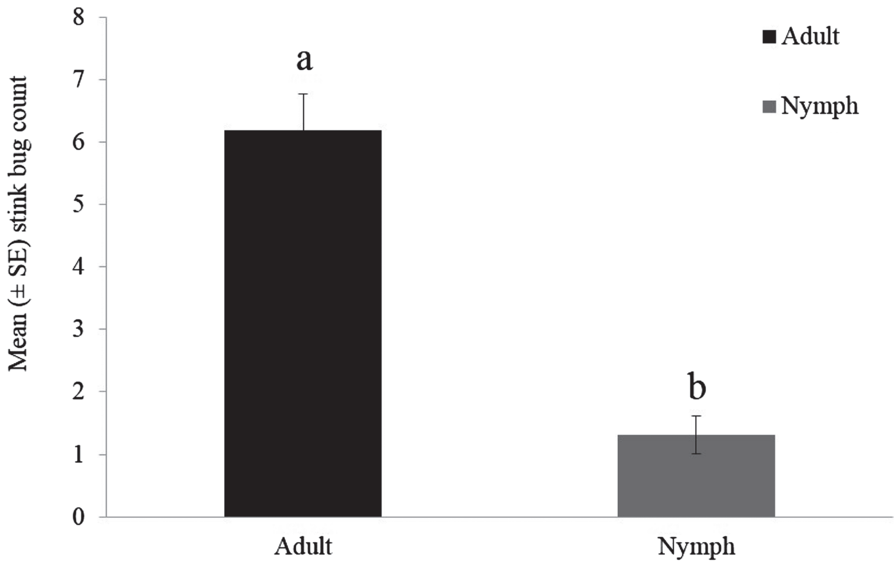

Fig. 2. Adult and nymphal populations (Mean ± SE) of stink bugs collected in raspberry plantings at Kentland Farm (southwestern VA). Bars with different letters are significantly different ($P \leq 0.05$)

established in the other regions of the USA, it will likely become a significant pest of soybean and other crops. These results could easily be applied to other field crops, such as cotton, corn and peanuts. The results suggested that in a 3-years period (2011 - 2013), the invasion of *H. halys* into a habitat substantially changed pentatomid species dominance in raspberries. The total impact of *H. halys* to commercial raspberries still needs to be determined by assessing damage, developing economic and treatment thresholds. This study on stink bug species composition in raspberry plantings helps to identify the stink bugs of economic importance and guide future management strategies for stink bugs.

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References Cited

Brennan, S. A., O. E. Liburd, J. E. Eger and E. M. Rhodes. 2013. Species composition, monitoring, and feeding injury of stink bugs (Heteroptera: Pentatomidae) in blackberry. J. Econ. Entomol. 106: 912-923.

Coombs, M. 2000. Seasonal phenology, parasitism, and evaluation of mowing as a control measure for *Nezara viridula* (Hemiptera: Pentatomidae) in Australian pecans. Environ. Entomol. 29: 1027-1033.

Day, E. R., T. McCoy, D. Miller, T. P. Kuhar and D. G. Pfeiffer. 2011. Brown marmorated stink bug. 2902-1100. http://www.pubs.ext.vt.edu/2902/2902-1100/2902-1100_pdf.pdf.

Elton, C. S. 2000. The ecology of invasions by animals and plants. University of Chicago Press. Chicago, IL.

Funayama, K. 2004. Importance of apple fruits as food for the brown-marmorated stink bug, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae). J. Appl. Entomol. Zool. 39: 617-623.

Hoebeke, E. R. and M. E. Carter. 2003. *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae): A polyphagous plant pest from Asia newly detected in North America. Proc. Entomol. Soc. Wash. 105: 225-237.

Hoffman, R. L. 1971. The insects of Virginia: no. 4. Shield bugs (Hemiptera: Scutelleroidea: Scutelleridae, Corimelaenidae, Cydnidae, Pentatomidae). Virginia Polytechnic Inst. and State Univ. Res. Div. Bull. 67: 1-61.

Jones, D. and R. Cherry. 1986. Species composition and seasonal abundance of stink bugs (Heteroptera: Pentatomidae) in southern Florida rice. J. Econ. Entomol. 79: 1226-1229.

Kamminga, K. L., D. A. Herbert Jr., T. P. Kuhar, S. Malone and A. L. Koppel. 2009a. Efficacy of insecticides against *Acrosternum hilare* and *Euschistus servus* (Hemiptera: Pentatomidae) in Virginia and North Carolina. J. Entomol. Sci. 44: 1.

Kamminga, K., D. A. Herbert Jr., T. P. Kuhar, S. Malone and H. Doughty. 2009b. Toxicity, feeding preference, and repellency associated with selected organic insecticides against *Acrosternum hilaris*, and *Euschistus servus* (Hemiptera: Pentatomidae). J. Econ. Entomol. 102: 1915-1921.

Kamminga, K., D. A. Herbert, Jr., S. Malone, T. P. Kuhar and J. Greene. 2009c. Field guide to stink bugs of agricultural importance in the upper southern region and mid-Atlantic states. Virginia Coop. Ext. Pub. 444-356.

Kieffer, J. N., C. H. Shanks and W. J. Turner. 1983. Populations and control of insects and spiders contaminating mechanically harvested red raspberries in Washington and Oregon. J. Econ. Entomol. 76: 649-653.

Koppel, A. L., D. A. Herbert Jr., T. P. Kuhar and K. Kamminga. 2009. Survey of stink bug (Hemiptera: Pentatomidae) egg parasitoids in wheat, soybean, and vegetable crops in southeast Virginia. Environ. Entomol. 38: 375-379.

Leskey, T.C., G.C. Hamilton, A.L. Nielsen, D. Polk, C. Rodriguez-Saona, J. C. Bergh, D. A Herbert Jr., T. P. Kuhar, D. G. Pfeiffer, G. Dively, C. Hooks, M. Raupp, P. Shrewsbury, G. Krawczyk, P. W. Shearer, J. Whalen, C. Koplinka-Loehr, E. Myers, D. Inkley, K. Hoelmer, D. H. Lee and S. E. Wright. 2012. Pest status of the brown marmorated stink bug, *Halyomorpha halys* (Stål) in the USA. Outlooks Pest Manag. 23: 218-226. Online. DOI: 10.1564/23oct07.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout and F. A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences and control. Ecol. Appl. 10: 689-710.

Maxey, L. M. 2011. Pest management of Japanese beetle (Coleoptera: Scarabidae) and a study of stink bug (Hemiptera: Pentatomidae) injury on primocane-bearing caneberries in southwestern Virginia. MS thesis,Virginia Polytechnic Inst. and State Univ.

McPherson, J. E. and R. McPherson. 2000. Stink bugs of economic importance in America north of Mexico, CRC Press, Boca Raton, FL.

McPherson, R. M., J. W. Todd and K. V. Yeargan. 1994. Stink bugs, Pp. 87-90. *In* Handbook of soybean insect pests. Entomol. Soc. Am. Lanham, MD.

Nielsen, A. L. and G. C. Hamilton. 2009. Life history of the invasive species *Halyomorpha halys* (Hemiptera: Pentatomidae) in northeastern United States. Ann. Entomol. Soc. Am. 102: 608-616.

Nielsen, A. L., G. C. Hamilton and P. W. Shearer. 2011. Seasonal phenology and monitoring of the non-native *Halyomorpha halys* (Hemiptera: Pentatomidae) in soybean. Environ. Entomol. 40: 231-238.

Paini, D. R. and R. D. Roberts. 2005. Commercial honey bees *Apis mellifera* reduce the fecundity of an Australian native bee *Hylaeus alcyoneus.* Biol. Conserv. 123: 103-112.

Paini, D. R., J. E. Funderbunk and S. R. Reitz. 2008. Competitive exclusion of a worldwide invasive pest by a native. Quantifying competition between two phytophagous insects on two host plant species. J. Anim. Ecol. 77: 184-190.

Panizzi, A. R. and B. S. Corrêa Ferreira. 1997. Dynamics in the insect fauna adaptation to soybean in the tropics. Trends Entomol. 1: 71-88.

Panizzi, A. R. and F. Slansky Jr. 1985. Review of phytophagous pentatomids (Hemiptera: Pentatomidae) associated with soybean in the Americas. Florida Entomol. 68: 184-214.

Roy, M., J. Brodeur and C. Cloutier. 1999. Seasonal abundance of spider mites and their predators on red raspberry in Quebec, Canada. Environ. Entomol. 28: 735-747.

Smith, J., R. Luttrell and J. Greene. 2009. Seasonal abundance, species composition, and population dynamics of stink bugs in production fields of early and late soybean in south Arkansas. J. Econ. Entomol. 102: 229-236.

Spellerberg, I. F. and P. J. Fedor. 2003. A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon–Wiener'Index. Glob. Ecol. Biogeogr. 12: 177-179.

Stiles, H. D., S. J. Donohue and J. C. Baker. 2009. Selected topics for raspberry producers in Virginia. 423-700. http://pubs.ext.vt.edu/423/423-700/423-700.html.

Temple, J. H., J. A. Davis, S. Micinski, J. T. Hardke, P. Price and B. R. Leonard. 2013. Species compostion and seasonal abundance of stink bugs (Hemiptera: Pentatomidae) in Louisiana soybean. Environ. Entomol. 42: 648-657.

Wallingford, A. K., T. P. Kuhar, P. B. Schultz and J. H. Freeman. 2011. Harlequin bug biology and pest management in brassicaceous crops. J. Integ. Pest Mgt. 2: H1-H4.

Westich, R. and J. Hough-Goldstein. 2001. Temperature and host plant effects on predatory stink bugs for augmentative biological control. Biol. Control 21: 160-167.