

## *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) nymph survival and adult feeding preferences for crop plants in Florida

Arjun Khadka<sup>1,†,\*</sup>, Amanda C. Hodges<sup>1</sup>, Norman C. Leppla<sup>1</sup>, and P. Glynn Tillman<sup>2</sup>

The invasive brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), was discovered in Allentown, Pennsylvania, USA, in 1996 (Hoebeke & Carter 2003) and to date has been detected in 46 states in the US. *Halyomorpha halys* is polyphagous, feeding on a wide variety of fruit, vegetable, and field crops, woody ornamentals, and wild hosts (Rice et al. 2014; Bakken et al. 2015; Basnet et al. 2015; Bergmann et al. 2016). Multiple host plant species, though, may be necessary for normal development (Acebes-Doria et al. 2016). This pest extracts nutrients from fruit, sap, or phloem with piercing and sucking mouthparts, which leads to fruit damage and yield loss in crops.

The pest risk potential for *H. halys* is high in terms of crops affected and potential losses (Holtz & Kamminga 2010). Unfortunately, some of its known hosts are economically important crops in Florida. For example, earlier research revealed that *H. halys* can complete its life cycle on peach, *Prunus persica* (L.) Batsch (Rosaceae); apple, *Malus pumila* Miller (Rosaceae); muscadine grapes, *Vitis rotundifolia* Michx. (Vitaceae); and tropical hibiscus, *Hibiscus* spp. L. (Malvaceae) (Poplin 2013; LeVeen 2015). The possibility of *H. halys* feeding and developing on other Florida crops has not been evaluated. Survival potential of *H. halys* on hosts in Florida is high, because this pest can complete its lifecycle in relatively high humidity (55–90%) typical of the state (Khadka et al. 2020). Indeed, an isolated *H. halys* population exists in peach in Lake County, Florida, USA (Penca & Hodges 2018). To continue evaluating the potential for *H. halys* to establish in Florida, we assessed various crops and a weed, including okra, *Abelmoschus esculentus* (L.) Moench (Malvaceae); sunflower, *Helianthus annuus* L. (Asteraceae); amaranthus, *Amaranthus* spp. L. (Amaranthaceae); tangerine, *Citrus tangerina* Tanaka (Rutaceae); olive, *Olea europaea* L. (Oleaceae); plum, *Prunus americana* Marsh. (Rosaceae); pomegranate, *Punica granatum* L. (Lythraceae); satsuma, *Citrus unshiu* (Yu. Tanaka ex Swingle) (Rutaceae); pear, *Pyrus pyrifolia* (Burm.) Nak. (Rosaceae); and apple for *H. halys* nymphal development to adults and adult feeding preference.

Besides apple, host selection was based on occurrence of the plants in Florida.

A colony of *H. halys* was established with egg clutches from USDA-ARS, Tifton, Georgia, USA, and maintained in the Entomology and Nematology Department quarantine laboratory in Gainesville, Florida. Adults were reared in 25 cm long × 18 cm wide × 10 cm deep plastic containers (Pioneer Plastics, Inc., North Dixon, Kentucky, USA) and nymphs in 18 cm diam × 7.5 cm deep plastic containers at 25 ± 3 °C, 55 ± 3% RH, and 16:8 h (L:D) (Medal et al. 2012). Peanuts, corn, carrots, and green beans were food sources; wet cotton balls provided water.

Except for amaranthus, sunflower, and okra grown from seed, plants were purchased from a local nursery in Alachua County, Florida. All plants except sunflower with floral heads (no seeds) were vegetative and were 145 to 150 cm tall when tested. Plants were washed with insecticidal soap (Safer®, Lancaster, Pennsylvania, USA) to remove insects 2 wk before the experiments were conducted. Cuttings, about 12 cm long, were mounted in 3.8 cm<sup>3</sup> rockwool grow cubes (FloraFlex®, Los Angeles, California, USA) and held in a greenhouse overnight to check for turgidity. Cuttings and whole plants were moved to the quarantine laboratory for nymphal development and adult preference tests, respectively.

Due to space limitations in the quarantine laboratory, the 10 plant species for nymphal survival tests were divided into 3 groups: (1) apple, okra, sunflower, and amaranthus; (2) apple, tangerine, olive, and plum; and (3) apple, pomegranate, satsuma, and pear. Six *H. halys* second instar nymphs were placed on a cutting of each species. Cuttings were placed in individual plastic containers (Pioneer Plastics, Inc., North Dixon, Kentucky, USA) (8 cm long × 8 cm wide × 18 cm deep) held at the conditions noted above. The number of individuals surviving to each instar and adults was recorded. Data on molting, mortality, and life cycle completion were collected daily; tests were terminated when nymphs died or became adults. Host plants were grouped into an incomplete block design and each of 3 plant groups was replicated 3 times.

<sup>1</sup>University of Florida, Entomology and Nematology Department, Gainesville, Florida 32611-0620, USA; E-mail: AKhadka@agcenter.lsu.edu (A. K.), achodges@ufl.edu (A. C. H.), ncleppla@ufl.edu (N. C. L.)

<sup>2</sup>US Department of Agriculture–Agriculture Research Service (USDA-ARS), Tifton, Georgia 31793, USA; E-mail: Glynn.Tillman@ars.usda.gov (P. G. T.)

\*Corresponding author; E-mail: AKhadka@agcenter.lsu.edu

<sup>†</sup>Current address: Louisiana State University, Department of Entomology, Baton Rouge, Louisiana 70802, USA; E-mail: AKhadka@agcenter.lsu.edu

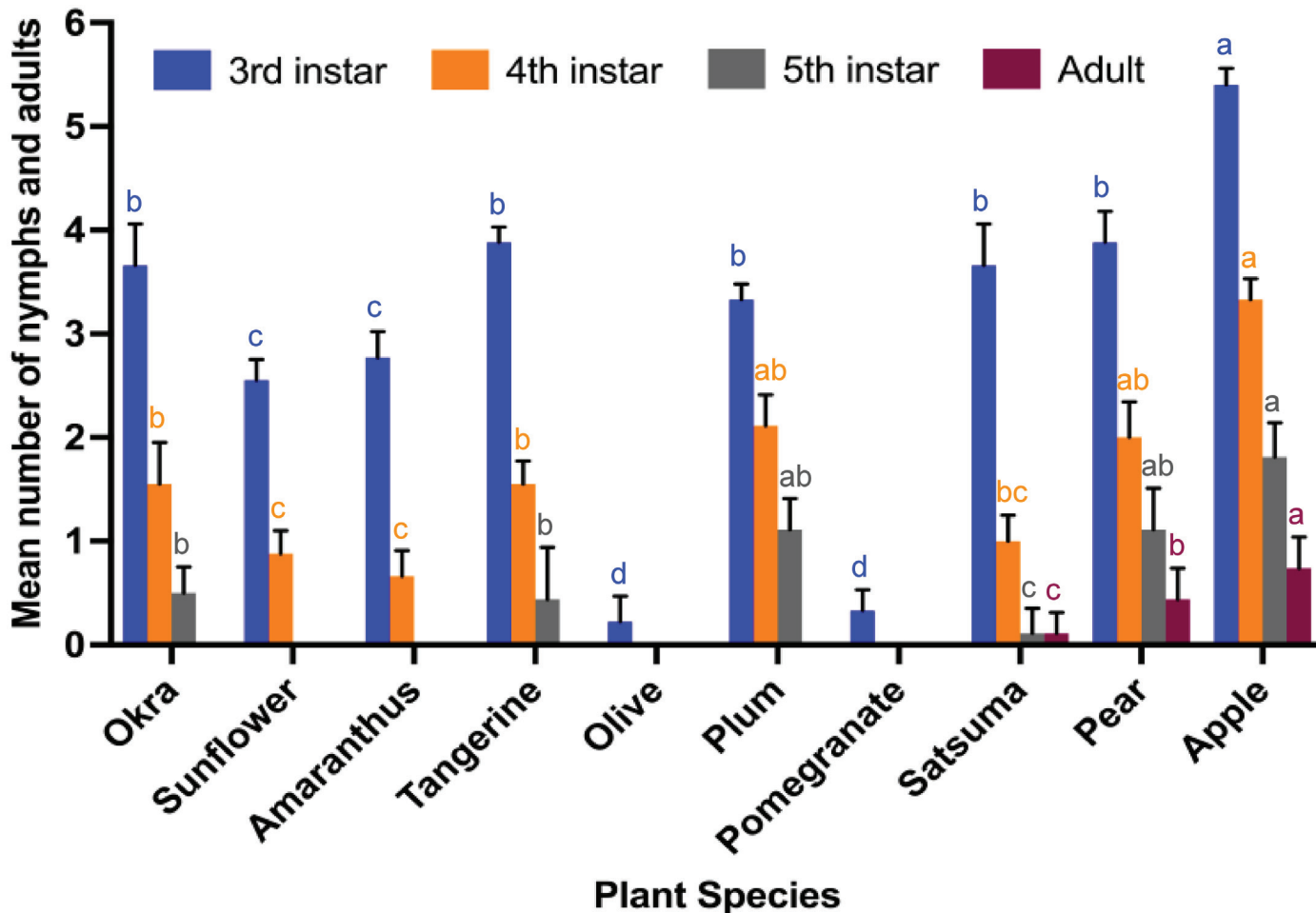


Fig. 1. Mean ( $\pm$  SE) survival of second instar *Halyomorpha halys* to the adult stage on various plant species. Means with the same letter are not significantly different (Tukey-Kramer test,  $P \leq 0.05$ , 3 replicates of 6 nymphs).

The 8 plant species were evaluated further in resting and feeding preference tests. Olive and pomegranate were excluded due to lack of feeding and high mortality of third instars. A pair of plant species was placed in a wooden container (75 cm long  $\times$  75 cm wide  $\times$  165 cm tall) that was built in our laboratory and held at the conditions noted above; after 24 h, 2 each 24-h-old male and female, unfed overnight, were added. All paired-plant species combinations (28) were tested at the same time and replicated 6 times. Tests were conducted each d from 8:00 A. M. to 8:00 P. M. The number of adults resting or feeding on each plant was recorded. Feeding was detected by insertion of a stylet into a plant, and visual observations were made for 30 min 3 times a d. Mean feeding per adult was calculated by dividing the total feeding by adults observed feeding on a specific plant by 24, i.e., the number of adults (4) times the number of replications (6). Total feeding was calculated by adding all the feeding observations on a specific plant over 6 replications. Data on nymphal survival and development into adults and on resting and feeding preferences were analyzed using a 1-way ANOVA and Tukey-Kramer HSD (R Core team 2013).

Nymph survival was not affected by plant pairing ( $P = 0.21$ ); however, significant differences occurred in survival to the next instar due to plant species ( $F = 12.74$ ;  $df = 9$ ;  $P < 0.05$ ). The second instar nymphs molted to third instars on all plants (Fig. 1). The greatest number of third instar nymphs survived on apple, followed by okra, tangerine, plum, satsuma, and pear. Fewer of them were on sunflower and amaranthus, and very few on olive and pomegranate. Survival of nymphs to fourth and fifth

instars took place on the same plants, except none were produced on olive and pomegranate, and no fifth instar nymphs were recovered from sunflower and amaranthus. Adults occurred only on apple, satsuma, and pear, but the number of adults from satsuma was very low.

In preference tests, observation time periods had no effect on the number of *H. halys* adults resting ( $\chi^2 = 5.18$ ;  $df = 2$ ;  $P > 0.05$ ) and feeding ( $\chi^2 = 8.25$ ;  $df = 2$ ;  $P > 0.05$ ) on different plant species. There was, however, a significant difference in the number of *H. halys* resting ( $\chi^2 = 47.64$ ;  $df = 7$ ;  $P < 0.05$ ) and feeding ( $\chi^2 = 67.60$ ;  $df = 7$ ;  $P < 0.05$ ) on the plants. Adults rested on all plants but more often on apple, tangerine, and pear (Fig. 2). Adults fed most on tangerine and about equally on the other plants, except for minimal feeding on sunflower.

*Halyomorpha halys* is polyphagous, potentially feeding and developing on a wide range of crops in Florida. In this study, *H. halys* adults fed on all plant species, although much less on sunflower. Adult *H. halys* are known to be attracted to sunflower (Nielsen 2016; Blaauw et al. 2017). Development of *H. halys* nymphs into adults generally requires feeding on fruit, as well as foliage and stems (Acebes-Doria et al. 2016), but nymphs completed development to adults on apple, pear, and satsuma without fruit in this study. Each of these crops, therefore, potentially is a host for *H. halys* in Florida orchards. If established, this pest could cause significant economic injury to satsuma oranges that are produced commercially in North Florida (Andersen & Ferguson 2015). Adults occur on fruiting apple and pear in other southeastern states (P. G. Tillman, personal observation). A considerable number of nymphs also

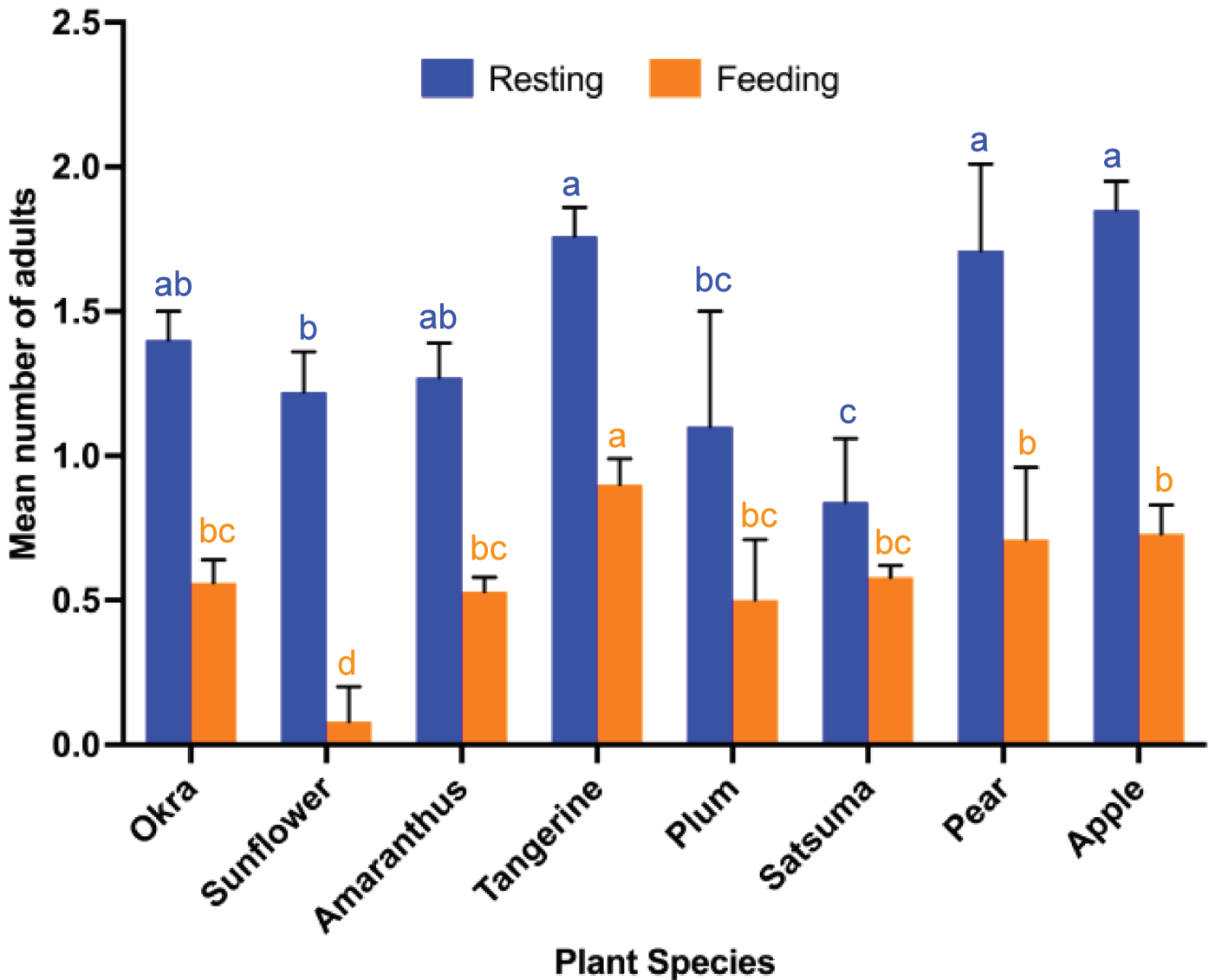


Fig. 2. Mean ( $\pm$  SE) number of *Halyomorpha halys* adults resting or feeding on various plant species in choice tests. Means with the same letter are not significantly different (Tukey-Kramer test,  $P \leq 0.05$ , 6 replicates of 4 adults).

developed into fifth instars on plum, okra, and tangerine. Development of the nymphs on these plants indicated that they may be able to reach the adult stage by feeding on host leaves and stems. The nymphs even would be more likely to develop into adults if these crops were fruiting. Thus, *H. halys* is a potential risk to apple, pear, satsuma, plum, okra, and tangerine production in Florida.

The authors thank Joseph E. Eger, formerly with Dow AgroSciences, for research guidance, and Julio Medal, previously with the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, for *H. halys* rearing guidance. We thank Jennifer Carr, Nick Goltz, and Remy Powell from the University of Florida, Biosecurity Research and Extension Laboratory, for assistance in collecting data. Partial funding was provided by USDA-NIFA award no. 2017-70006-27149.

## Summary

Florida crop plants, including okra, sunflower, tangerine, olive, plum, pomegranate, satsuma, pear, and apple, plus amaranthus were

evaluated as hosts for *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae). This invasive stink bug fed on all plant species, except olive and pomegranate, but completed development only on apple, pear, and satsuma. However, a significant number of nymphs developed into fifth instars on okra, tangerine, and plum. *Halyomorpha halys*, therefore, has the potential to complete development on apple, pear, satsuma, plum, okra, and tangerine crops in Florida.

Key Words: brown marmorated stink bug; feeding preference; survivorship

## Sumario

Se evaluaron plantas de cultivo de la Florida, incluyendo okra, girasol, mandarina, olivo, ciruela, granada, satsuma, pera, y manzana, además de amaranto, como hospederas de *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae). Esta chinche hedionda invasora se alimentaba de todas las especies de plantas, menos el olivo y la granada, pero completó su desarrollo solo en manzanas, peras y satsuma. Sin embar-

go, un número significativo de ninfas desarrolló su quinto estadio en la okra, mandarina y ciruela. *Halyomorpha halys*, por lo tanto, tiene el potencial de completar el desarrollo en cultivos de manzana, pera, satsuma, ciruela, okra y mandarina en la Florida.

Palabras Claves: chinche hedionda marmorino café; preferencia de alimentación; sobrevivencia

## References Cited

- Acebes-Doria AL, Leskey TC, Bergh JC. 2016. Host plant effects on *Halyomorpha halys* (Hemiptera: Pentatomidae) nymphal development and survivorship. *Environmental Entomology* 45: 663–670.
- Andersen PC, Ferguson JJ. 2015. The satsuma mandarin (*Citrus unshiu*). Publication #HS195. University of Florida IFAS Extension, Gainesville, Florida, USA. <http://edis.ifas.ufl.edu/ch116> (last accessed 25 Mar 2021).
- Bakken AJ, Schoof SC, Bickerton M, Kamminga KL, Jenrette JC, Malone S, Abney MA, Herbert DA, Reisig D, Kuhar TP, Walgenbach JF. 2015. Occurrence of brown marmorated stink bug (Hemiptera: Pentatomidae) on wild hosts in non-managed woodlands and soybeans in North Carolina and Virginia. *Environmental Entomology* 44: 1011–1021.
- Basnet S, Kuhar TP, Laub CA, Pfeiffer DG. 2015. Seasonality and distribution pattern of brown marmorated stink bug (Hemiptera: Pentatomidae) in Virginia vineyards. *Journal of economic entomology* 108:1902-1909.
- Bergmann EJ, Venugopal PD, Martinson HM, Raupp MJ, Shrewsbury PM. 2016. Host plant use by the invasive *Halyomorpha halys* (Stål) on woody ornamental trees and shrubs. *PLoS One* 11: e0149975. doi: 10.1371/journal.pone.0149975
- Blaauw BR, Morrison III WR, Mathews C, Leskey TC, Nielsen AL. 2017. Measuring host plant selection and retention of *Halyomorpha halys* by a trap crop. *Entomologia Experimentalis et Applicata* 163: 197–208.
- Hoebeke ER, Carter ME. 2003. *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae): a polyphagous plant pest from Asia newly detected in North America. *Proceedings of Entomological Society of Washington* 105: 225–237.
- Holtz T, Kamminga K. 2010. Qualitative analysis of the pest risk potential of the brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål), in the United States. USDA, APHIS, PPQ, East Lansing, Michigan, USA.
- Khadka A, Hodges AC, Leppla NC, Tillman PG. 2020. The effects of relative humidity on *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) egg hatch, nymph survival, and adult reproduction. *Florida Entomologist* 103: 136–138.
- LeVein E. 2015. Before the invasion: determining the potential host range in Florida of *Halyomorpha halys* (Stål) (Hemiptera: Heteroptera: Pentatomidae), p. 71. Master's thesis, Department of Entomology and Nematology, University of Florida, Gainesville, Florida, USA.
- Medal J, Smith T, Fox A, Cruz AS, Poplin A, Hodges A. 2012. Rearing the brown marmorated stink bug *Halyomorpha halys* (Heteroptera: Pentatomidae). *Florida Entomologist* 95: 800–802.
- Nielsen AL, Dively G, Pote JM, Zinati G, Mathews C. 2016. Identifying a potential trap crop for a novel insect pest, *Halyomorpha halys* (Hemiptera: Pentatomidae), in organic farms. *Environmental Entomology* 45: 472–478.
- Penca C, Hodges A. 2018. First report of brown marmorated stink bug (Hemiptera: Pentatomidae) reproduction and localized establishment in Florida. *Florida Entomologist* 101: 708–712.
- Poplin AV. 2013. A Florida perspective on host preference, early detection, and identification of the brown marmorated stink bug, *Halyomorpha halys* (Stål), pp. 37–39. Master's thesis, Department of Entomology and Nematology, University of Florida, Gainesville, Florida USA.
- R Core Team. 2013. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>
- Rice KB, Bergh CJ, Bergmann EJ, Biddinger DJ, Dieckhoff C, Dively G, Fraser H, Garipey T, Hamilton G, Haye T, Herbert A, Hoelmer K, Hooks CR, Jones A, Krawczyk G, Kuhar T, Martinson H, Mitchell W, Nielsen AL, Pfeiffer DG, Raupp MJ, Rodriguez-Saona C, Shearer P, Shrewsbury P, Venugopal PD, Whalen J, Wiman NG, Leskey TC, Tooker JF. 2014. Biology, ecology, and management of brown marmorated stink bug (Hemiptera: Pentatomidae). *Journal of Integrated Pest Management* 5: 1–13.