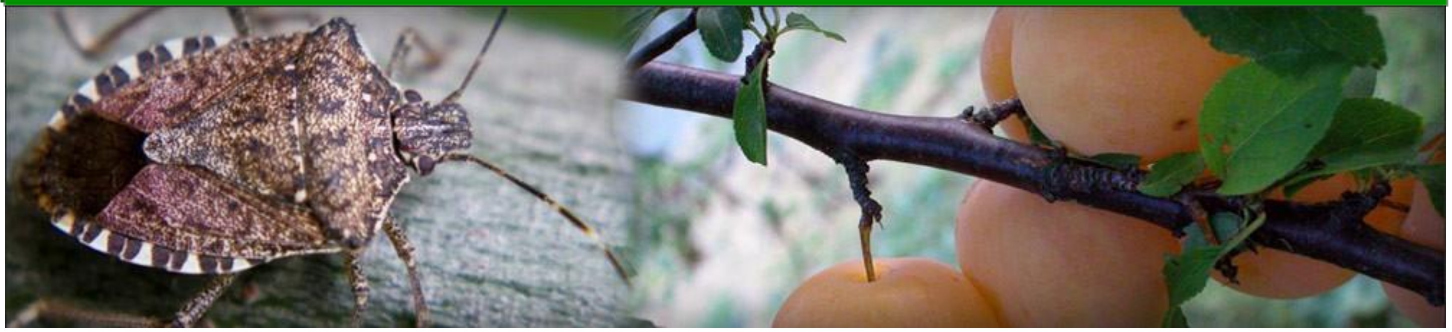
Biology, Ecology, and Management of Brown Marmorated Stink Bug in Orchard Crops, Small Fruit, Grapes, Vegetables and Ornamentals



OBJECTIVES

Objective 1. Establish biology and phenology of BMSB in specialty crops.

Objective 2. Develop monitoring and management tools for BMSB.

Objective 3. Establish effective management programs for BMSB in specialty crops.

Objective 4. Integrate stakeholder input and research findings to deliver practical outcomes.

IN THIS ISSUE

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Stop BMSB

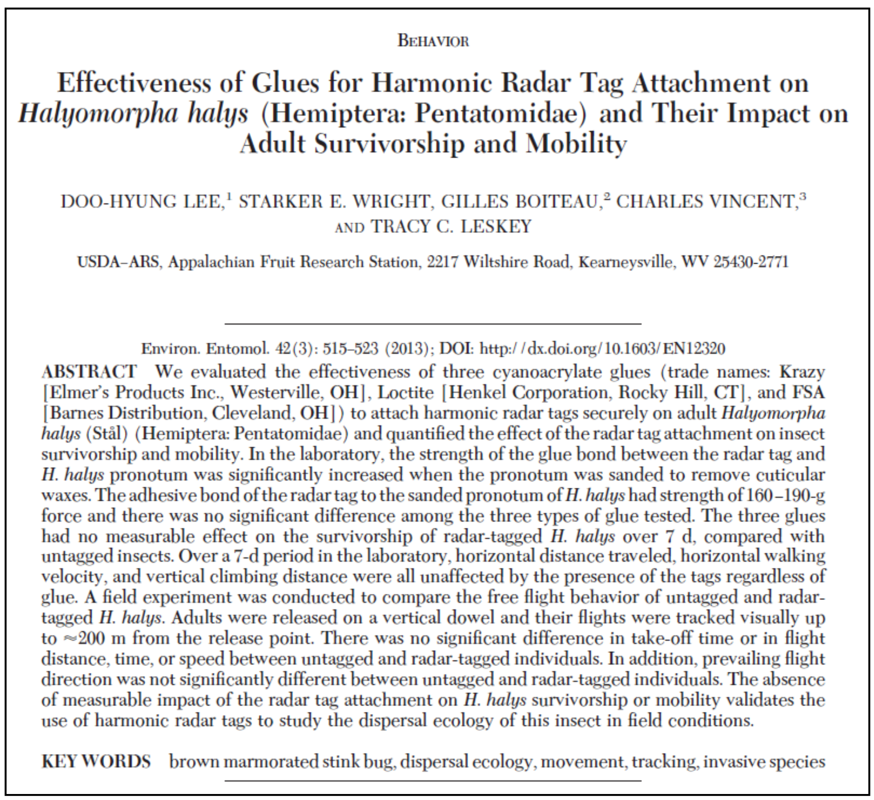
Published Outputs From The BMSB SCRI CAP

As we enter the final year of the BMSB SCRI CAP, we wanted to provide an overview of published research articles, reports, and Extension pieces from this national collaborative project. These studies have contributed to a better understanding of the biology, ecology and behavior of BMSB and provided an excellent basis for continued development of sustainable pest management practices for BMSB in specialty crops. In addition, many more contributions will be forthcoming from the BMSB SCRI CAP Team in the near future.

Objective 1 Outputs

1.1 Evaluate key factors associated with BMSB survivorship, population growth and seasonal phenology.

Lee et al. (2013 and 2014) published several manuscripts establishing the use of harmonic radar as a reliable means to detect tagged adults in nature. These studies have led to enhanced understanding of BMSB dispersal and retention patterns on host plants, particularly host fruit trees.



BEHAVIOR

Effectiveness of Glues for Harmonic Radar Tag Attachment on *Halyomorpha halys* (Hemiptera: Pentatomidae) and Their Impact on Adult Survivorship and Mobility

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Environ. Entomol. 42(3): 515–523 (2013); DOI: http://dx.doi.org/10.1603/EN12320

ABSTRACT We evaluated the effectiveness of three cyanoacrylate glues (trade names: Krazy [Elmer's Products Inc., Westerville, OH], Loctite [Henkel Corporation, Rocky Hill, CT], and FSA [Barnes Distribution, Cleveland, OH]) to attach harmonic radar tags securely on adult *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) and quantified the effect of the radar tag attachment on insect survivorship and mobility. In the laboratory, the strength of the glue bond between the radar tag and *H. halys* pronotum was significantly increased when the pronotum was sanded to remove cuticular waxes. The adhesive bond of the radar tag to the sanded pronotum of *H. halys* had strength of 160–190-g force and there was no significant difference among the three types of glue tested. The three glues had no measurable effect on the survivorship of radar-tagged *H. halys* over 7 d, compared with untagged insects. Over a 7-d period in the laboratory, horizontal distance traveled, horizontal walking velocity, and vertical climbing distance were all unaffected by the presence of the tags regardless of glue. A field experiment was conducted to compare the free flight behavior of untagged and radar-tagged *H. halys*. Adults were released on a vertical dowel and their flights were tracked visually up to ≈200 m from the release point. There was no significant difference in take-off time or in flight distance, time, or speed between untagged and radar-tagged individuals. In addition, prevailing flight direction was not significantly different between untagged and radar-tagged individuals. The absence of measurable impact of the radar tag attachment on *H. halys* survivorship or mobility validates the use of harmonic radar tags to study the dispersal ecology of this insect in field conditions.

KEY WORDS brown marmorated stink bug, dispersal ecology, movement, tracking, invasive species

Lee et al.: Harmonic Radar Tracking of *Halyomorpha halys* 1131

DETECTABILITY OF *HALYOMORPHA HALYS* (HEMIPTERA: PENTATOMIDAE) BY PORTABLE HARMONIC RADAR IN AGRICULTURAL LANDSCAPES

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Abstract

Harmonic radar technology enhances capability to track the movement of individual small insects under field conditions. To maximize the capacity of this technology, it is necessary that radar tags must be securely attached to insects and that the tags remain functional when subjected to mechanical stress. In this study, a series of experiments was carried out to test an improved harmonic radar tag designed to be more resistant to mechanical stresses and to establish that a portable harmonic radar system can effectively detect adult *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) on various structures in different landscapes. The functional resistance of radar tags to ~1-m free falls on a hard surface was improved significantly by reinforcing the adhesive bond between the radar transponder and the radar wire by application of cyanoacrylate glue. This measure did not affect the detectability of radar tags, and it significantly increased the resistance of radar tags against random mechanical impacts inflicted on the insects and tags. The success rates of locating radar-tagged *H. halys* were compared among different landscapes, including a mowed grass-covered plot (250 m^2), a mature peach tree plot (50 m^2), and an unmanaged hedgerow (50 m^2). The success rates were > 90% in all landscapes tested. There was no significant difference in the search time needed to locate tagged adults. In general, it took less than 2 min to detect and recover *H. halys*. The success rates of locating radar-tagged *H. halys* were also compared among different locations within mature fruit trees. There was no significant difference in the success rates between the inner third (87%) and the outer third of the host tree canopy (100%). However, a significantly longer period of time was required to locate *H. halys* in the inner canopy (372 s ± 95 SE) compared with the outer canopy (148 s ± 39 SE). When *H. halys* were concealed in the lower, middle and upper thirds of the outer tree canopy, the success rates of locating tagged adults were consistently 95% or greater at all canopy heights with no significant difference in search times needed to locate tagged adults. The results of this study provide context for researchers to reliably use this radar system in the field to study the dispersal biology of *H. halys*.

Key Words: brown marmorated stink bug, invasive species, tracking, detection

Rice et al. (2015) published a manuscript on using another unique technique to track BMSB in the field. In this case, modified handheld lasers allowed for reliable detection of BMSB marked with fluorescent powers.

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RESEARCH ARTICLE

Handheld Lasers Allow Efficient Detection of Fluorescent Marked Organisms in the Field

Kevin B. Rice, Shelby J. Fleischer, Consuelo M. De Moraes, Mark C. Mescher, John F. Tooker, Moshe Gish

Published: June 2, 2015 • DOI: 10.1371/journal.pone.0129175

Article | Authors | Metrics | Comments | Related Content

Abstract
Introduction
Materials and Methods
Results
Discussion
Acknowledgments
Author Contributions
References

Reader Comments (0)
Media Coverage (0)
Figures

Abstract

Marking organisms with fluorescent dyes and powders is a common technique used in ecological field studies that monitor movement of organisms to examine life history traits, behaviors, and population dynamics. External fluorescent marking is relatively inexpensive and can be readily employed to quickly mark large numbers of individuals; however, the ability to detect marked organisms in the field at night has been hampered by the limited detection distances provided by portable fluorescent ultraviolet lamps. In recent years, significant advances in LED lamp and laser technology have led to development of powerful, low-cost ultraviolet light sources. In this study, we evaluate the potential of these new technologies to improve detection of fluorescent-marked organisms in the field and to create new possibilities for tracking marked organisms in visually challenging environments such as tree canopies and aquatic habitats. Using handheld lasers, we document a method that provides a fivefold increase in detection distance over previously available technologies. This method allows easy scouting of tree canopies (from the ground), as well as shallow aquatic systems. This novel detection method for fluorescent-marked organisms thus promises to significantly enhance the use of fluorescent marking as a non-destructive technique for tracking organisms in natural environments, facilitating field studies that aim to document otherwise inaccessible aspects of the movement, behavior, and population dynamics of study organisms, including species with significant economic impacts or relevance for ecology and human health.

Wiman et al. (2015) and Lee et al. (2015) published complimentary manuscripts examining the flight capacity of BMSB. In particular, the presence of long distance fliers (>5 km within a single day) and increased flight distances during the period of peak dispersal from overwintering sites highlight the fact that BMSB is truly a landscape-level pest to specialty crops.

J Pest Sci (2015) 88:37–47
DOI 10.1007/s10340-014-0582-6

ORIGINAL PAPER

Factors affecting flight capacity of brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae)

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Peter W. Shearer · Silvia I. Rondon ·
Jana C. Lee

Received: 30 January 2014 / Accepted: 16 March 2014 / Published online: 29 March 2014

Abstract Brown marmorated stink bug, *Halyomorpha halys* (Stål) is a highly destructive invasive pest of annual and perennial crops in the eastern United States and is an increasing threat to agriculture in the Pacific Northwest. Flight mills were used to examine flight capacity of *H. halys* in order to better understand its invasive characteristics. Specifically, we examined generational, sexual, and phenotypical effects on flight distance, frequency, velocity, and diel flight patterns of field-collected *H. halys* from two seasons. There was a clear dichotomy in total flight distance for insects that flew 5 km or less and those that flew more than 5 km in 24 h. The tendency for long distance flight of *H. halys* changed over the course of a given season, peaking at the end of the growing season. Summer generation *H. halys* flew farther and faster than overwintered adults, but not as frequently. Males and females had similar numbers of flights, but females went farther. Pre-flight weight of insects was correlated flight activity of adults in terms of speed, frequency, and distance. Overwintered *H. halys* lost a greater proportion of their pre-flight body weight during the assay than did the summer generation adults. Despite many limitations extrapolating flight mill data to the field, this study nonetheless provided evidence that *H. halys* has the capacity for long distance flight, particularly in the summer generation. The nutritional status and fat reserves of overwintered versus summer generation adults are discussed as potential explanations for the flight patterns found in this study.

Keywords Flight mill · Dispersal · Invasive species · BMSB

Introduction

Brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) is a highly destructive invasive pest of both annual and perennial crops in the eastern US (Nielsen et al. 2008; Nielsen and Hamilton 2009; Leskey

Flight behavior of foraging and overwintering brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae)

D.-H. Lee[1]* and T.C. Leskey[2]

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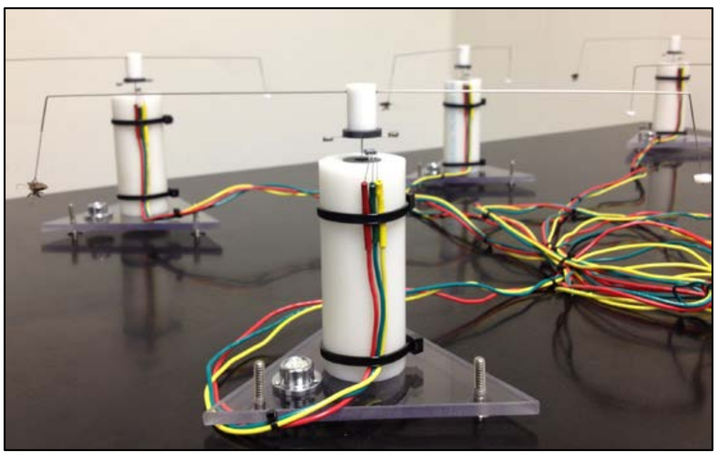
Abstract

Brown marmorated stink bug, *Halyomorpha halys* (Stål), is a highly polyphagous invasive species attacking both cultivated and wild plants increasing its threat to ecosystems as a global pest. However, dispersal biology of this invasive species is not well understood. This study evaluated the flight capacity and behavior of *H. halys* under laboratory, semi-field, and field conditions. Flight mills were used to measure the baseline flight capacity of adults collected year round from the field and included both foraging and overwintering populations. The effects of abiotic conditions such as wind speed and temperatures on the free flight parameters of *H. halys* were evaluated under semi-field and field conditions. The mean flight distances over a 22-h period were 2442 and 2083 m for male and female, respectively. Most individuals (89%) flew <5 km, though some flew much further with a maximum flight distance observed of 117 km. Flight distances by *H. halys* increased after emergence from overwintering sites in spring and reached their highest point in June. The incidence of take off by *H. halys* was significantly affected by the wind speed; when provided with still air conditions, 83% of individuals took off, but the rates decreased to <10% when wind speed was increased to or above 0.75 m s^{-1}. The incidence of take off by *H. halys* was significantly affected by ambient temperature and light intensity in the field, whereas relative humidity and insect sex did not. When the temperature was at 10–15°C, 3% of individuals took off, but the proportion of *H. halys* taking flight increased to 61, 84, and 87% at 15–20, 20–25, and 25–30°C, respectively. In the field, prevailing flight direction was biased toward the opposite direction of the sun's position, especially in the morning. The implications of *H. halys* flight biology are discussed in the context of developing monitoring and management programs for this invasive species.



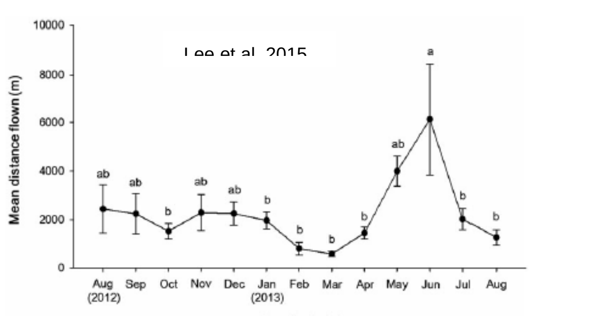


Fig. 2 Mean flight distance by *Halyomorpha halys* (±SE) measured on flight mills from Aug 2012 through Aug 2013. Means followed by different letters were significantly different ($P < 0.05$).

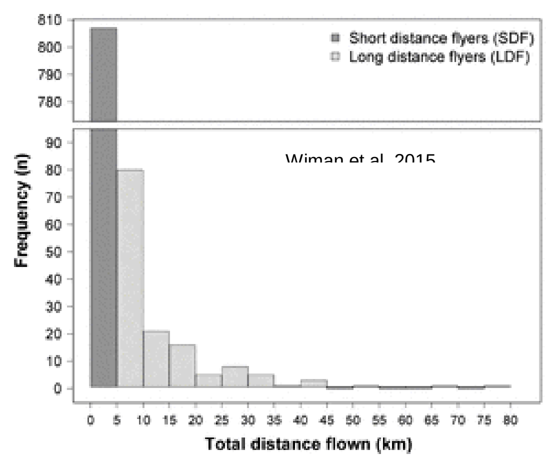


Fig. 1 Frequency histograms for total flight distances per assay for 949 individual *H. halys*. The y axis is broken to account for disproportionate frequency of flights of 0–5 km (*SDF* short distance flyers, *LDF* long distance flyers)

Lee et al. (2014) determined that BMSB overwinter in the natural landscape in dead, standing trees and established that source populations invading specialty crops in the spring could also originate from natural, forested landscapes.

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Characterization of Overwintering Sites of the Invasive Brown Marmorated Stink Bug in Natural Landscapes Using Human Surveyors and Detector Canines

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Abstract

Halyomorpha halys is an invasive species from Asia causing major economic losses in agricultural production in the mid-Atlantic region of the United States. Unlike other crop pests, *H. halys* is also well-known for nuisance problems in urban, suburban, and rural areas, as massive numbers of adults often invade human-made structures to overwinter inside protected environments. Research efforts have focused on populations in human-made structures while overwintering ecology of *H. halys* in natural landscapes is virtually unknown. We explored forested landscapes in the mid-Atlantic region to locate and characterize natural overwintering structures used by *H. halys*. We also evaluated the use of detector canines to locate overwintering *H. halys* to enhance the accuracy and efficiency of surveys. From these studies, we indentified shared characteristics of overwintering sites used by *H. halys* in natural landscapes. Overwintering *H. halys* were recovered from dry crevices in dead, standing trees with thick bark, particularly oak (*Quercus* spp.) and locust (*Robinia* spp.); these characteristics were shared by 11.8% of all dead trees in surveyed landscapes. For trees with favorable characteristics, we sampled ~20% of the total above-ground tree area and recovered 5.9 adults per tree from the trees with *H. halys* present. Two detector canines were successfully trained to recognize and detect the odor of adult *H. halys* yielding >84% accuracy in laboratory and semi-field trials. Detector canines also found overwintering *H. halys* under field conditions. In particular, overwintering *H. halys* were recovered only from dead trees that yielded positive indications from the canines and shared key tree characteristics established by human surveyors. The identified characteristics of natural overwintering sites of *H. halys* will serve as baseline information to establish crop economic risk levels posed by overwintering populations, and accordingly develop sustainable management programs.

Citation: Lee D-H, Cullum JP, Anderson JL, Daugherty JL, Beckett LM, et al. (2014) Characterization of Overwintering Sites of the Invasive Brown Marmorated Stink Bug in Natural Landscapes Using Human Surveyors and Detector Canines. PLoS ONE 9(4): e91575. doi:10.1371/journal.pone.0091575

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Competing Interests: The authors have declared that no competing interests exist.

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1.2 Define parameters for diagnosis of injury and characterize severity and specialty crops

Hedstrom et al. (2014) characterized BMSB damage to hazelnuts as well as established the effects of timing of feeding and shell thickness on damage, clearly demonstrating the threat BMSB poses to the hazelnut industry.

HORTICULTURAL ENTOMOLOGY

The Effects of Kernel Feeding by *Halyomorpha halys* (Hemiptera: Pentatomidae) on Commercial Hazelnuts

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J. Econ. Entomol. 107(5): 1858–1865 (2014); DOI: http://dx.doi.org/10.1603/EC14263

ABSTRACT *Halyomorpha halys* Stål, the brown marmorated stink bug (Hemiptera: Pentatomidae), is an invasive pest with established populations in Oregon. The generalist feeding habits of *H. halys* suggest it has the potential to be a pest of many specialty crops grown in Oregon, including hazelnuts, *Corylus avellana* L. The objectives of this study were to: 1) characterize the damage to developing hazelnut kernels resulting from feeding by *H. halys* adults, 2) determine how the timing of feeding during kernel development influences damage to kernels, and 3) determine if hazelnut shell thickness has an effect on feeding frequency on kernels. Adult brown marmorated stink bugs were allowed to feed on developing nuts for 1-wk periods from initial kernel development (spring) until harvest (fall). Developing nuts not exposed to feeding by *H. halys* served as a control treatment. The degree of damage and diagnostic symptoms corresponded with the hazelnut kernels' physiological development. Our results demonstrated that when *H. halys* fed on hazelnuts before kernel expansion, development of the kernels could cease, resulting in empty shells. When stink bugs fed during kernel expansion, kernels appeared malformed. When stink bugs fed on mature nuts the kernels exhibited corky, necrotic areas. Although significant differences in shell thickness were observed among the cultivars, no significant differences occurred in the proportions of damaged kernels based on field tests and laboratory choice tests. The results of these studies demonstrated that commercial hazelnuts are susceptible to damage caused by the feeding of *H. halys* throughout the entire period of kernel development.

KEY WORDS *Halyomorpha halys*, *Corylus avellana*, hazelnut, feeding, stink bug

1860 JOURNAL OF ECONOMIC ENTOMOLOGY Vol. 107, no. 5

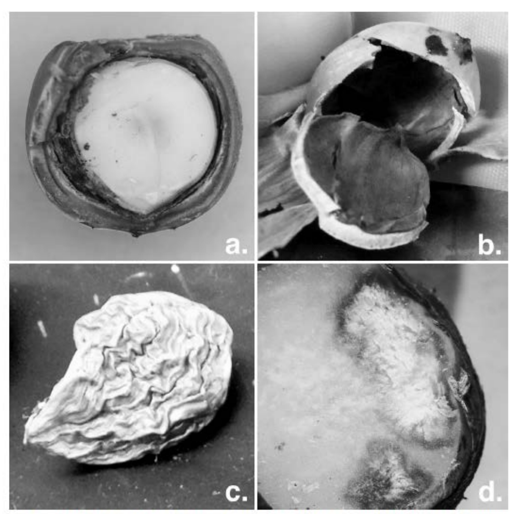

Fig. 1. Primary damage symptoms observed following feeding by *H. halys* on hazelnut kernels at the USDA-ARS Hazelnut Germplasm Repository, Corvallis, OR, in 2012 and 2013. (a) Healthy kernel (in shell). (b) Blank nut (empty shell). (c) Shriveled kernel. (d) Corking damage.

Basnet et al. (2014) found that while BMSB was not present in primocane-bearing raspberries in 2008 or 2009, it became the dominant species by 2013. However, while both adults and nymphs will feed on raspberry, it does not appear to be a reproductive host.

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

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J. Entomol. Sci. 49(3): 304-312 (July 2014)

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

Wiman et al. (2015) characterized BMSB feeding damage on blueberries and established that if environmental conditions are favorable, feeding may lead to premature ripening, discolored, necrotic fruit and shriveled berries.

HORTICULTURAL ENTOMOLOGY

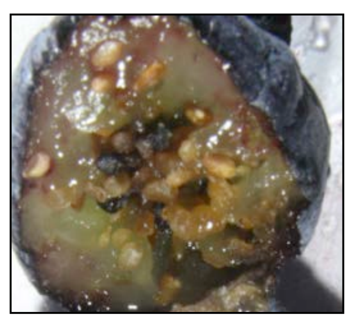
Characterizing Damage of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) in Blueberries

NIK G. WIMAN,[1,2] JOYCE E. PARKER,[3,4] CESAR RODRIGUEZ-SAONA,[3] AND VAUGHN M. WALTON[1]

J. Econ. Entomol. 108(3): 1156–1163 (2015); DOI: 10.1093/jee/tov036

ABSTRACT Brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), is a severe economic pest of growing importance in the United States, Canada, and Europe. While feeding damage from *H. halys* has been characterized in tree fruit, vegetables, and agronomic crops, less is known about the impacts of stink bugs on small fruits such as blueberries. In this study, we examined *H. halys* feeding on two representative early and late ripening blueberry cultivars in Oregon and New Jersey. This research examined how different densities of *H. halys* confined on blueberry clusters for week-long periods affected fruit quality at harvest. After fruit were ripe, we stained and quantified the number of salivary sheaths on berries as an indication of feeding pressure. Feeding by *H. halys* damaged the fruits by causing increased levels of external discoloration, and internal damage in the form of tissue necrosis. Exposure of berries to *H. halys* was also associated with decreasing berry weights and lower soluble solids in fruits. However, the different cultivars did not respond consistently to feeding pressure from *H. halys*. Weekly variability in feeding pressure of two of the cultivars as quantified by the number of stylet sheaths per berry was largely accounted for by environmental variables. We conclude that *H. halys* does have potential to severely damage blueberries and may become an important economic pest. Characterization of damage is important because correct identification of insect damage is key for successful management.

KEY WORDS BMSB, *Vaccinium*, stink bug, feeding damage



Basnet et al. (2015) established that BMSB can use grape as a reproductive host. All lifestages were documented in vineyards and as with other crops, a pronounced edge effect was documented.

Horticultural Entomology

Seasonality and Distribution Pattern of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) in Virginia Vineyards

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J. Econ. Entomol. 108(4): 1902–1909 (2015); DOI: 10.1093/jee/tov124

ABSTRACT Brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), is a highly polyphagous invasive insect pest from eastern Asia that feeds on numerous fruit, vegetable, and field crops. Four commercial vineyards in Virginia were sampled in 2012 and 2013 to study the basic biology, seasonality, and distribution pattern of *H. halys* in vineyards. At each vineyard, two blocks were selected. Weekly 3-min timed count visual samplings were performed in border and interior sections from late May until mid-September. Overwintering adult bugs were first detected in vineyards in May; however, the timing of first detection differed among vineyards. Egg masses were found primarily in June and July, and were usually found on the lower surface of grape leaves, although they were occasionally on the upper leaf surface, on the berry, or on the rachis. All developmental stages of *H. halys* were found in vineyards, suggesting that grape can serve as a reproductive host for *H. halys*. Substantial variation in *H. halys* densities was found among vineyards and throughout the growing season. The first instars were found on egg masses and after molting, dispersed throughout the grape vines. The date on which the first egg mass was collected was considered as a biofix. Based on a degree–day model, there were sufficient degree–days for completion of a generation in Virginia vineyards. Significantly higher numbers of *H. halys* were collected in border sections compared with interior sections. These results are discussed in relation to the potential pest status of *H. halys* in vineyards and implications for possible control strategies.

KEY WORDS *Halyomorpha halys*, grape, phenology, distribution, border effect

Cissel et al. (2015) documented that greatest yield losses to sweet corn, a highly preferred host, from BMSB feeding occurred during the early stages of ear development. BMSB can inflict substantial economic losses to sweet corn in a short period of time at low densities.

Field and Forage Crops

Effects of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) Feeding Injury on Sweet Corn Yield and Quality

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J. Econ. Entomol. 108(3): 1065–1071 (2015); DOI: 10.1093/jee/tov059

ABSTRACT The brown marmorated stink bug, *Halyomorpha halys* (Stål), is an Asian species that now dominates the stink bug complex in many cultivated crops throughout the mid-Atlantic United States. Sweet corn (*Zea mays* L.) is a preferred host of *H. halys*, and the bug can cause kernel injury on developing ears. Currently, there is limited information available on which plant growth stages are most sensitive to *H. halys* feeding or density of bugs required to cause yield and quality reductions on processing and fresh market sweet corn ears. In 2011 and 2012, sweet corn ears were infested at three different corn growth stages: silking (R1), blister (R2), and milk (R3) at densities of zero, one, three, and five *H. halys* adults per ear for 7 d. At harvest, four yield measurements were assessed and ears were inspected for quality reductions. The greatest yield loss from *H. halys* occurred when infestations were initiated during early stages of ear development, and the greatest quality reductions (damaged kernels) occurred during later stages of ear development. A density of one *H. halys* per ear resulted in levels of kernel damage great enough to cause significant quality reductions. This study highlights the ability of *H. halys* to cause substantial economic losses in both fresh market and processing sweet corn in a relatively short period of time at low population densities. Therefore, infestations by this insect in sweet corn must be considered when making pest management decisions in regions where it has become established.

KEY WORDS *Halyomorpha halys*, pest management, economic loss, invasive species, ear damage

HORTICULTURAL ENTOMOLOGY

Temporal Effects on the Incidence and Severity of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) Feeding Injury to Peaches and Apples during the Fruiting Period in Virginia

SHIMAT V. JOSEPH,[1,2,3] MIZUHO NITA,[1] TRACY C. LESKEY,[4] AND J. CHRISTOPHER BERGH[1]

J. Econ. Entomol. 108(2): 592–599 (2015); DOI: 10.1093/jee/tou059

ABSTRACT Exclusion cages were used to compare the incidence and severity of feeding injury from brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), on 'Redhaven' peaches, 'Golden Delicious' apples, and 'Smoothee Golden' apples at harvest, following sequential periods of exposure to natural *H. halys* populations during the 2011 and 2012 growing seasons in Virginia. The fruit used in these experiments were in orchards or on trees that were not managed for *H. halys*. Treatments were sets of 50 fruit that were always caged, never caged, or exposed during one interval during the fruiting period of peaches and apples in the Mid-Atlantic region of the United States. The cages effectively prevented feeding injury from *H. halys*. Peaches and apples that were never caged showed the highest percentages of injured fruit at harvest. Exposure treatment had a significant effect on the percentage of fruit showing external injury at harvest in both years for apples and in 2012 for peaches, and a significant effect on the percentage of apples and peaches showing internal injury at harvest in both years. There was no consistent effect of each exposure period on peach injury, but apples exposed during the mid- to latter portion of the season tended to show most injury. Across all exposure periods, more internal than external injuries were recorded at harvest from peaches, while apples tended to have equal or very similar numbers of both kinds of injury. The implications of these results to *H. halys* management in eastern apple orchards are discussed.

KEY WORDS *Halyomorpha halys*, *Malus domestica*, *Prunus persica*, injury

Joseph et al. (2015) documented that peach appears to be vulnerable to BMSB damage throughout the growing season, while apple is more prone to injury in the mid- and late-season.

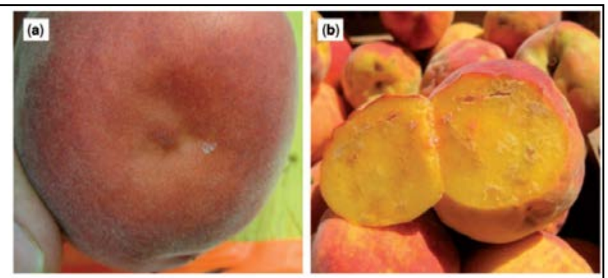

Fig. 1. *H. halys* feeding injury on peach fruit: (a) surface deformation/depression; (b) internal necrosis.

1.3 Determine risk and impact of BMSB on specific specialty crops

Research Article

Impact of the Invasive Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål), in Mid-Atlantic Tree Fruit Orchards in the United States: Case Studies of Commercial Management

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Four commercial orchards in the mid-Atlantic region of the United States were surveyed weekly in 2010 and 2011 for the presence of brown marmorated stink bug and the injury caused to both apple and peaches. Among tested sampling techniques, pyramid traps baited with the aggregation pheromone of *Plautia stali* Scott, methyl-(2*E*,4*E*,6*Z*)-decatrienoate, yielded the most brown marmorated stink bug adults and nymphs, followed by visual observations. Brown marmorated stink bugs began to feed on apples and peaches soon after fruit set and continued to feed on fruit throughout the growing season. Injury to apple was relatively inconsequential until after mid-June, whereas feeding on peaches resulted in immediate economic injury as the surface became distorted, dented, discolored, and the flesh beneath turned brown. Significantly more apples were injured and with greater severity in 2010 than in 2011. Likewise, percent injury on the exterior portion of each apple plot was significantly greater than injury reported from the interior in both years. Growers increased the number of insecticide applications nearly 4-fold from 2010 to 2011. In addition to the increased number of targeted insecticide applications, growers also reduced the interval between treatments in 2011. A metric was created to compare the relative intensity of each grower's commercial management program between seasons and amongst each other.

Leskey et al. (2012) documented that during outbreak densities of BMSB, damage in stone and pome fruit orchards reached extreme levels. Subsequently, growers responded with management programs that included up to 4-fold increases in insecticide applications.

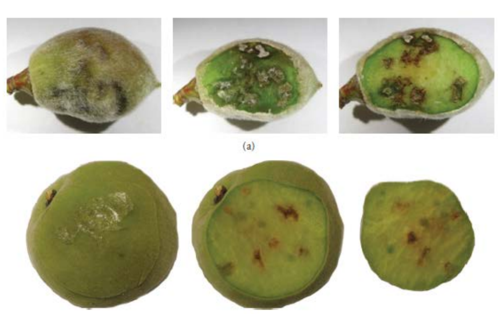

FIGURE 2: (a) Photos of subsurface corking injury to a 15 mm "Loring" peach in the early season and to (b) a 40 mm "Red Haven" peach ~3 weeks prior to harvest.

Kuhar et al. (2012) documented the risk BMSB poses to vegetable crops and described the damage symptoms created by BMSB feeding.

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The Pest Potential of Brown Marmorated Stink Bug on Vegetable Crops

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Kuhar, T. P., Kamminga, K. L., Whalen, J., Dively, G. P., Brust, G., Hooks, C. R. R., Hamilton, G., and Herbert, D. A. 2012. The pest potential of brown marmorated stink bug on vegetable crops. Online. Plant Health Progress doi:10.1094/PHP-2012-0523-01-BR.

The brown marmorated stink bug, *Halyomorpha halys* (Stål) (Fig. 1), is an invasive insect from east Asia that was first reported in the USA near Allentown, PA, in the late 1990s (3). Since that time, the pest has spread rapidly across the United States, although significant pest densities and concomitant crop damage have largely remained centered in the mid-Atlantic from New Jersey to Virginia (2). The insect is highly polyphagous (1) and has been reported as a serious pest of tree fruit in the United States (4,2), but its damage and risk to vegetable crops has not been well documented to date. Herein, we report our observations from the mid-Atlantic United States on the relative pest risk that *H. halys* poses to vegetable crops.

Fig. 5. Severe infestations of brown marmorated stink bug can result in total loss of fruiting vegetable crops.

Fig. 6. Brown marmorated stink bug feeding scars on tomato fruit.

Fig. 7. Spongy area left by stink bug feeding on bell pepper.

Fig. 8. Brown marmorated stink bug feeding scars on bell pepper.

Fig. 9. Brown marmorated stink bug feeding injury on eggplant.

Fig. 10. Brown marmorated stink bug feeding injury on okra.

Invasive Stink Bug Wounds Trees, Liberates Sugars, and Facilitates Native Hymenoptera

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Ann. Entomol. Soc. Am. 106(1): 47–52 (2013); DOI: http://dx.doi.org/10.1603/AN12088

ABSTRACT Biological invasions often have devastating impacts on ecosystems and economies, while facilitative interactions between invasive and native species are often overlooked. Here, we demonstrate how the invasive brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), facilitates native Hymenoptera by opening a novel feeding niche. In the invaded mid-Atlantic region of the United States, several species of native ants and wasps feed on wound exudates from stink bug feeding sites; these exudates have high sugar concentrations and are rapidly used by indigenous Hymenoptera. Positive facilitative interactions between invasive and keystone native species such as ants may have far reaching impacts on invaded ecosystems.

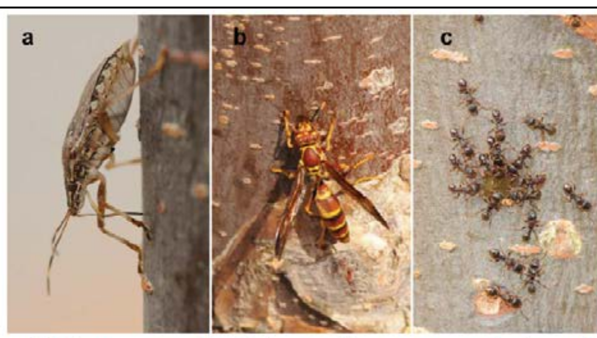

Fig. 1. *Halyomorpha halys*, an invasive stink bug, feeds on tree phloem, creating wound exudates used by wasps and ants, here on American elm, *Ulmus americana*, at Harpers Ferry, WV. (a) *H. halys* probing bark. (b) The common paper wasp, *Polistes exclamans* (Hymenoptera: Vespidae), at a feeding wound. (c) *Tetramorium cf. caespitum* (Hymenoptera: Formicidae), a pavement ant, using sap exudates after stink bug feeding.

Martinson et al. (2013) demonstrated that BMSB feed on woody ornamentals by piercing through the bark to liberate sugary exudates. These wound sites also attract native hymenoptera including wasps and ants.

In addition, Venugopal et al. (2015) and Martinson et al. (2015) demonstrated that edge effects and fruit availability affect seasonal abundance of BMSB in ornamental nurseries.

Edge Effects Influence the Abundance of the Invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) in Woody Plant Nurseries

P. DILIP VENUGOPAL[1,2], HOLLY M. MARTINSON[1,2], ERIK J. BERGMANN[2], PAULA M. SHREWSBURY[2], AND MICHAEL J. RAUPP[2,3]

Environ. Entomol. 1–6 (2015); DOI: 10.1093/ee/nvv061

ABSTRACT The invasive brown marmorated stink bug, *Halyomorpha halys* (Stål), has caused severe economic losses in the United States and is also a major nuisance pest invading homes. In diverse woody plant nurseries, favored host plants may be attacked at different times of the season and in different locations in the field. Knowledge of factors influencing *H. halys* abundance and simple methods to predict where *H. halys* are found and cause damage are needed to develop effective management strategies. In this study, we examined *H. halys* abundance on plants in tree nurseries as a function of distance from field edges (edge and core samples) and documented the abundance in tree nurseries adjoining different habitat types (corn, soybean, residential areas, and production sod). We conducted timed counts for *H. halys* on 2,016 individual trees belonging to 146 unique woody plant cultivars at two commercial tree nurseries in Maryland. Across three years of sampling, we found that *H. halys* nymphs and adults were more abundant at field edges (0–5 m from edges) than in the core of fields (15–20 m from edges). Proximity of soybean fields was associated with high nymph and adult abundance. Results indicate that monitoring efforts and intervention tactics for this invasive pest could be restricted to field edges, especially those close to soybean fields. We show clearly that spatial factors, especially distance from edge, strongly influence *H. halys* abundance in nurseries. This information may greatly simplify the development of any future management strategies.

J Pest Sci (2015) 88:461–468
DOI 10.1007/s10340-015-0677-8

CrossMark

RAPID COMMUNICATION

Fruit availability influences the seasonal abundance of invasive stink bugs in ornamental tree nurseries

Holly M. Martinson[1] · P. Dilip Venugopal[1] · Erik J. Bergmann[1] · Paula M. Shrewsbury[1] · Michael J. Raupp[1]

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Abstract Invasive plant-feeding insects cause billions of dollars in economics losses annually around the world. Understanding how they utilize different host plants directly informs their management. The highly invasive brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), has destroyed crops and invaded homes since its discovery in the U.S. in the mid-1990s. In this study, we test the hypothesis that in diverse resource environments, the presence and maturity of fruits on trees influences the abundance of *H. halys*. Observational surveys of the abundance of *H. halys* life stages (egg masses, nymphs, and adults) on 3884 trees of 223 cultivars in woody plant nurseries revealed that fruit maturity was a strong predictor of the seasonal abundance and within-tree distribution of *H. halys*. We next explicitly tested whether fruits themselves were the key resource for *H. halys* through a manipulative field experiment. Removal of fruits from trees suppressed stink bug abundance throughout the season. Despite being considered a broad feeding generalist, our results highlight that in landscapes with highly heterogeneous and ephemeral resources, *H. halys* specializes on finding mature fruits. Therefore, *H. halys* can be controlled by designing landscapes with fruitless varieties of popular trees, exploiting phenological mismatches between the pest and its host plants, and through targeted management of *H. halys* on fruiting trees in the landscape.

Keywords Fruit phenology · *Halyomorpha halys* · Invasive species · Ornamental plants · Resource heterogeneity

Key message

- *Halyomorpha halys* is a highly invasive and broadly polyphagous plant-feeding bug. Thus, identifying factors that influence its abundance across host plants will inform management.
- In an extensive field survey and a season-long experiment, the abundance of *H. halys* was strongly influenced by the presence and maturity of fruit.
- Considering this pest as a fruit specialist may aid in management, monitoring, and the development of landscapes refractory to stink bugs.

Introduction

Biotic introductions are one of the leading causes of global environmental change (Vitousek 1994; Sala et al. 2000; Pimentel et al. 2005). Species that successfully establish and spread in a new range engage in a host of unprecedented ecological relationships, including novel consumer-

PLOS | ONE

RESEARCH ARTICLE

Electronically Monitored Labial Dabbing and Stylet 'Probing' Behaviors of Brown Marmorated Stink Bug, *Halyomorpha halys*, in Simulated Environments

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OPEN ACCESS

Citation: Wiman NG, Walton VM, Shearer PW, Rondon SI (2014) Electronically Monitored Labial Dabbing and Stylet 'Probing' Behaviors of Brown Marmorated Stink Bug, *Halyomorpha halys*, in Simulated Environments. PLoS ONE 9(12): e113514. doi:10.1371/journal.pone.0113514

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Data Availability: The authors confirm that all data underlying the findings are fully available without restriction. All relevant data are within the paper.

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Competing Interests: The authors have declared that no competing interests exist.

Abstract

Brown marmorated stink bug, *Halyomorpha halys* (Stål), (Hemiptera: Pentatomidae) is an invasive polyphagous agricultural and urban nuisance pest of Asian origin that is becoming widespread in North America and Europe. Despite the economic importance of pentatomid pests worldwide, their feeding behavior is poorly understood. Electronically monitored insect feeding (EMIF) technology is a useful tool in studies of feeding behavior of Hemiptera. Here we examined *H. halys* feeding behavior using an EMIF system designed for high throughput studies in environmental chambers. Our objectives were to quantify feeding activity by monitoring proboscis contacts with green beans, including labial dabbing and stylet penetration of the beans, which we collectively define as 'probes'. We examined frequency and duration of 'probes' in field-collected *H. halys* over 48 hours and we determined how environmental conditions could affect diel and seasonal periodicity of 'probing' activity. We found differences in 'probing' activity between months when the assays were conducted. These differences in activity may have reflected different environmental conditions, and they also coincide with what is known about the phenology of *H. halys*. While a substantial number of 'probes' occurred during scotophase, including some of the longest mean 'probe' durations, activity was either lower or similar to 'probing' activity levels during photophase on average. We found that temperature had a significant impact on *H. halys* 'probing' behavior and may influence periodicity of activity. Our data suggest that the minimal temperature at which 'probing' of *H. halys* occurs is between 3.5 and 6.1°C (95% CI), and that 'probing' does not occur at temperatures above 26.5 to 29.6°C (95% CI). We estimated that the optimal temperature for 'probing' is between 16 and 17°C.

Wiman et al. (2014) developed a technique for assessing feeding of BMSB using an electronic monitor. Results revealed temperatures at which BMSB will probe, i.e., feed.

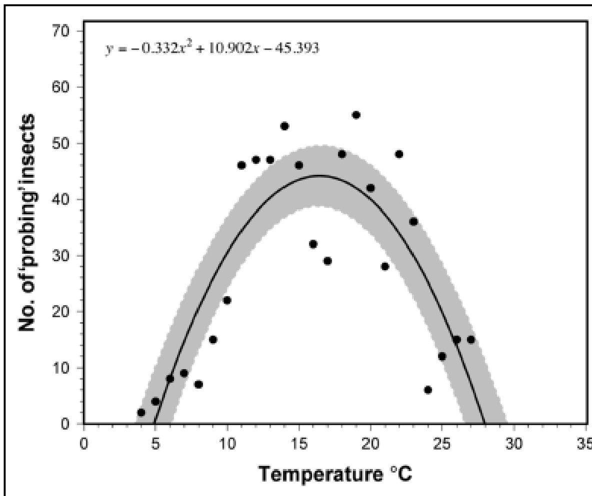

Figure 6. Temperature-dependent 'probing' activity curve of *H. halys*.

Spatial Distribution of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) Injury at Harvest in Mid-Atlantic Apple Orchards

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J. Econ. Entomol. 107(5): 1839–1848 (2014); DOI: http://dx.doi.org/10.1603/EC14154

ABSTRACT Brown marmorated stink bug, *Halyomorpha halys* (Stål), injury to late-season apple cultivars was measured at harvest in 2011 and 2012 in commercial orchards in four mid-Atlantic states. In each orchard block, a border zone (adjacent to woods), an interior zone (near orchard center), and an intermediate zone (between border and interior zones) comprised 1–3 tree rows per zone, depending on block size. Just before commercial harvest, 10 fruit were sampled from the upper, middle, and lower third of the canopy from five trees in each zone. After 3–5 wk in cold storage, fruit were examined for external and internal injury, and severity of internal injury (number of injury sites per fruit) from *H. halys*. A zero-inflated negative binomial model accounted for significant variation among the orchards and showed that apples from the upper canopy of border zone trees had the highest probability of experiencing external and internal injury. A minor interaction was detected among the orchards and zones for injury prevalence and severity, but there was no evidence of an orchard showing less expected injury in the border zone compared with other zones. Adjusting for orchard-to-orchard variation, differences in injury distributions among the zones and canopies were primarily due to injury prevalence rather than expected injury severity. The implications of these results to scouting and managing *H. halys* in eastern apple orchards are discussed.

KEY WORDS *Halyomorpha halys*, *Malus domestica*, scouting, sampling

Joseph et al. (2014) quantified BMSB injury in apples at sites in four mid-Atlantic states and found that injury was greatest in the upper canopy of border row trees, further establishing the border-driven invasion of BMSB in specialty crops.

Occurrence of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) on Wild Hosts in Nonmanaged Woodlands and Soybean Fields in North Carolina and Virginia

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Environ. Entomol. 1–11 (2015); DOI: 10.1093/ee/nvv092

ABSTRACT Nonmanaged plants occurring along forest edges and in suburban settings were sampled for brown marmorated stink bug, *Halyomorpha halys* (Stål), in North Carolina (NC) and Virginia (VA) over the course of three growing seasons. Commercial soybeans (*Glycine max*), an attractive cultivated host, were also sampled in 2014 in NC and in VA from 2010–2014. Very few *H. halys* were found on nonmanaged plants or soybean fields in the coastal plain region of either state, but substantial populations were recorded in the piedmont and mountain regions. From 2011 to 2013, *H. halys* comprised from 51 to 97% of all stink bug species observed on nonmanaged plants in the piedmont and mountain regions. In VA, the distribution expanded from detection in 12 counties in 2010 to 53 counties in 2014, with economically damaging levels occurring in the piedmont region. During these studies, *H. halys* were observed to complete one and a partial second generation per year in western NC and southwestern VA, similar to that previously observed in regions farther north. Several plants were identified as preferred hosts, with tree of heaven, catalpa, yellowwood, paulownia, cherry, walnut, redbud, and grape having consistently high numbers of *H. halys*. Knowing that these plants are preferred by *H. halys* during certain stages of the insects' development will aid in the search for *H. halys* in new areas, as well as serve as one predictor of the likelihood of a certain area to attract and sustain large *H. halys* populations.

Bakken et al. (2015) documented that BMSB were found in greater numbers in piedmont and mountain regions of VA and NC compared with coastal plains. In addition, preferred host plants including tree of heaven, caltapa, paulownia, and redbud, among others, were identified.

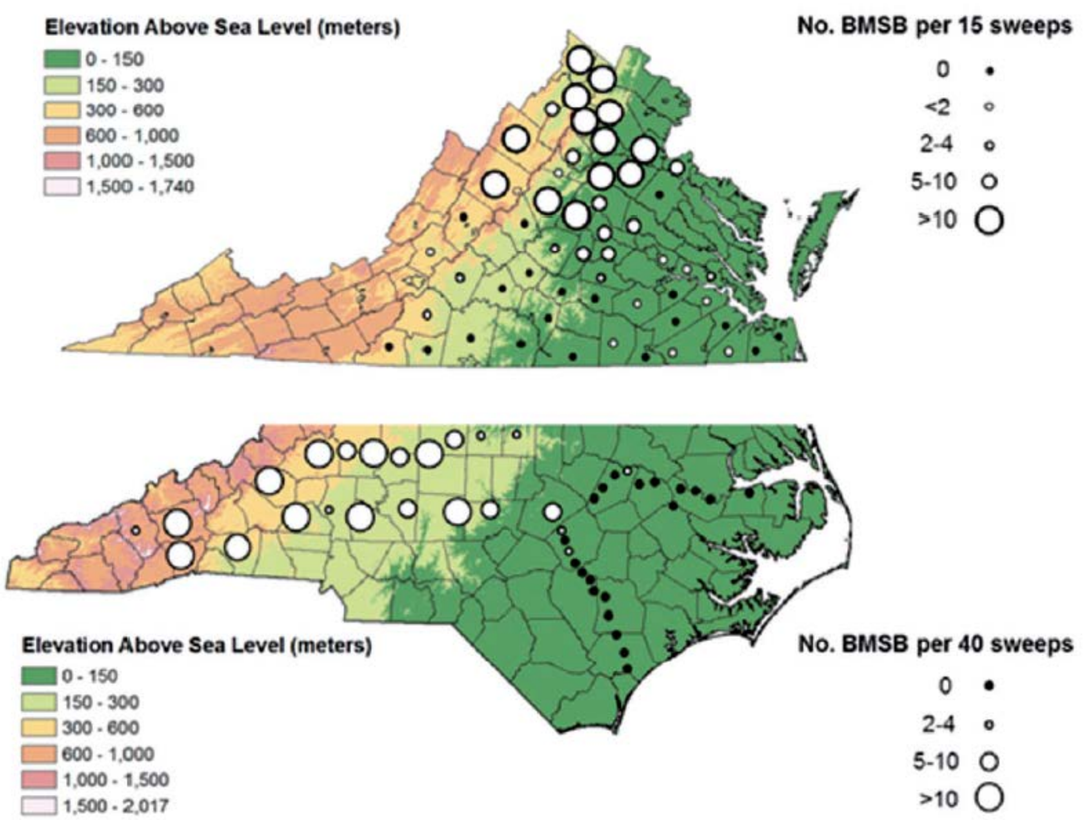

Fig. 1. Density of *H. halys* in soybean fields in 2013 in VA and 2014 in NC. Densities in individual fields are depicted by the size and color of data points. Data from VA represent the highest density recorded from multiple sample dates, while NC data represent densities on a single sample date.

1.4. Identify landscape and temporal risk factors associated with BMSB on crops and in adjacent ecosystems.

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Landscape Factors Facilitating the Invasive Dynamics and Distribution of the Brown Marmorated Stink Bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), after Arrival in the United States

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Abstract

The brown marmorated stink bug, *Halyomorpha halys*, a native of Asia, has become a serious invasive pest in the USA. *H. halys* was first detected in the USA in the mid 1990s, dispersing to over 41 other states. Since 1998, *H. halys* has spread throughout New Jersey, becoming an important pest of agriculture, and a major nuisance in urban developments. In this study, we used spatial analysis, geostatistics, and Bayesian linear regression to investigate the invasion dynamics and colonization processes of this pest in New Jersey. We present the results of monitoring *H. halys* from 51 to 71 black light traps that were placed on farms throughout New Jersey from 2004 to 2011 and examined relationships between total yearly densities of *H. halys* and square hectares of 48 landscape/land use variables derived from urban, wetland, forest, and agriculture metadata, as well as distances to nearest highways. From these analyses we propose the following hypotheses: (1) *H. halys* density is strongly associated with urban developments and railroads during its initial establishment and dispersal from 2004 to 2006; (2) *H. halys* overwintering in multiple habitats and feeding on a variety of plants may have reduced the Allee effect, thus facilitating movement into the southernmost regions of the state by railroads from 2005 to 2008; (3) density of *H. halys* contracted in 2009 possibly from invading wetlands or sampling artifact; (4) subsequent invasion of *H. halys* from the northwest to the south in 2010 may conform to a stratified-dispersal model marked by rapid long-distance movement, from railroads and wetland rights-of-way; and (5) high densities of *H. halys* may be associated with agriculture in southern New Jersey in 2011. These landscape features associated with the invasion of *H. halys* in New Jersey may predict its potential rate of invasion across the USA and worldwide.

Walner et al. (2014) used blacklight trap captures and spatial analysis to establish that BMSB likely spread from urban centers to rural, agricultural areas via human-mediated transport and high adaptability of BMSB to novel overwintering sites and alternative host plants.

1.5 Genetic Studies of BMSB.

Ioannidis et al. (2014) published the first rapid transcriptome sequencing of BMSB and found novel targets for potential biocontrol based on RNAi strategies including targeting bacterial endosymbiotic genes.

RESEARCH ARTICLE **Open Access**

Rapid transcriptome sequencing of an invasive pest, the brown marmorated stink bug *Halyomorpha halys*

Panagiotis Ioannidis[1,4], Yong Lu[2], Nikhil Kumar[1], Todd Creasy[1,5], Sean Daugherty[1], Marcus C Chibucos[1,3], Joshua Orvis[1], Amol Shetty[1], Sandra Ott[1], Melissa Flowers[1], Naomi Sengamalay[1], Luke J Tallon[1], Leslie Pick[2] and Julie C Dunning Hotopp[1,3]*

Abstract

Background: *Halyomorpha halys* (Stål) (Insecta:Hemiptera;Pentatomidae), commonly known as the Brown Marmorated Stink Bug (BMSB), is an invasive pest of the mid-Atlantic region of the United States, causing economically important damage to a wide range of crops. Native to Asia, BMSB was first observed in Allentown, PA, USA, in 1996, and this pest is now well-established throughout the US mid-Atlantic region and beyond. In addition to the serious threat BMSB poses to agriculture, BMSB has become a nuisance to homeowners, invading home gardens and congregating in large numbers in human-made structures, including homes, to overwinter. Despite its significance as an agricultural pest with limited control options, only 100 bp of BMSB sequence data was available in public databases when this project began.

Results: Transcriptome sequencing was undertaken to provide a molecular resource to the research community to inform the development of pest control strategies and to provide molecular data for population genetics studies of BMSB. Using normalized, strand-specific libraries, we sequenced pools of all BMSB life stages on the Illumina HiSeq. Trinity was used to assemble 200,000 putative transcripts in >100,000 components. A novel bioinformatic method that analyzed the strand-specificity of the data reduced this to 53,071 putative transcripts from 18,573 components. By integrating multiple other data types, we narrowed this further to 13,211 representative transcripts.

Conclusions: Bacterial endosymbiont genes were identified in this dataset, some of which have a copy number consistent with being lateral gene transfers between endosymbiont genomes and Hemiptera, including ankyrin-repeat related proteins, lysozyme, and mannanase. Such genes and endosymbionts may provide novel targets for BMSB-specific biocontrol. This study demonstrates the utility of strand-specific sequencing in generating shotgun transcriptomes and that rapid sequencing shotgun transcriptomes is possible without the need for extensive inbreeding to generate homozygous lines. Such sequencing can provide a rapid response to pest invasions similar to that already described for disease epidemiology.

Keywords: Brown marmorated stink bug, *Halyomorpha halys*, Transcriptome, Hemiptera, Invasive species, Lateral gene transfer, Horizontal gene transfer, Mannanase, Lysozyme

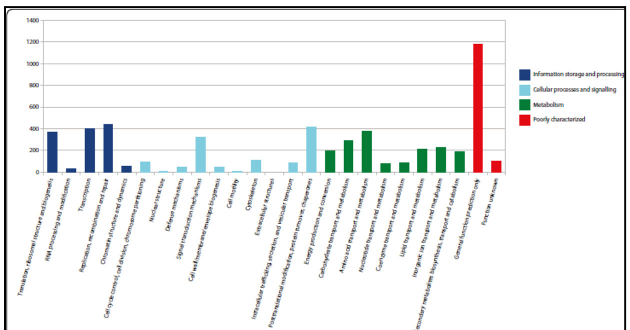
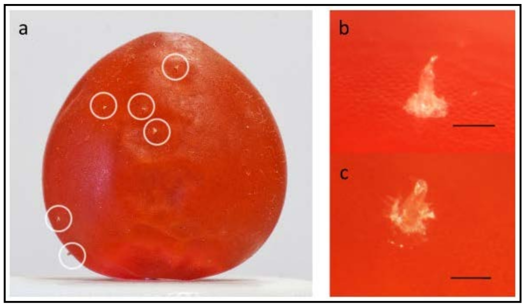
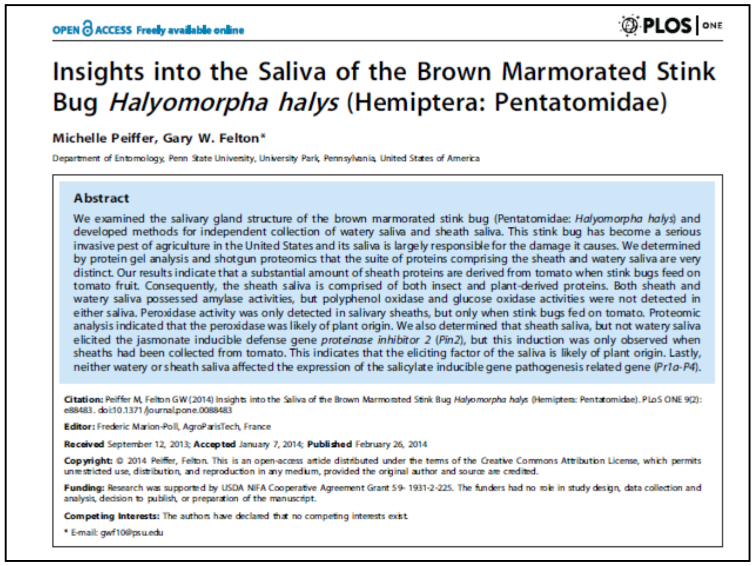


Figure 6 Transcript functional categories. The NCBI Cluster of Orthologous Groups (COG) database was used to classify the predicted proteins in the 13,211 representative transcripts. Assignment of COG categories showed that a large number of ORFs belonged to categories of proteins whose functions are poorly characterized, namely those that have general function prediction only and those with unknown function.

In addition, the characterization of salivary proteins, including feeding sheath and watery saliva by Peiffer and Felton (2015) provide other novel targets that potentially could be disrupted.





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Insights into the Saliva of the Brown Marmorated Stink Bug *Halyomorpha halys* (Hemiptera: Pentatomidae)

Michelle Peiffer, Gary W. Felton*

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Abstract

We examined the salivary gland structure of the brown marmorated stink bug (Pentatomidae: *Halyomorpha halys*) and developed methods for independent collection of watery saliva and sheath saliva. This stink bug has become a serious invasive pest of agriculture in the United States and its saliva is largely responsible for the damage it causes. We determined by protein gel analysis and shotgun proteomics that the suite of proteins comprising the sheath and watery saliva are very distinct. Our results indicate that a substantial amount of sheath proteins are derived from tomato when stink bugs feed on tomato fruit. Consequently, the sheath saliva is comprised of both insect and plant-derived proteins. Both sheath and watery saliva possessed amylase activities, but polyphenol oxidase and glucose oxidase activities were not detected in either saliva. Peroxidase activity was only detected in salivary sheaths, but only when stink bugs fed on tomato. Proteomic analysis indicated that the peroxidase was likely of plant origin. We also determined that sheath saliva, but not watery saliva elicited the jasmonate inducible defense gene *proteinase inhibitor 2* (*Pin2*), but this induction was only observed when sheaths had been collected from tomato. This indicates that the eliciting factor of the saliva is likely of plant origin. Lastly, neither watery or sheath saliva affected the expression of the salicylate inducible gene pathogenesis related gene (*Pr1a-P4*).

Citation: Peiffer M, Felton GW (2014) Insights into the Saliva of the Brown Marmorated Stink Bug *Halyomorpha halys* (Hemiptera: Pentatomidae). PLoS ONE 9(2): e88483. doi:10.1371/journal.pone.0088483

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Competing Interests: The authors have declared that no competing interests exist.

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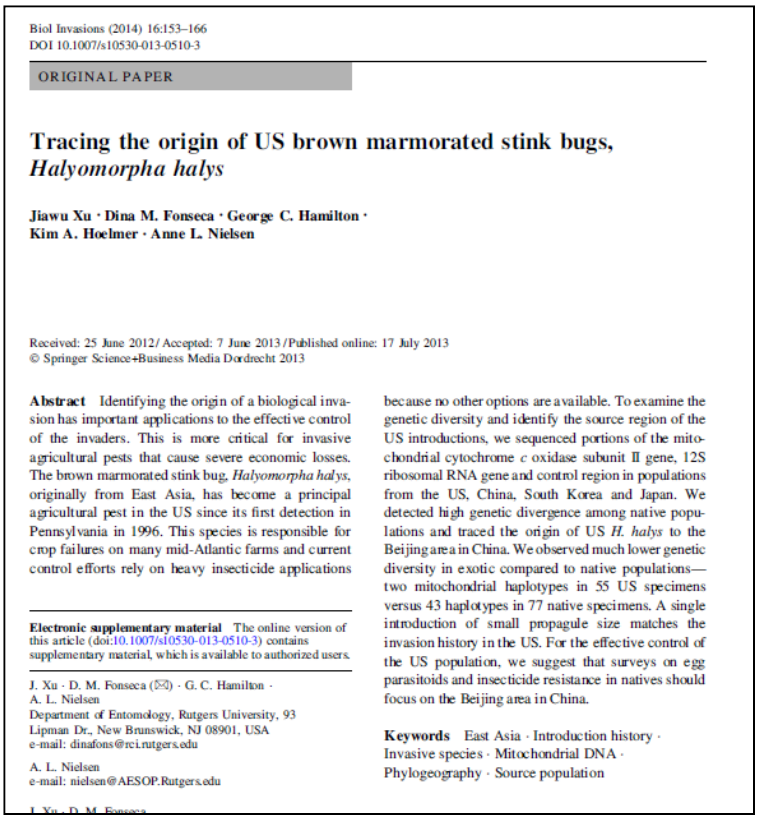

Biol Invasions (2014) 16:153–166
DOI 10.1007/s10530-013-0510-3

ORIGINAL PAPER

Tracing the origin of US brown marmorated stink bugs, *Halyomorpha halys*

Jiawu Xu · Dina M. Fonseca · George C. Hamilton · Kim A. Hoelmer · Anne L. Nielsen

Received: 25 June 2012 / Accepted: 7 June 2013 / Published online: 17 July 2013

Abstract Identifying the origin of a biological invasion has important applications to the effective control of the invaders. This is more critical for invasive agricultural pests that cause severe economic losses. The brown marmorated stink bug, *Halyomorpha halys*, originally from East Asia, has become a principal agricultural pest in the US since its first detection in Pennsylvania in 1996. This species is responsible for crop failures on many mid-Atlantic farms and current control efforts rely on heavy insecticide applications because no other options are available. To examine the genetic diversity and identify the source region of the US introductions, we sequenced portions of the mitochondrial cytochrome *c* oxidase subunit II gene, 12S ribosomal RNA gene and control region in populations from the US, China, South Korea and Japan. We detected high genetic divergence among native populations and traced the origin of US *H. halys* to the Beijing area in China. We observed much lower genetic diversity in exotic compared to native populations—two mitochondrial haplotypes in 55 US specimens versus 43 haplotypes in 77 native specimens. A single introduction of small propagule size matches the invasion history in the US. For the effective control of the US population, we suggest that surveys on egg parasitoids and insecticide resistance in natives should focus on the Beijing area in China.

Keywords East Asia · Introduction history · Invasive species · Mitochondrial DNA · Phylogeography · Source population

Electronic supplementary material The online version of this article (doi:10.1007/s10530-013-0510-3) contains supplementary material, which is available to authorized users.

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Xu et al. (2014) sequenced portions of the mitochondrial genome to establish that the origin of the US population was likely from the Beijing, China area.

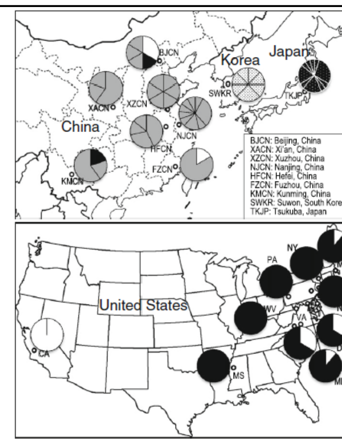

Fig. 1 Maps of East Asia and the US showing the sampling locations and mtDNA haplotype distribution of *H. halys*. Native specimens were collected from China (*CN*), South Korea (*KR*) and Japan (*JP*). The US specimens were sampled from Massachusetts (*MA*), New York (*NY*), New Jersey (*NJ*), Pennsylvania (*PA*), Maryland (*MD*), Delaware (*DE*), West Virginia (*WV*), Virginia (*VA*), Mississippi (*MS*) and California (*CA*). Two haplotypes identified in the US are shown in *white* (H1) and *black* (H2). Haplotypes unique to China, South Korea and Japan are shown in *grey*, *stippled white* and *stippled black*, respectively. No shared haplotypes were detected among the three native countries

1.7 Investigate relationship between BMSB and gut symbionts (Renewal)

Finally, Taylor et al. (2014) established the importance of maternally transferred gut symbionts, as development time and survivorship are heavily affected by their absence. These symbionts are likely acquired by first instar nymphs as they feed on the surfaces of eggs soon after hatching.

The Importance of Gut Symbionts in the Development of the Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål)

Christopher M. Taylor*, Peter L. Coffey, Bridget D. DeLay, Galen P. Dively

University of Maryland, Department of Entomology, College Park, Maryland, United States of America

Abstract

The invasive brown marmorated stink bug, *Halyomorpha halys* (Stål), has become a severe agricultural pest and nuisance problem since its introduction in the U.S. Research is being conducted to understand its biology and to find management solutions. Its symbiotic relationship with gut symbionts is one aspect of its biology that is not understood. In the family Pentatomidae, the reliance on gut symbionts for successful development seems to vary depending on the species of stink bug. This research assessed the role of gut symbionts in the development, survivorship, and fecundity of *H. halys*. We compared various fitness parameters of nymphs and adults reared from surface sterilized and untreated egg masses during two consecutive generations under laboratory conditions. Results provided direct evidence that *H. halys* is negatively impacted by the prevention of vertical transmission of its gut symbionts and that this impact is significant in the first generation and manifests dramatically in the subsequent generation. Developmental time and survivorship of treated cohorts in the first generation were significantly affected during third instar development through to the adult stage. Adults from the sterilized treatment group exhibited longer pre-oviposition periods, produced fewer egg masses, had significantly smaller clutch sizes, and the hatch rate and survivorship of those eggs were significantly reduced. Observations following hatch of surface sterilized eggs also revealed significant effects on wandering behavior of the first instars. The second generation progeny from adults of the sterilized cohorts showed significantly lower survival to adulthood, averaging only 0.3% compared to 20.8% for the control cohorts. Taken together, results demonstrate that *H. halys* is heavily impacted by deprival of its gut symbionts. Given the economic status of this invasive pest, further investigations may lead to management tactics that disrupt this close symbiotic relationship in the biology of *H. halys*.

Citation: Taylor CM, Coffey PL, DeLay BD, Dively GP (2014) The Importance of Gut Symbionts in the Development of the Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål). PLoS ONE 9(3): e90312. doi:10.1371/journal.pone.0090312

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Funding: Grant: United States Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA) Specialty Crop Research Initiative (SCRI) #2011-51181-30937: Biology, Ecology, and Management of Brown Marmorated Stink Bug in orchard Crops, Small Fruit, Grapes, Vegetables and Ornamentals. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

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Objective 2 Outputs

2.1 Develop effective monitoring tools for BMSB

Leskey et al. (2012) found that a black pyramid trap baited with methyl (2E, 4E, 6Z)-decatrienoate (MDT), the aggregation pheromone of another Asian stink bug species and cross-attractive to BMSB, captured more BMSB adults and nymphs than compared with pyramid traps of other colors and canopy-deployed traps from Japan.

Development of Behaviorally-Based Monitoring Tools for the Brown Marmorated Stink Bug (Heteroptera: Pentatomidae) in Commercial Tree Fruit Orchards[1]

Tracy C. Leskey[2], Starker E. Wright, Brent D. Short, and Ashot Khrimian[3]

USDA-ARS, Appalachian Fruit Research Station, 2217 Wiltshire Road, Kearneysville, West Virginia 25430-2771 USA

J. Entomol. Sci. 47(1): 76-85 (January 2012)

Abstract Captures of the invasive brown marmorated stink bug, *Halyomorpha halys* (Stål), were significantly greater in pyramid traps baited with the known attractant, methyl (2*E*,4*E*,6*Z*)-decatrienoate, compared with unbaited traps. A dose-dependent response by adults to lures formulated with increasing amounts of methyl (2*E*,4*E*,6*Z*)-decatrienoate and deployed in association with black pyramid traps also was observed. Among pyramid traps representing different visual stimuli including black, green, yellow, clear, white and yellow, significantly greater captures were recorded in baited black pyramid traps for adults in 2009 and nymphs in 2010 compared with other trap types; the dark upright silhouette created by this trap likely represents a trunk-mimicking visual stimulus to foraging bugs. A ground-deployed baited black pyramid trap also captured significantly greater numbers of nymphs and adults compared with canopy-deployed commercially available baited traps from Japan. Based on semi-field cage studies, brown marmorated stink bug was confirmed to be bivoltine within the mid-Atlantic region. Thus, the need for a reliable monitoring tool to detect presence, abundance and seasonal activity of brown marmorated stink bug in tree fruit and other cropping systems is critical.

Joseph et al. (2013) documented the impact of modifications to the pyramid trap collection jar as well as the effect of aged MDT lures and kill strips on captures of BMSB. Fresh MDT lures resulted in far greater captures, demonstrating the need for lure improvement.

Factors Affecting Captures of Brown Marmorated Stink Bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), in Baited Pyramid Traps[1]

Shimat V. Joseph[2], J. Christopher Bergh, Starker E. Wright[3], and Tracy C. Leskey[3]

Alson H. Smith, Jr. Agricultural Research and Extension Center, Virginia Polytechnic Institute and State University, 595 Laurel Grove Road, Winchester, Virginia 22602 USA

J. Entomol. Sci. 48(1): 43-51 (January 2013)

Abstract Trapping experiments targeting brown marmorated stink bug, *Halyomorpha halys* (Stål), addressed the effects of: (1) a modification to the trap container of a commercial trap, (2) the age of methyl (2*E*,4*E*,6*Z*)-decatrienoate lures, and (3) the age of dichlorvos-impregnated kill strips on bug captures. In the trap modification study, ventilation holes in the containers atop standard, commercial AgBio™ traps were modified to resemble a USDA prototype trap. Captures were compared among the standard traps, modified commercial traps, and prototype traps. *Halyomorpha halys* captures were significantly greater in the prototype trap than in standard commercial traps, whereas captures in modified commercial traps were intermediate between but not significantly different from AgBio or prototype traps. Traps baited with kill strips that were fresh or that had been field-aged for 1, 2, 3 or 4 wk showed no significant differences in the total number of *H. halys* captured over a 15-d trapping interval, although the percentage of dead bugs was significantly greater in traps containing fresh kill strips than in those with 3- or 4-wk-old kill strips. In the aged lure experiment, captures were not significantly different among traps baited with fresh, 1- and 2-wk-old lures or among those baited with 2-, 3- or 4-wk old lures or unbaited. Most (64.8%) bugs were captured during the first 3-d sample interval, during which traps with fresh lures captured more *H. halys* than those with each aged lure treatment. Weekly gravimetric measurements to determine the release of methyl (2*E*,4*E*,6*Z*)-decatrienoate from lures over 4 wk showed a sharp decrease in lure weight during the first 3-d interval at 20 and 25°C.

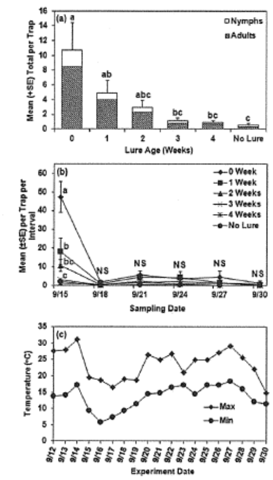

Fig. 4. Captures of *H. halys* in traps with aged, methyl (2*E*,4*E*,6*Z*)-decatrienoate lures during (a) the entire trapping period (12 - 30 September, 2011) and (b) per 3-d interval. Daily high and low temperatures during the experiment are shown in (c). Bars (a) or lined data-points (b) (within same sampling date) with the same letter are not significantly different (Tukey's HSD Test: $\alpha < 0.05$).

Khrimian et al. (2014) identified the two-component aggregation pheromone of BMSB.

Discovery of the Aggregation Pheromone of the Brown Marmorated Stink Bug (*Halyomorpha halys*) through the Creation of Stereoisomeric Libraries of 1-Bisabolen-3-ols

Ashot Khrimian,*[,†] Aijun Zhang,[†] Donald C. Weber,[†] Hsiao-Yung Ho,[‡] Jeffrey R. Aldrich,[†,§] Karl E. Vermillion,[⊥] Maxime A. Siegler,[∥] Shyam Shirali,[†] Filadelfo Guzman,[†] and Tracy C. Leskey[∇]

[†]U.S. Department of Agriculture, Agricultural Research Service, Beltsville Area, IIBBL, Maryland 20705, United States
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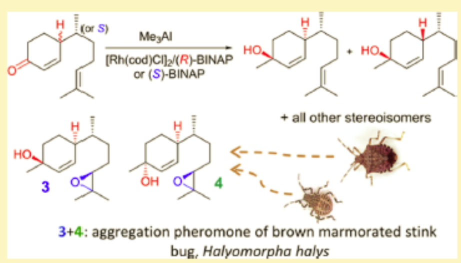
Supporting Information

ABSTRACT: We describe a novel and straightforward route to all stereoisomers of 1,10-bisaboladien-3-ol and 10,11-epoxy-1-bisabolen-3-ol via the rhodium-catalyzed asymmetric addition of trimethylaluminum to diastereomeric mixtures of cyclohex-2-enones **1** and **2**. The detailed stereoisomeric structures of many natural sesquiterpenes with the bisabolane skeleton were previously unknown because of the absence of stereoselective syntheses of individual stereoisomers. Several of the bisabolenols are pheromones of economically important pentatomid bug species. Single-crystal X-ray crystallography of underivatized triol **13** provided unequivocal proof of the relative and absolute configurations. Two of the epoxides, (3*S*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol (**3**) and (3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol (**4**), were identified as the main components of a male-produced aggregation pheromone of the brown marmorated stink bug, *Halyomorpha halys*, using GC analyses on enantioselective columns. Both compounds attracted female, male, and nymphal *H. halys* in field trials. Moreover, mixtures of stereoisomers containing epoxides **3** and **4** were also attractive to *H. halys*, signifying that the presence of additional stereoisomers did not hinder attraction of *H. halys* and relatively inexpensive mixtures can be used in monitoring, as well as control strategies. *H. halys* is a polyphagous invasive species in the U.S. and Europe that causes severe injury to fruit, vegetables, and field crops and is also a serious nuisance pest.



Results demonstrated attraction to the pheromone by adults and nymphs as well as lack of inhibition when additional non-pheromonal stereoisomers were present, potentially reducing the cost of pheromone production.

In addition, Weber et al. (2014) documented a synergistic increase in capture in traps baited with the BMSB aggregation pheromone in combination with MDT compared with either alone.

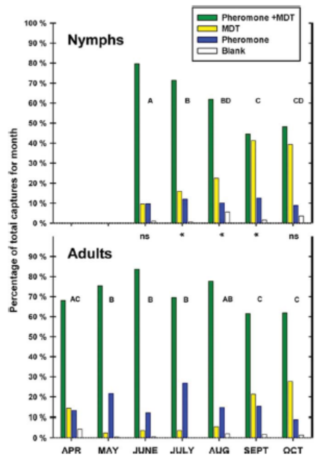


Fig. 2. Seasonal response of *H. halys* nymphs and adults to pheromone, MDT, and combination. Letters indicate a difference in proportion of captures according to Bonferroni-corrected chi-square multiple-comparison tests (experiment-wise $\alpha = 0.05$; comparison-wise $\alpha = 0.0024$ for adults [21 paired tests], and $\alpha = 0.005$ for nymphs [10 paired tests]). Asterisks (or ns = no significant difference) indicate difference in proportion of captures between adults and nymphs within the same month (Bonferroni-corrected chi-square multiple-comparison tests with experiment-wise $\alpha = 0.05$; comparison-wise $\alpha = 0.01$ [five tests]). Monthly totals for 6 April through 23 October 2012, Beltsville, MD; nymphs were not captured before early June.

ECOLOGY AND BEHAVIOR

Synergy of Aggregation Pheromone With Methyl (*E,E,Z*)-2,4,6-Decatrienoate in Attraction of *Halyomorpha halys* (Hemiptera: Pentatomidae)

DONALD C. WEBER,[1,2] TRACY C. LESKEY,[3] GUILLERMO CABRERA WALSH,[4] AND ASHOT KHRIMIAN[1]

J. Econ. Entomol. 107(3): 1061–1068 (2014); DOI: http://dx.doi.org/10.1603/EC13502

ABSTRACT The reported male-produced aggregation pheromone of the brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), identified as a mixture of (3*S*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol and (3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol, offers new opportunities for its management. We found that black pyramid traps deployed along crop borders in Maryland and West Virginia, containing lures with both stereoisomers of this reported aggregation pheromone combined with methyl (*E,E,Z*)-2,4,6-decatrienoate (MDT) lures, attracted more adult and nymphal *H. halys* than either the aggregation pheromone or MDT alone. In season-long totals, combined lures acted synergistically by catching 1.9–3.2 times more number of adults, and 1.4–2.5 times more number of nymphs, than expected from an additive effect of the lures deployed individually. There were no significant differences in patterns of male and female captures. MDT alone was not significantly attractive to adults during most of the growing season, but became increasingly attractive to adults and especially nymphs in autumn. Mixed-isomer lures containing eight stereoisomers of 10,11-epoxy-1-bisabolen-3-ol, including the two active stereoisomers, were as effective at catching adults and nymphs with or without MDT as were lures loaded only with the two active stereoisomers in the natural ratio ((3*S*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol: (3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol) of 3.5:1. These results identify a combination of semiochemicals that is attractive season-long for detection, monitoring, and potential control of this polyphagous invasive pest of North America and Europe.

Leskey et al. (2015) published a manuscript on a multistate collaborative project evaluating season-long captures of BMSB in pyramid traps baited with BMSB aggregation pheromone alone, MDT alone and in combination. Results suggested that traps baited with combined stimuli provide reliable season-long detection of BMSB.

CHEMICAL ECOLOGY

Attraction of the Invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) to Traps Baited with Semiochemical Stimuli Across the United States

TRACY C. LESKEY,[1,2] ARTHUR AGNELLO,[3] J. CHRISTOPHER BERGH,[4] GALEN P. DIVELY,[5] GEORGE C. HAMILTON,[6] PETER JENTSCH,[7] ASHOT KHRIMIAN,[8] GRZEGORZ KRAWCZYK,[9] THOMAS P. KUHAR,[10] DOO-HYUNG LEE,[11] WILLIAM R. MORRISON III,[1] DEAN F. POLK,[12] CESAR RODRIGUEZ-SAONA,[6] PETER W. SHEARER,[13] BRENT D. SHORT,[1] PAULA M. SHREWSBURY,[5] JAMES F. WALGENBACH,[14] DONALD C. WEBER,[8] CELESTE WELTY,[15] JOANNE WHALEN,[16] NIK WIMAN,[17] AND FARUQUE ZAMAN[18]

Environ. Entomol. 1–11 (2015); DOI: 10.1093/ee/nvv049

ABSTRACT A recent identification of the two-component aggregation pheromone of the invasive stink bug species, *Halyomorpha halys* (Stål), in association with a synergist, has greatly improved the ability to accurately monitor the seasonal abundance and distribution of this destructive pest. We evaluated the attraction of *H. halys* to black pyramid traps baited with lures containing the pheromone alone, the synergist methyl (2*E*,4*E*,6*Z*)-decatrienoate (MDT) alone, and the two lures in combination. Traps were deployed around areas of agricultural production including fruit orchards, vegetables, ornamentals, or row crops in Delaware, Maryland, North Carolina, New Jersey, New York, Ohio, Oregon, Pennsylvania, Virginia, and West Virginia from mid-April to mid-October, 2012 and 2013. We confirmed that *H. halys* adults and nymphs are attracted to the aggregation pheromone season long, but that attraction is significantly increased with the addition of the synergist MDT. *H. halys* adults were detected in April with peak captures of overwintering adults in mid- to late May. The largest adult captures were late in the summer, typically in early September. Nymphal captures began in late May and continued season long. Total captures declined rapidly in autumn and ceased by mid-October. Captures were greatest at locations in the Eastern Inland region, followed by those in the Eastern Coastal Plain and Pacific Northwest. Importantly, regardless of location in the United States, all mobile life stages of *H. halys* consistently responded to the combination of *H. halys* aggregation pheromone and the synergist throughout the entire season, suggesting that these stimuli will be useful tools to monitor for *H. halys* in managed systems.

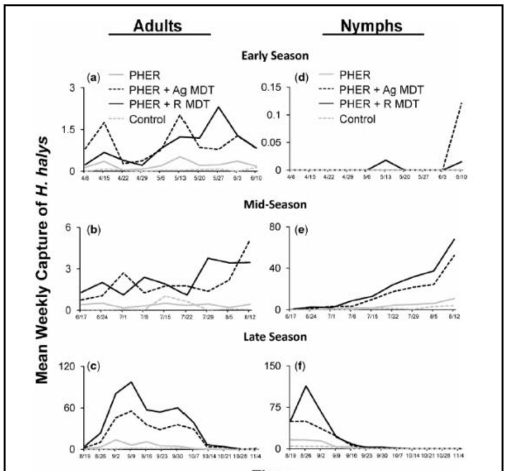


Fig. 5. Season-long mean weekly captures of *H. halys* adults (right column) and nymphs (left column) by traps during 2013 in the early (a and d), mid- (b and e), and late season (c and f), throughout the United States. The control remained unbaited, while MDT refers to lures containing the synergist methyl (2*E*,4*E*,6*Z*)-decatrienoate, and PHER indicates lures containing the *H. halys* aggregation pheromone. Two sources of MDT were used in 2013, one from AgBio Inc. (Ag), and one from Sterling International Inc. (Rescue, R). Error bars were left off of the lines for the sake of clarity.

Additional studies by Leskey et al. (2015) demonstrated that non-pheromonal stereoisomers were attractive and not inhibitory to BMSB as well, further increasing the flexibility of development of pheromone-based products for BMSB.

Behavioral Responses of the Invasive *Halyomorpha halys* (Stål) to Traps Baited with Stereoisomeric Mixtures of 10,11-Epoxy-1-bisabolen-3-OL

Tracy C. Leskey[1] · Ashot Khrimian[2] · Donald C. Weber[2] · Jeffrey C. Aldrich[2] · Brent D. Short[1] · Doo-Hyung Lee[3] · William R. Morrison III[1]

Received: 6 November 2014 /Revised: 26 February 2015 /Accepted: 5 March 2015 /Published online: 9 April 2015

Abstract The brown marmorated stink bug, *Halyomorpha halys*, is an invasive insect in the United States that is capable of inflicting significant yield losses for fruit, vegetable, and soybean growers. Recently, a male-produced aggregation pheromone of *H. halys* was identified as a 3.5:1 mixture of (3*S*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol and (3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol, two stereoisomers of a natural sesquiterpene with a bisabolane skeleton, potentially existing in 16 stereoisomeric forms. In this study, we assessed attraction to pheromonal and non-pheromonal stereoisomeric mixtures of 10,11-epoxy-1-bisabolen-3-ol, which are easier to synthesize than single isomers, and evaluated dose-dependent responses to attractive mixtures in field trials. Some treatments not containing the natural pheromone components were moderately active in field-trapping studies, signifying that some stereoisomers of 10,11-epoxy-1-bisabolen-3-ol are sufficiently similar to the true pheromone in structure to trigger behavioral responses. Importantly, we found that mixtures of stereoisomers containing pheromone components were also highly attractive to *H. halys*, even in the presence of multiple "unnatural" stereoisomers. Further, adult and nymphal captures were dose-dependent, regardless of whether the lure contained pheromonal or non-pheromonal components. Our findings of attraction to pheromonal and non-pheromonal stereoisomers and lack of inhibition from non-pheromonal stereoisomers of 10,11-epoxy-1-bisabolen-3-ol increase the flexibility of developing pheromone-based products for *H. halys*.

Keywords Semiochemicals · Behavior · *Halyomorpha halys* · Monitoring · Integrated pest management · Aggregation pheromones · Hemiptera · Pentatomidae · Invasive pest

Introduction

Halyomorpha halys (Stål), the brown marmorated stink bug (BMSB), is an invasive insect native to China, Taiwan, Korea, and Japan, which was accidently introduced into the United States sometime in the mid–late 1990s (Hoebeke and Carter 2003). Currently, as of June 2014 (www.stopbmsb.org for updates), *H. halys* is well established throughout the mid-

Morrison et al. (2015) compared trap size (4' and 2') and deployment location (ground- or tree-canopy-deployed) for pyramid traps in tree fruit orchards. The 4' ground-deployed coroplast pyramid trap was the most sensitive trap, capturing more BMSB than other trap designs. However, there was a strong correlation among traps throughout the season indicating that smaller and easier to use trap types the potential to be used for monitoring purposes

Evaluation of Trap Designs and Deployment Strategies for Capturing *Halyomorpha halys* (Hemiptera: Pentatomidae)

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ABSTRACT *Halyomorpha halys* (Stål) is an invasive pest that attacks numerous crops. For growers to make informed management decisions against *H. halys*, an effective monitoring tool must be in place. We evaluated various trap designs baited with the two-component aggregation pheromone of *H. halys* and synergist and deployed in commercial apple orchards. We compared our current experimental standard trap, a black plywood pyramid trap 1.22 m in height deployed between border row apple trees with other trap designs for two growing seasons. These included a black lightweight coroplast pyramid trap of similar dimension, a smaller (29 cm) pyramid trap also ground deployed, a smaller limb-attached pyramid trap, a smaller pyramid trap hanging from a horizontal branch, and a semipyramid design known as the Rescue trap. We found that the coroplast pyramid was the most sensitive, capturing more adults than all other trap designs including our experimental standard. Smaller pyramid traps performed equally in adult captures to our experimental standard, though nymphal captures were statistically lower for the hanging traps. Experimental standard plywood and coroplast pyramid trap correlations were strong, suggesting that standard plywood pyramid traps could be replaced with lighter, cheaper coroplast pyramid traps. Strong correlations with small ground- and limb-deployed pyramid traps also suggest that these designs offer promise as well. Growers may be able to adopt alternative trap designs that are cheaper, lighter, and easier to deploy to monitor *H. halys* in orchards without a significant loss in sensitivity.

Acebes-Doria et al. (in press) developed trunk-deployed traps to track nymphal movement onto and from host trees. These traps can be used to look at dispersal among host trees in the field.

Development and comparison of trunk traps to monitor movement of *Halyomorpha halys* nymphs on host trees

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Key words: brown marmorated stink bug, *Ailanthus altissima*, gravitaxis, phototaxis, walking behavior, Hemiptera, Pentatomidae, Simaroubaceae

Abstract

Halyomorpha halys Stål (Hemiptera: Pentatomidae) has recently become a major orchard pest in the Mid-Atlantic, USA. Large *H. halys* populations can develop on wild tree hosts adjacent to orchards, posing an ongoing threat to fruit. Adults and nymphs feed on tree fruit, causing economic injury. Understanding the seasonal patterns of nymphal host use among trees at the orchard-woodland interface may aid the development of integrated pest management strategies for this pest. In laboratory and field experiments, modified versions of published trap designs – 'Circle', 'Hanula', 'M&M' (after Moeed & Meads) traps – were compared for their effectiveness for capturing *H. halys* nymphs walking up and down tree trunks. In the laboratory, second instars were released at the top and bottom of ailanthus (tree of heaven), *Ailanthus altissima* (Mill.) Swingle (Simaroubaceae), logs and captures were recorded after 24 h. Circle and M&M traps, respectively, were most effective for capturing nymphs walking up and down. In the field, traps were deployed on ailanthus trees next to apple orchards and captures were recorded weekly from 24 July to 11 September 2013. As in the laboratory, Circle and M&M traps captured the greatest number of upward- and downward-walking nymphs. Hanula traps were least effective in both experiments. In the field, 88% of total captures were of nymphs walking up trees. This was at least partially explained by behavioral assays in the laboratory demonstrating that nymphs exhibited negative gravitaxis and positive phototaxis. Stage-specific trends in captures of instars walking up during field sampling were observed. These results suggest that trunk traps can be used to address important ecological questions about seasonal patterns of host use by *H. halys* nymphs.

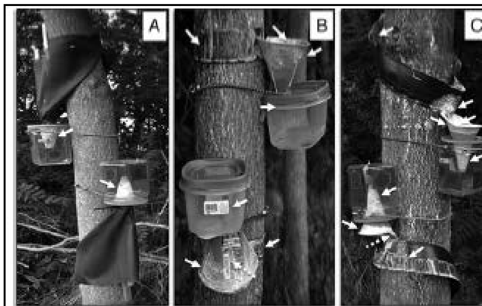

Figure 1 (A) Circle, (B) Hanula, and (C) M&M (Moeed & Meads) traps used to capture *Halyomorpha halys* nymphs walking on *Ailanthus altissima* logs and trees in laboratory and field studies, respectively, at Winchester (VA, USA). Solid arrows indicate surfaces coated with fluon and the broken arrow indicates the roughened area in the interior of the funnel.

Using Citizen Scientists to Evaluate Light Traps for Catching Brown Marmorated Stink Bugs in Homes in Virginia

Abstract

More and more, citizen scientists are playing an integral role in research studies. This has been particularly evident as entomologists unravel the biology, spread, and management of the brown marmorated stink bug, which has plagued many homeowners in the mid-Atlantic U.S. in recent years. We used citizen scientists to evaluate different indoor light traps for catching the bugs in houses. Throughout the late winter and early spring months, these traps were tested inside homes and enabled us to determine that the most efficacious trap was an aluminum foil water pan trap, developed by—you guessed it—a citizen scientist.

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Aigner and Kuhar (2014) published an article evaluating the efficacy of various indoor light traps for capturing BMSB in homes. Citizen scientists collected data on captures in traps from their homes and found that the most effective trap was a homemade aluminum foil water pan trap compared with commercially available light trap designs.

Further, Leskey et al. (in press) demonstrated that BMSB respond positively to light-based stimuli in the laboratory and field. Pyramid traps augmented with compact fluorescent bulbs were used to monitor BMSB adult activity in the field season-long.

Behavioral responses of the invasive *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) to light-based stimuli in the laboratory and field

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Abstract *Halyomorpha halys* (Stål), brown marmorated stink bug, is an invasive insect native to Asia that was accidently introduced into the United States. The species is a polyphagous pest that has caused serious economic injury to specialty and row crops in the mid-Atlantic region. Growers have targeted *H. halys* with broad-spectrum materials by increasing the number of and decreasing the interval between insecticide applications. While it is known that adults reliably respond to semiochemical cues, much less is known about the response of *H. halys* to visual stimuli. Field observations suggest that *H. halys* adults respond to light-based stimuli, with large aggregations of adults documented at outdoor light sources and captured in commercial blacklight traps. Therefore, we conducted a series of studies aimed at identifying optimal wavelengths and intensities of light attractive to *H. halys* adults. We found that intensity and wavelength of light affected *H. halys* response in the laboratory and field. In the laboratory, *H. halys* demonstrated positive phototactic responses to full-spectrum and wavelength-restricted stimuli at a range of intensities, though the levels of stimulus acceptance and attraction, respectively, changed according to intensity. The species is most attracted to white, blue and black (ultraviolet) wavelength-restricted stimuli in the laboratory and field. In the field, traps baited with blue light sources were less attractive to non-target insect species, but white light sources were more attractive to *H. halys* indicating that these two light sources may be good candidates for inclusion in light-based monitoring traps.

2.2. Examine utility of conventional, organic, and alternative management tools.

Leskey et al. (2012) and Lee et al. (2013) published complimentary laboratory studies examining the effect of insecticide residue on BMSB survivorship and mobility, respectively. Leskey et al. (2012) created a lethality index on 37 insecticides taking into account percent mortality and time until death.

HORTICULTURAL ENTOMOLOGY

Impact of Insecticides on the Invasive *Halyomorpha halys* (Hemiptera: Pentatomidae): Analysis of Insecticide Lethality

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ABSTRACT The efficacy of 37 insecticide treatments against adult *Halyomorpha halys* (Stål) was established based on exposure to 18-h old dry insecticide residue in laboratory bioassays. Individual adult *H. halys* were exposed to an insecticide residue for 4.5 h and then monitored daily for survivorship over a 7-d period. The proportion of dead and moribund insects was used as an estimate of overall insecticide efficacy against *H. halys* immediately after the exposure period and over the 7-d trial. Among all materials evaluated, 14 insecticides exhibited increasing efficacy, in which the percentage of dead and moribund insects (used as a measure of insecticide efficacy) increased by >10% after 7 d. By contrast, insecticide efficacy values of eight insecticides declined by >10% (based on recovery of adults from a moribund state) over the 7-d period with most belonging to the pyrethroid class. In this study, the efficacy value of neonicotinoid, acetamiprid, showed the greatest decline from 93 to 10% over 7 d. A lethality index (scale of 0–100) was developed to compare insecticides based on quantifying the immediate and longer-term effects of insecticide exposure on *H. halys*. Among all materials evaluated, dimethoate, malathion, bifenthrin, methidathion, endosulfan, methomyl, chlorpyrifos, acephate, fenpropathrin, and permethrin yielded the highest values (>75) because of a high degree of immediate mortality with very little recovery. Our results provide baseline information regarding potential of candidate insecticides against adult *H. halys* and highlight the need to consider longer-term effects in establishing overall efficacy ratings against this invasive species.

Table 2. Lethality index of each candidate insecticide as well as the initial efficacy rating and the change in efficacy over the 7-d trial

Rank	Insecticide	Class[a]	Lethality index	Initial efficacy[b] (E_0)	Efficacy change[c] (E_7 - E_0)
1	Dimethoate	O	93.3	High	Stable
2	Malathion	O	92.5	High	Stable
3	Bifenthrin	P	91.5	High	Stable
4	Methidathion	O	90.4	High	Stable
5	Endosulfan	—	90.4	Moderate	Increasing
6	Methomyl	C	90.1	High	Stable
7	Chlorpyrifos	O	89.0	Moderate	Increasing
8	Acephate	O	87.5	Moderate	Increasing
9	Fenpropathrin	P	78.3	High	Stable
10	Permethrin	P	77.1	High	Stable
11	Dinotefuran	N	67.3	High	Stable
12	Kaolin clay + Thiamethoxam	—	66.7	High	Stable
13	Gamma-cyhalothrin	P	64.2	High	Decreasing
14	Formetanate HCl	C	63.5	Moderate	Stable
15	Thiamethoxam	N	56.3	High	Stable
16	Clothianidin	N	55.6	High	Stable
17	Beta-cyfluthrin	P	54.8	High	Decreasing
18	Lambda-cyhalothrin	P	52.9	High	Decreasing
19	Zeta-cypermethrin	P	52.1	High	Decreasing
20	Cyfluthrin	P	49	High	Decreasing
21	Oxamyl	C	46.8	Moderate	Stable
22	Esfenvalerate	P	43.3	Moderate	Decreasing
23	Imidacloprid	N	39.2	Moderate	Increasing
24	Tolfenpyrad (SC)	—	36.5	Moderate	Increasing
25	Tolfenpyrad (EC)	—	33.3	Moderate	Decreasing
26	Pyrifluquinazon	—	28.3	Low	Increasing
27	Kaolin clay	—	23.1	Low	Increasing
28	Diazinon	O	20.4	Low	Increasing
29	Phosmet	O	20.0	Low	Increasing
30	Acetamiprid	N	18.8	High	Decreasing
31	Thiacloprid	N	18.3	Moderate	Stable
32	Abamectin	—	16.3	Low	Increasing
33	Indoxacarb	—	11.3	Low	Increasing
34	Spirotetramat	—	9.8	Low	Increasing
35	Carbaryl	C	9.0	Low	Increasing
36	Flonicamid	—	7.7	Low	Increasing
37	Cyantraniliprole	—	1.7	Low	Stable

[a] C, carbamates; N, neonicotinoids; O, organophosphates; P, pyrethroids; —, others; EC, emulsifiable concentrate; SC, suspension concentrate (see Table 1).
[b] E_0 = the percentage of dead and moribund insects at day 0. Low for $E_0 \leq 10\%$; Moderate for $10\% < E_0 < 90\%$; High for $E_0 \geq 90\%$.
[c] Increasing for $(E_7 - E_0) > 10\%$; Decreasing for $(E_7 - E_0) < -10\%$; Stable for $-10\% \leq (E_7 - E_0) \leq 10\%$.

ECOTOXICOLOGY

Impact of Insecticide Residue Exposure on the Invasive Pest, *Halyomorpha halys* (Hemiptera: Pentatomidae): Analysis of Adult Mobility

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ABSTRACT Twenty eight insecticides were evaluated in the laboratory to characterize the impact of specific compounds on locomotory behavior and mobility of adult *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae). Horizontal distance and angular velocity were measured for individuals exposed to dry insecticide residue for 4.5 h to evaluate how quickly and intensely a given insecticide induced changes in motor activities in no-choice glass arenas. Eight out of nine pyrethroid insecticides induced uncoordinated and irregular movement within 10 min after exposure to insecticides. After 1.5 h, most adults were incapacitated. By contrast, there was no immediate stimulation when *H. halys* were exposed to organophosphate residues. After 1.5 h, four out of seven organophosphates resulted in increased horizontal distance moved and angular velocity indicating irregular walking paths by exposed adults. Carbamate and neonicotinoid insecticides produced fairly similar patterns with virtually no stimulation in horizontal distance moved or angular velocity, except for imidacloprid and thiacloprid. Neither endosulfan (organochlorine) nor indoxacarb (oxadiazine) affected the horizontal movement of *H. halys*. Vertical distance climbed by adult *H. halys* was measured immediately after the 4.5-h insecticide exposure period and at 7 d. In general, adults that survived until day 7 were able to climb vertical distances similar to those in the control. In particular, this result was observed for seven out of nine pyrethroid materials that incapacitated all adults after the 4.5-h exposure period. Mobility changes of adult *H. halys* are discussed in the context of enhancing integrated pest management programs.

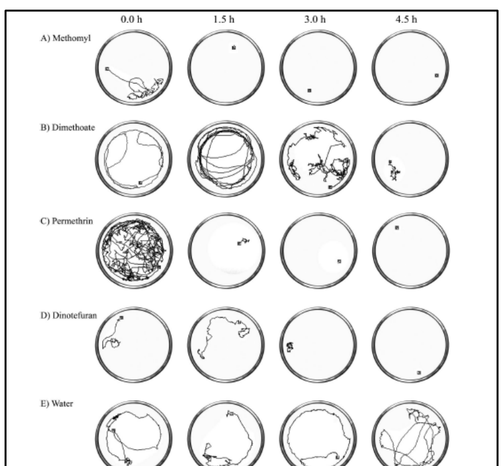

Fig. 1. Representative horizontal movement signatures of adult *Halyomorpha halys* recorded over 10 min on insecticide residues or untreated control (water) in glass petri dish arenas at 0.0, 1.5, 3.0, and 4.5 h.

In the laboratory, Kamminga et al. (2012) evaluated lethality of green beans dipped in the insecticides novaluron (Rimon) and diflubenzuron (Dimilin) and then fed to BMSB. They reported that these materials were effective against BMSB nymphs, but not adults. Kuhar et al. (2012) also conducted laboratory bioassays with green beans dipped in various insecticides and then fed to BMSB adults and nymphs. Baythroid, Thionex and Trebon killed 100% of adults and Acephate, Bifenture, Mustang Maxx, Thionex, Trebon, Up-Cyde, Venom and Warrior killed 100% of nymphs.

Effects of the Insect Growth Regulators Novaluron and Diflubenzuron on the Brown Marmorated Stink Bug

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Abstract

The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål), is an invasive pest from China that causes economic damage to field crops, vegetables, and tree fruit. Due to its destructive potential, applications of broad-spectrum insecticides have escalated. Researchers are trying to identify options for controlling BMSB that have less of a negative impact on non-target species. Chitin biosynthesis inhibitors are more selective than the commonly used pyrethroids and organophosphates. They are active on the larval stage of the insect and are reported as having sublethal effects such as reducing adult fecundity. In our studies, bioassays were completed with chitin biosynthesis inhibitors novaluron and diflubenzuron to evaluate the effectiveness of these insecticides on adult mortality, nymphal growth, adult fecundity, and egg hatch. Our data indicate that treatments of novaluron at 362.2 g ai/ha or diflubenzuron at 280.2 g ai/ha effectively controlled BMSB nymphs. However, the insecticides were not effective at reducing egg hatch, adult fecundity, or adult life span. If novaluron or diflubenzuron are used in agriculture for BMSB control, then the nymphal stage should be targeted.

EVALUATION OF INSECTICIDES USING A BEAN DIP BIOASSAY FOR CONTROL OF BROWN MARMORATED STINK BUG, 2011

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Brown marmorated stink bug (BMSB): *Halyomorpha halys* (Stål)

Laboratory bioassays were conducted at Virginia Tech, Blacksburg, VA in 2011 to determine the efficacy of various insecticides against the invasive BMSB. A colony of BMSB was initiated in Jan 2011 from > 1000 dispersing adults collected from several different houses and structures near Roanoke, VA. The BMSB colony was also infused with fresh field-collected eggs, nymphs, and adults that were collected from trees and agricultural fields during the 2011 field season. Stink bugs were maintained in 24 × 24 × 36 inch fine mesh rearing cages (Bioquip, USA) at approximately 27°C and 14:10 (L:D). Stink bugs were fed fresh green beans (*Phaseolus vulgaris*), raw peanuts (*Arachis hypogaea*) and occasionally other fruit and vegetables when available. All cages contained a moistened cotton wick for a water source. Insecticide solutions were mixed based on the highest labeled rate and an estimated output of 100 gpa. Green bean pods were dipped in the solution for 5 s then allowed to dry for ≈½ h under a fume hood. Green beans for the untreated checks were dipped in water. The green beans were placed in a 9-cm Petri dish with a cotton wick as a water source. For each bioassay bout, either five BMSB adults or nymphs (2nd–4th instars) were placed in each dish. There were four Petri dishes per treatment for a total of 20 insects tested per treatment for each bioassay. At least two replicates were performed for each experiment. After 72 h, stink bugs were evaluated as live, dead, or moribund. Stink bugs were considered moribund if they were unable to right themselves when turned on their back.

Treatment Formulation	Rate amt product/acre	# times tested	Mean (±SE) % mortality[a] Nymphs (2nd-4th instars)	Adults
Thionex 3EC	42.6 fl. oz	5	100.0 ± 0.0	100.0 ± 0.0
Trebon EC	8 fl. oz	4	100.0 ± 0.0	100.0 ± 0.0
Baythroid 2E	2.8 fl. oz	5	83.3 ± 16.7	100.0 ± 0.0
Permethrin 3.2EC	8 fl. oz	8	97.5 ± 1.4	98.8 ± 1.3
Endigo ZC	5.5 fl. oz	6	75.0 ± 25.0	98.7 ± 1.3
Scorpion 3.24	7.7 fl. oz	6	76.7 ± 20.9	90.0 ± 5.0
Baythroid XL	2.8 fl. oz	7	92.5 ± 7.5	88.2 ± 8.7
Bifenture 10DF	12.8 oz	9	100.0 ± 0.0	81.9 ± 2.4
Actara 50WG	5.5 oz	5	66.7 ± 33.3	81.0 ± 15.0
Venom 70SG	5.5 oz	5	100.0 ± 0.0	80.0 ± 10.4
Lannate LV	40 fl. oz	8	66.7 ± 25.0	75.3 ± 5.8
Leverage 360	2.8 fl. oz	6	97.3 ± 1.7	74.5 ± 22.8
Warrior II	2.5 fl. oz	8	100.0 ± 0.0	72.8 ± 22.8
Brigadier 2SC	9.8 fl. oz	6	76.7 ± 13.3	70.0 ± 30.0
Belay 2.13SC	4 fl. oz	5	75.0 ± 25.0	67.5 ± 32.5
Calypso	8 fl. oz	7	46.7 ± 20.3	54.0 ± 15.8
Acephate 97UP	16 oz	6	100.0 ± 0.0	51.8 ± 16.2
Hero 1.24 EC	10.3 fl. oz	6	91.7 ± 4.4	50.0 ± 13.0
Vydate L	48 fl. oz	6	85.0 ± 5.0	47.0 ± 17.4
Danitol 2.4EC	16 fl. oz	5	93.3 ± 6.7	42.5 ± 37.5
Up-Cyde 2.5 EC	5 fl. oz	6	100.0 ± 0.0	40.0 ± 25.7
Sevin XLR Plus	48 fl. oz	5	80.0 ± 20.0	38.0 ± 18.0
Mustang Max	4 fl. oz	4	100.0 ± 0.0	35.0 ± 10.0
Assail 30SG	4 oz	8	90.0 ± 10.0	32.8 ± 18.0
Lambda-cy 1EC	3.84 fl. oz	6	86.0 ±7.0	32.3 ± 20.7
Asana XL	9 fl. oz	6	35.0 ± 15.0	27.5 ± 10.3
Provado 1.6F	8 fl. oz	4	25.0 ± 25.0	26.0 ± 10.0
Belt SC	5 fl. oz	4	40.0 ± 30.0	0.0 ± 0.0

[a] Mortality refers to the percentage of dead + moribund individuals after 72 h.

Bergh (2013) published a report examining the effect of various single active ingredients applied to experimental apple plots as 7-d-interval alternate row middle sprays compared with a 14-d-interval whole plot spray of Venom 70SG. All alternate row middle treatments significantly reduced stink bug injury compared with the 14-d. Bergh (2013) also published a similar report where he compared the efficacy of various insecticides applied to experimental apple orchards using 10-d-interval whole plot sprays. Lowest levels of injury were observed in plots sprayed with Venom 70SG, Leverage 360SC, and Danitol 2.4EC. Bergh also suggested that 7-d-interval alternate row middle programs would likely be a better fit for commercial orchard management of BMSB.

ALTERNATE-ROW-MIDDLE APPLICATIONS OF SINGLE INSECTICIDES TARGETING BROWN MARMORATED STINK BUG, 2012

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SINGLE INSECTICIDES TARGETING BROWN MARMORATED STINK BUG IN APPLE, 2011

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Table 4.

Treatment	Amt/acre	No. fruit with BMSB injury 19 Jun (25 fruit/plot)	17 Jul(25 fruit/plot)	15 Aug(100 fruit/plot)
Baythroid XL	2.8 fl oz	0.25b	0.00c	2.50d
Belay 2.13SC	6.0 fl oz	0.75b	0.25bc	4.25bcd
Danitol 2.4EC	16.0 fl oz	0.25b	0.25bc	3.25bcd
Declare 1.25CS	1.0 fl oz	0.50b	0.50b	6.50b
Declare 1.25CS	2.0 fl oz	0.50b	0.00c	4.25bcd
Leverage 360SC	2.8 fl oz	0.75b	0.00c	1.75d
Venom 70SG	4.0 oz	0.75b	0.00c	3.00cd
Venom 70SG[a]	4.0 oz	0.25b	0.00c	6.00bc
Untreated control		2.75a	1.75a	12.25a

Means within columns followed by the same letter are not significantly (P > 0.05) different according to ANOVA and Fisher's Protected LSD.
[a]Sprayed complete at about 14-d intervals; all others sprayed alternate-row-middle at about 7-d intervals

Table 4.

Treatment/ formulation	Amt/acre	No. fruit with BMSB injury 27 Jun	2 Aug	23 Aug	29 Sep
Baythroid 1EC	2.8 fl oz	0.50a	0.25ab	0.75a	3.00bcd
Leverage 360SC	2.8 fl oz	0.75a	1.25a	0.00a	2.00cd
Declare 1.25CS	1.0 fl oz	0.75a	0.75ab	0.00a	6.25abcd
Declare 1.25CS	2.0 fl oz	0.00a	0.00b	0.00a	7.00abc
Lannate 90SP	12.0 oz	0.00a	0.50ab	0.00a	6.00abcd
Vydate 2L	3.0 pt	0.75a	1.25a	0.25a	8.25ab
Thionex 3EC	1.67 qt	0.00a	0.50ab	0.50a	10.75a
Perm-UP 3.2EC	12.0 fl oz	0.00a	0.50ab	0.50a	3.75bcd
Danitol 2.4EC	16.0 fl oz	0.00a	0.50ab	0.25a	2.75bcd
Belay 2.13SC	6.0 fl oz	0.50a	0.00b	0.00a	4.25bcd
Venom 70SG	6.75 oz	0.00a	0.25ab	0.00a	0.50d
Untreated control		0.50a	1.25a	1.50a	10.50a

Means within columns followed by the same letter are not significantly different (P > 0.05) according to ANOVA and Fisher's Protected LSD. Samples consisted of 25 fruit per tree for in-season evaluations, 100 fruit per tree at harvest on 29 Sep

Kuhar et al. (2013 a, b, c) and (2014) evaluated foliar insecticides in bell peppers for management of BMSB.

EVALUATION OF INSECTICIDES FOR THE CONTROL OF BROWN MARMORATED STINK BUG IN BELL PEPPERS IN VIRGINIA – EXPERIMENT 1, 2011

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Table 1.

Treatment/ formulation	Rate – amt product / acre	% stink bug damage 20-Aug	% stink bug damage 4-Sep	% lepidopteran damage 20-Aug	% lepidopteran damage 4-Sep
Untreated Check		27.5	23.8a	0.0	2.5
Hero	7.10 fl oz	3.8	3.8bc	1.3	0.0
Athena	16 fl oz	7.5	2.5c	0.0	2.5
Gladiator	19 fl oz	0.0	3.8bc	1.3	2.5
Mustang Max	4 fl oz	12.5	7.5bc	6.3	0.0
Triple Crown	7.9 fl oz	5.0	5.0bc	0.0	0.0
Bifenture 2EC	6.4 fl oz	1.3	2.5c	2.5	0.0
Beleaf 50SG	2.8 oz	7.5	3.8bc	2.5	2.5
Mustang Max + Lannate LV	4 fl oz + 16 fl oz	10.0	6.3bc	0.0	1.3
Vydate L	32 fl oz	3.8	10.0abc	0.0	1.3
Lannate LV	24 fl oz	1.3	3.8bc	7.5	0.0
Lannate LV + Asana XL	24 fl oz + 6 fl oz	16.3	12.5ab	3.8	0.0

All data were analyzed using ANOVA. Means were separated using Fisher's LSD at the 0.05 level of significance. Means followed by the same letter within a column are not significantly different (P>0.05).

Table 1.

Treatment / formulation	Rate / acre	% stink bug damage 9 Aug	% stink bug damage 19 Aug	% stink bug damage 1 Sep
Untreated check		28.8a	17.5	65.0a
Vydate L	16 fl oz	3.8b	11.3	5.0b
Vydate L	24 fl oz	13.8b	5.0	7.5b
Vydate L	48 fl oz	13.8b	3.8	5.0b
Lannate LV	16 fl oz	12.5b	8.8	18.8b
Lannate LV	24 fl oz	12.5b	6.3	3.8b
Lannate LV	36 fl oz	7.5b	2.5	12.5b
Asana XL	9 fl oz	7.5b	7.5	11.3b

All data were analyzed using ANOVA. Means were separated using Fisher's LSD at the 0.05 level of significance. Means followed by the same letter within a column are not significantly different (P>0.05).

Table 1.

Treatment / formulation	Rate / acre	% stink bug damage 9 Aug	% stink bug damage 19 Aug	% stink bug damage 1 Sep	% sticky peppers from aphid honey dew (1 Sep)	Mean no. GPA / 20 leaves (9 Sep)
Untreated Check		40.0	15.0a	32.5	0.0c	2.8c
Hero	6.4 fl. oz	17.5	2.5bcd	10.0	41.3a	1014.0ab
Hero	7.1 fl. oz	21.3	5.0bcd	11.3	28.8ab	398.5bc
Hero	8 fl. oz	17.5	7.5a-d	15.0	17.5abc	1195.0a
Hero	10.3 fl. oz	10.0	3.8cd	10.0	0.0c	53.3c
Brigadier	8 fl. oz	15.0	7.5abc	3.8	0.0c	0.3c
Athena	16 fl. oz	12.5	5.0bcd	17.5	3.8bc	63.3c
Mustang Max	4 fl. oz	7.5	8.8ab	7.5	18.8abc	155.0c
Mustang Max + Lannate LV	4 fl. oz + 16 fl. oz	21.3	1.3 d	7.5	1.3c	13.0c
Beleaf	2.8 oz	23.8	7.5a-d	16.3	0.0c	1.0c
F9318	18 fl. oz	16.3	6.3abc	8.8	0.0c	40.0c
Baythroid XL	2.8 fl. oz	25.0	6.3a-d	10.0	5.0bc	201.8c
Leverage 360	2.8 fl. oz	20.0	8.8ab	15.0	0.0c	0.5c
P-Value from ANOVA		ns	0.0592	ns	0.0208	0.018

All data were analyzed using ANOVA. Means were separated using Fisher's LSD at the 0.05 level of significance. Means followed by the same letter within a column are not significantly different (P>0.05).

Kuhar et al. (2012) also published foliarinsecticide efficacy trials against BMSB on tomoatoes.

EVALUATION OF FOLIAR INSECTICIDES FOR THE CONTROL OF BROWN MARMORATED STINK BUGS IN TOMATOES IN VIRGINIA, 2011

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Table 1.

Treatment/ formulation	Rate/ acre	% stink bug damage
Untreated check		19.2
Hero	6.4 fl oz	3.8
Hero	7.1 fl oz	9.4
Hero	8 fl oz	3.8
Hero	10.3 fl oz	0.0
Brigadier 2SC	8 fl. oz	3.0
Athena	16 fl oz	3.3

All data were analyzed using ANOVA. Means were separated using Fisher's LSD at the 0.05 level of significance. Means followed by the same letter within a column are not significantly different (P>0.05).

Bergmann and Raupp (2014) tested various ready-to-use insecticides against BMSB adults and nymphs. In laboratory tests, permethrin was the most effective material for both adult and nymph management.

EFFICACIES OF COMMON READY TO USE INSECTICIDES AGAINST *HALYOMORPHA HALYS* (HEMIPTERA: PENTATOMIDAE)

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Abstract

Efficacies of topical applications and dry residues of 9 common ready-to-use (RTU) insecticides were evaluated against brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) at intervals of exposure of 1 and 48 h. Permethrin and acetamiprid, were further evaluated to determine if *H. halys* recovered after an initial exposure. Topical applications of carbaryl, permethrin, insecticidal soap, petroleum oil, and acetamiprid, and residues of permethrin and acetamiprid increased mortality of adults. Topical applications of spinosad, essential oils, carbaryl, permethrin, insecticidal soap, petroleum oil, and acetamiprid, and residues of carbaryl, permethrin, and acetamiprid increased mortality of nymphs. Topical applications of carbaryl, neem oil, insecticidal soap, and acetamiprid increased egg mortality. In general, nymphs were more susceptible to insecticides than adults. Adult *H. halys* recovered after exposure to topical applications, but not dry residues of permethrin. Clearly, several RTU insecticides in the marketplace demonstrated potential to help gardeners manage *H. halys*.

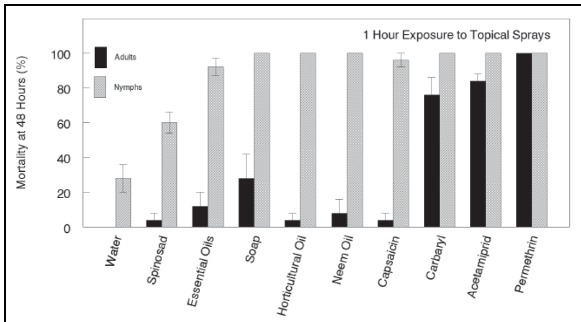

Fig. 1. Percentage mortality at 48 h post exposure of *H. halys* adults (black bars) and nymphs (gray bars) exposed to topical sprays of insecticides for 1 hour. Bars represent means and vertical lines are standard errors. Treatments differed significantly within each life stage (Kruskal - Wallis Analyses, $P < 0.0001$). Comparisons were not made between life stages.

Leskey et al. (2013) published a report on the residual efficacy of numerous insecticides for management of BMSB adults in apple and peach orchards. Their research suggested that BMSB were more susceptible to insecticides early in the growing season and that residual activity for most materials was very short.

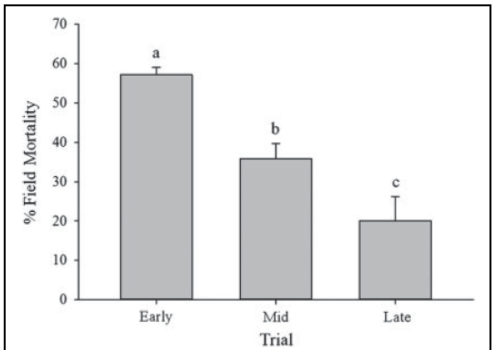

Figure 3. Mean field mortality rates (± SE) of *Halyomorpha halys* by insecticides that yielded 100% mortality rate in a laboratory bioassay[9] across field trials tested in this study. Means followed by the same letter are not significantly different ($P < 0.05$).

Efficacy of insecticide residues on adult *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) mortality and injury in apple and peach orchards

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Abstract

BACKGROUND: The primary threat from *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) originates from populations continuously dispersing from and among wild and cultivated hosts, so many individuals may not be directly sprayed with insecticides. Limited information exists regarding field-based residual activity of insecticides for management of *H. halys* in tree fruit. Thus, we conducted field-based bioassays in apple and peach orchards to evaluate residual activity of insecticides commonly applied against *H. halys*. Adults used in these trials were collected from wild and cultivated hosts less than one week prior to testing to more accurately reflect the susceptibility of wild *H. halys* populations in the field throughout the season.

RESULTS: Significantly higher mortality rates of *Halyomorpha halys* were observed early in the growing season, when overwintered adults were prevalent, compared with populations present later in the growing season that included new generation adults. Significantly higher mortality was recorded for adults exposed to fresh insecticide applications compared with three- and seven-day old residues. Typically, the addition of an adjuvant did not enhance efficacy or residual activity of insecticides. Significantly fewer injury sites were recorded on apples treated with dinotefuran and fenpropathrin compared with the untreated apples for all residue ages.

CONCLUSIONS: Overwintered *Halyomorpha halys* populations are easier to kill with insecticide applications than the first and second generation which are present in the field during the mid- to late-season. Residual activity of nearly all insecticides decreased significantly three days after application and adjuvants generally did not increase residual activity. These factors should be considered in developing season-long programs for management of this invasive species in tree fruit.

EFFECT OF AN ADJUVANT ON CONTROL OF BROWN MARMORATED STINK AND OTHER PESTS IN APPLE, 2012

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Bergh (2013) compared full-season management programs for BMSB in apple orchards with and without an adjuvant (LI-700) added to the insecticides. There was no significant effect to fruit injury at harvest with the addition of the adjuvant to spray applications.

Table 4.

Program	No. fruit with specified injury (50 fruit/tree)							
	TPB	PC	SJS	LR	CM/OFM sting	CM/OFM entry	BMSB	% clean
With LI-700	0.60a	0.40a	0.80b	0.00a	1.00b	2.60b	0.80b	93.80a
Without LI-700	0.60a	1.00a	0.60b	0.20a	3.80a	3.00b	2.20b	88.60a
Untreated control	0.20a	1.80a	8.60a	0.40a	0.00b	17.40a	6.80a	64.80b

Means followed by the same letters are not significantly different (*P* > 0.05) according to according to ANOVA and Fisher's Protected LSD.

Hull et al. (2013 a,b) published trials of full-season insecticide programs for management of lepidopteran pests and BMSB.

EVALUATION OF PRODUCTS FOR INTERNAL LEPIDOPTERA AND BROWN MARMORATED STINK BUG CONTROL, 2012

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Table 8.

Treatment/formulation	Amt/acre	No. fruit sampled	No. apples w/SB injury/100 apples sampled	No. external SB injuries /SB injured fruit	No. 1st cut SB injuries /SB injured fruit	No. 2nd cut SB injuries /SB injured fruit
GF-2032 2SC	89.0 ml					
Imidan 70W	1360.0 g					
Delegate 25W	148.0 g					
Altacor 35WDG	85.0 g					
Scorpion 35SL	296.0 ml	525	16.3a	2.7a	1.3a	0.3a
Assail 30SG	142.0 g					
Imidan 70W	1360.0 g					
Altacor 35WDG	85.0 g					
Delegate 25W	148.0 g					
Scorpion 35SL	296.0 ml	516	7.2a	1.7a	0.8a	0.3a
F-9318 0.33EW	532.0 ml +					
+ Damoil	3785.0 ml					
Altacor 35WDG	85.0 g					
Imidan 70W	1360.0 g					
Mustang Max 0.8EC	118.0 ml	524	8.7a	1.7a	0.9a	0.4a
Danitol 2.4EC	473.0 ml					
Delegate 25W	148.0 g +					
+ Zeal 72W	57.0 g					
Delegate 25W	1480.0 g					
Belay 2.13SL	177.0 ml					
Imidan 70W	1360.0 g					
+ Venom 70SG	273.0 g					
Altacor 35WDG	85.0 g +					
+ Lannate 90SP	255.0 g					
Venom 70SG	273.0 g	515	12.6a	2.6a	1.1a	0.3a
Imidan 70W	1360.0 g					
Altacor 35WDG	85.0 g +					
+ Zeal 72W	57.0 g					
Altacor 35WDG	85.0 g					
Belay 2.13SL	177.0 ml					
Danitol 2.4EC	473.0 ml					
Delegate 25W	148.0 g +					
+ Lannate 90SP	255.0 g	515	18.1a	3.0a	1.1a	0.3a
Rimon 0.83EC	590.0 ml					
Altacor 35WDG	85.0 g					
Lannate LV	1065.0 ml	522	11.9a	2.4a	1.1a	0.4a
Assail 30SG	170.0 g					
Altacor 35WDG	71.0 g					
Declare 1.25CS	30.0 ml	520	8.3a	2.7a	1.3a	0.2a
Assail 30SG	170.0 g					
Delegate 25W	128.0 g					
Declare 1.25CS	60.0 ml	516	5.4a	2.2a	0.4a	0.1a
Avaunt 30WDG	170.0 g					
Delegate 25W	148.0 g					
Imidan 70W	1360.0 g +					
+ Admire Pro	148.0 ml					
Assail 30SG	142.0 g					
Voliam Flexi 40W	142.0 g					
Bifenture 2EC	189.0 ml	518	10.4a	1.9a	1.0a	0.6a
Untreated check	---	519	14.7a	2.8a	0.9a	0.3a

Means followed by the same letters are not significantly different (*P* > 0.05) according to Fisher's Protected LSD Test.

Sargent et al. (2014) tested commercially available traps as a mass-trapping strategy in tomatoes for backyard gardeners. Significantly more injury was found on tomatoes in gardens with traps baited with MDT than gardens without traps.

Traps and Trap Placement May Affect Location of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) and Increase Injury to Tomato Fruits in Home Gardens

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Environ. Entomol. 43(2): 432–438 (2014); DOI: http://dx.doi.org/10.1603/EN13237

ABSTRACT The invasive brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), is an important pest of field crops, fruit orchards, commercial vegetables, ornamental plants, and home vegetable gardens. Pheromone-baited traps designed to attract, trap, and kill *H. halys* are marketed for use in home gardens to reduce damage to plants. To test this assertion, we conducted the following experiment: One group of 15 gardeners placed stink bug traps at the end of a row of tomatoes, *Solanum lycopersicum* (L.), in their vegetable garden and another group of 14 placed no traps in their garden and served as controls. Gardeners with traps were no more or less likely to have *H. halys* on tomato plants than those without traps, but the abundance of *H. halys* on tomato fruits was marginally greater in gardens with traps. However, tomato fruits grown in gardens with traps sustained significantly more injury than tomato fruits grown in gardens without traps. Furthermore, tomato fruits on plants near the trap housed more *H. halys* than tomato fruits on plants at the end of a row away from the trap. Traps may be useful in identifying gardens where *H. halys* is likely to be found and ones in which stink bug injury to tomatoes is likely. We found no evidence that stink bug traps protected tomatoes from *H. halys*, and it appears that the addition of traps to gardens may increase injury to tomato fruits.

Fig. 1. *H. halys* nymphs pierce fruit and create feeding punctures and cloudy zones visible on the surface of the tomato (Photographic credit: Barbara Knapp).

Morrison et al. (2015) established that given the strong attraction to, the small area of arrestment and long retention time at potential attract and kill sites, this techniques may be an effective management strategy in apple orchards.

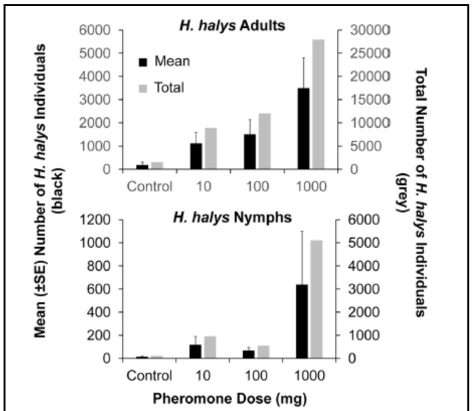

Fig. 4 Mean (± SE; *black bars, left axis*) and total (*gray bars, right axis*) *H. halys* adults (*top panel*) or nymphs (*bottom panel*) killed over the course of 6 days at 4 attract-and-kill trees (per treatment) with varying amounts of *H. halys* aggregation pheromone + MDT deployed during the late season in 2013 at the Appalachian Fruit Research Station (Jefferson Co., WV)

Establishing the behavioral basis for an attract-and-kill strategy to manage the invasive *Halyomorpha halys* in apple orchards

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Abstract *Halyomorpha halys* (Stål), the brown marmorated stink bug, is an invasive, polyphagous insect that causes serious economic injury in particular to specialty crops in the United States. Growers have been forced to respond by increasing the frequency of broad-spectrum insecticide (e.g., neonicotinoid, pyrethroid, and carbamate) applications. One strategy to reduce reliance on insecticides is known as "attract-and-kill" whereby the targeted insect is attracted to a spatially precise location to be eliminated by a killing agent such as an insecticide. This approach can substantially reduce the amount of insecticide used by sparing alternate row middle or whole block sprays. For apple orchards, we propose baiting select border row trees with the *H. halys* aggregation pheromone and synergist and subsequently treating these baited trees with effective insecticides to kill *H. halys* throughout the growing season. To evaluate the behavioral basis of this approach, we conducted orchard trials with black pyramid traps, harmonic radar, and trials using baited apple trees sprayed weekly to quantify *H. halys* arrestment area, retention time, adult and nymph annihilation, and fruit injury in and near these attract-and-kill sites. The arrestment area for *H. halys* was confined to a 2.5 m radius around the pheromone- and pheromone synergist-baited trap regardless of pheromone dose (84 or 840 mg), while the retention capacity of adults was significantly increased by pairing the aggregation pheromone and synergist with a fruiting host plant compared with non-host sites. Damage to fruit harvested from baited attract-and-kill trees was high, but minimal in surrounding unbaited neighboring apple trees. Our results suggest attract-and-kill may be an effective strategy for managing *H. halys* season-long.

Keywords Integrated pest management · Brown marmorated stink bug · Behaviorally based management · Harmonic radar · Invasive species · Pheromone · Hemiptera · Pentatomidae

Key messages

Soergel et al. (2015) evaluated sunflowers as a trap crop to protect bell peppers from BMSB injury. Significantly more BMSB were observed on sunflowers than on peppers, but there was no difference in fruit injury to peppers compared with plots without sunflowers.

Sunflower as a Potential Trap Crop of *Halyomorpha halys* (Hemiptera: Pentatomidae) in Pepper Fields

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Environ. Entomol. 1–9 (2015); DOI: 10.1093/ee/nvv136

ABSTRACT The brown marmorated stink bug, *Halyomorpha halys* (Stål), feeds on a variety of fruits and vegetables, and is an economically important invasive hemipteran pest. Trap cropping of *H. halys* was examined at the Pennsylvania State University Southeast Agriculture Research and Extension Center (SEAREC) in Lancaster Co., PA, from 2012 to 2013, with sunflowers used as a trap crop to protect bell pepper. *H. halys* were observed frequently on sunflowers planted surrounding the pepper field, and in both years of this experiment significantly more *H. halys* were observed in sunflowers than peppers. Both adults and nymphs were observed with equal frequency, with higher numbers of both observed in September. A 2:1 ratio of females to males was observed throughout both years. While sunflowers were attractive to *H. halys*, no difference in fruit damage was observed in peppers surrounded by the sunflower trap crop versus those peppers surrounded by peppers. While sunflowers present an interesting potential trap crop for *H. halys*, future research is needed to clarify the feasibility of this crop protection technique.

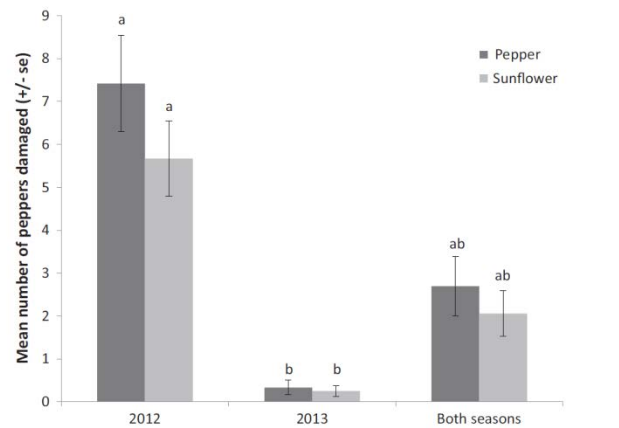

Fig. 5. Surrounding crops had no impact on damage levels. Inner rows of mean pepper damage during 2012 season, 2013 season, and both seasons (2012 and 2013 combined). There was no significant difference between damage levels to inner peppers, regardless of surrounding pepper or sunflower rows (Fisher Exact Test, $P = 0.1102$; Fisher Exact Test, $P = 0.7905$; Fisher Exact Test, $P = 0.0922$, respectively). Damage data were collected at ~2-wk intervals, with three evaluations in 2012 and six evaluations in 2013. Each evaluation examined 128 peppers for damage.

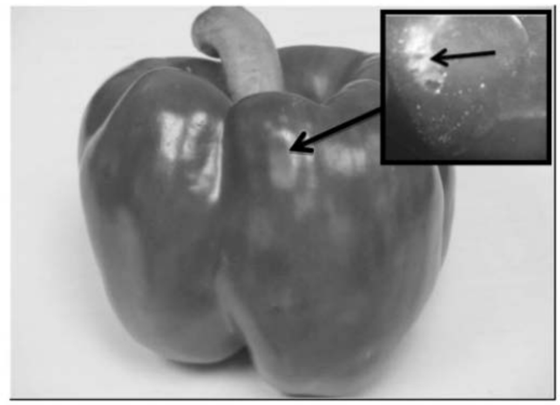

Fig. 3. Feeding damage on pepper fruit. External pepper damage from stink bug feeding. The external, pale discoloration is indicative of damaged tissue. Internal injury where feeding occurred is spongy and pale, as shown in insert.

Talamas et al. (2013) reported that an important Asian parasitoid wasp of BMSB, *Trissolcus halyomorphae*, is synonymous with the species, *Trissolcus japonicus*, clarifying the taxonomy of this genus and species.

New synonymy of *Trissolcus halyomorphae* Yang

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Trissolcus japonicus (Ashmead) (Hymenoptera, Scelionidae) emerges in North America

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http://zoobank.org/9DE21476-E644-4288-A5CA-8C68E778D80D

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Abstract

Trissolcus japonicus (Ashmead) is an Asian egg parasitoid of the brown marmorated stink bug, *Halyomorpha halys* (Stål). It has been under study in U.S. quarantine facilities since 2007 to evaluate its efficacy as a candidate classical biological control agent and its host specificity with regard to the pentatomid fauna native to the United States. A survey of resident egg parasitoids conducted in 2014 with sentinel egg masses of *H. halys* revealed that *T. japonicus* was already present in the wild in Beltsville, MD. Seven parasitized egg masses were recovered, of which six yielded live *T. japonicus* adults. All of these were in a wooded habitat, whereas egg masses placed in nearby soybean fields and an abandoned apple orchard showed no *T. japonicus* parasitism. How *T. japonicus* came to that site is unknown and presumed accidental.

Figure 1. *Trissolcus japonicus*, female (USNMENT01059357), specimen preserved during emergence from BMSB egg. Scale bar in millimeters.[1]

Talamas et al. (2015) reported that the parasitoid wasp, *Trissolcus japonicus,* currently under quarantine testing for possible mass release was found naturally occurring in the United States in Beltsville, MD.

Sentinel eggs underestimate rates of parasitism of the exotic brown marmorated stink bug, *Halyomorpha halys*

CrossMark

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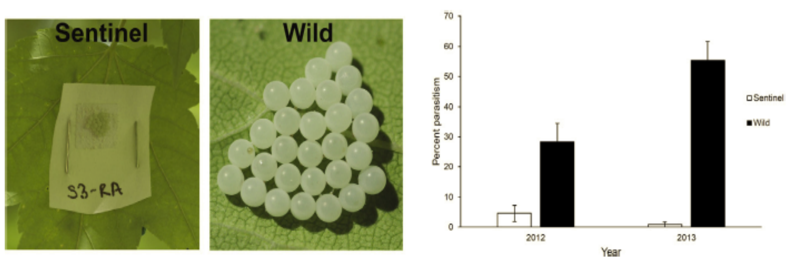
HIGHLIGHTS

- We compared parasitism of wild (field-laid) and sentinel (laboratory-laid) eggs.
- Wild egg masses had higher parasitism, parasitoid abundance and species richness.
- *Anastatus reduvii* was the most common parasitoid species overall.
- Sentinel egg masses underestimate parasitoid communities and impact.
- Wild egg masses should be used for estimating biological control impacts.

GRAPHICAL ABSTRACT



Jones et al. (2014) compared parasitism rates of wild and laboratory egg masses. More parasitism occurred in wild egg masses compared with laboratory reared eggs.

Objective 4 Outputs Integrate stakeholder input and research findings to form and deliver practical outcomes

PEST STATUS OF THE BROWN MARMORATED STINK BUG, *HALYOMORPHA HALYS* IN THE USA

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Keywords: *Halyomorpha halys*, brown marmorated stink bug, invasive pest, IPM, specialty crops, row crops

Abstract
Since its initial discovery in Allentown, PA, USA, the brown marmorated stink bug (BMSB), *Halyomorpha halys* (Heteroptera: Pentatomidae) has now officially has been detected in 38 states and the District of Columbia in the USA. Isolated populations also exist in Switzerland and Canada. This Asian species quickly became a major nuisance pest in the mid-Atlantic USA region due to its overwintering behavior of entering structures. BMSB has an extremely wide host range in both its native home and invaded countries where it feeds on numerous tree fruits, vegetables, field crops, ornamental plants, and native vegetation. In 2010, populations exploded causing severe crop losses to apples, peaches, sweet corn, peppers, tomatoes and row crops such as field corn and soybeans in several mid-Atlantic states. Damaging populations were detected in vineyards, small fruit and ornamentals. Researchers are collaborating to develop management solutions that will complement current integrated pest management programs. This article summarizes the current pest status and strategies being developed to manage BMSB in the USA.

Introduction
Native Geographic Distribution, Introduction and Spread. The brown marmorated stink bug (BMSB), *Halyomorpha halys*, is native to China, Japan, Korea and Taiwan (Hoebeke & Carter 2003). Early Asian literature refers to BMSB as the yellow-brown stink bug and as *H. picus* or *H. mista*. The first USA populations were discovered in the mid-1990s in or near Allentown, PA. In 2001, Karen Bernhardt with Penn State Cooperative Extension recognized that the insect invading homes was probably not native and sent a specimen to Richard Hoebeke at Cornell University who identified it as BMSB (Hoebeke & Carter 2003). Today BMSB has been detected in 38 states and the District of Columbia (Figure 1) with isolated populations in Switzerland (Wermelinger *et al.* 2008) and Canada (Fogain & Graff 2011).

General Biology. Adults are distinguished from other brown stink bugs in the USA by their larger size, light colored banding on the antennae and legs and alternating light and dark bands around the abdomen (Figure 2). The term 'marmorated' means having a marbled or streaked appearance. Females emerge with undeveloped ovaries and must feed before mating. Once mated, females lay light green egg masses of ~28 eggs on the undersides of leaves. Depending

Figure 1. Distribution and impact of BMSB in the USA based on State records and BMSB Working Group assessments as reported by May 2012. In addition, at least one unofficial detection has been made in CO.

Member of the BMSB SCRI CAP Team published a mini review in 2012 entitled "Pest status of the brown marmorated stink bug, Halyomorpha halys, in the USA". This was the first review describing the impact BMSB was having on specialty and row crops as well as nuisance problems for homeowners.

Lee et al. published an article reviewing the biology, ecology and management of BMSB in its native Asian range including descriptions of host plants and natural enemies.

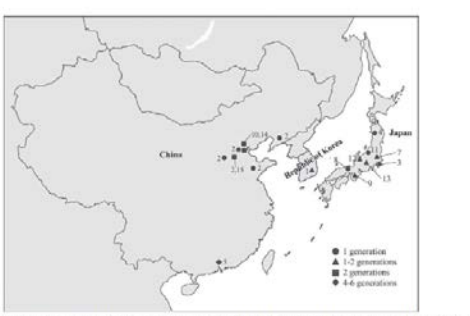

Fig. 2. Number of generations of *Halyomorpha halys* reported in Asia. Numbers in the figure correspond to the following references: [1]Bae et al. 2008; [2]Chu et al. 1997; [3]Fujiie 1985; [4]Funayama 2008; [5]Hoffmann 1931; [6]Hou et al. 2009; [7]Katayama et al. 1993; [8]Kawada and Kitamura 1983a; [9]Oda et al. 1980; [10]Qin 1990; [11]Saito et al. 1964; [12]Watanabe et al. 1978; [13]Yanagi and Hagihara 1980; [14]Yang et al. 2009; [15]Zhang et al. 1993. Map is not to scale.

POPULATION ECOLOGY

Review of the Biology, Ecology, and Management of *Halyomorpha halys* (Hemiptera: Pentatomidae) in China, Japan, and the Republic of Korea

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Environ. Entomol. 42(4): 627–641 (2013); DOI: http://dx.doi.org/10.1603/EN13006

ABSTRACT Native to China, Japan, Korea, and Taiwan, the brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) was first detected in the United States in the mid-1990s. Since establishing in the United States, this invasive species has caused significant economic losses in agriculture and created major nuisance problems for home and business owners, especially in the mid-Atlantic region. Basic and applied questions on *H. halys* have been addressed in its native range in Asia since the mid-1900s and the research outcomes have been published in at least 216 articles from China, Japan, and the Republic of Korea. In Asia, *H. halys* is described as an occasional or outbreak pest of a number of crops such as apple, pear, persimmon, and soybeans. This species is considered a nuisance pest as well, particularly in Japan. This review summarizes 100 articles primarily translated from Chinese, Japanese, and Korean to English. The content of this review focuses on the biology, ecology, and management of *H. halys* in Asia, with specific emphasis on nomenclature, life history, host range, damage, economic importance, sampling and monitoring tools, and management strategies. This information from the native range of *H. halys* provides greater context and understanding of its biology, ecology, and management in North America.

KEY WORDS brown marmorated stink bug, invasive species, Asia

Rice et al. (2014) and many members of the BMSB SCRI CAP Team as well as international colleagues published a comprehensive review article on biology, ecology and management of BMSB.

Biology, Ecology, and Management of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae)

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ABSTRACT. Brown marmorated stink bug, *Halyomorpha halys* Stål, is an invasive, herbivorous insect species that was accidentally introduced to the United States from Asia. First discovered in Allentown, PA, in 1996, *H. halys* has now been reported from at least 40 states in the United States. Additional invasions have been detected in Canada, Switzerland, France, Germany, Italy, and Lichtenstein, suggesting this invasive species could emerge as a cosmopolitan pest species. In its native range, *H. halys* is classified as an outbreak pest; however, in North America, *H. halys* has become a major agricultural pest across a wide range of commodities. *H. halys* is a generalist herbivore, capable of consuming >100 different species of host plants, often resulting in substantial economic damage; its feeding damage resulted in US$37 million of losses in apple in 2010, but this stink bug species also attacks other fruit, vegetable, field crop, and ornamental plant species. *H. halys* has disrupted integrated pest management programs for multiple cropping systems. Pesticide applications, including broad-spectrum insecticides, have increased in response to *H. halys* infestations, potentially negatively influencing populations of beneficial arthropods and increasing secondary pest outbreaks. *H. halys* is also challenging because it affects homeowners as a nuisance pest; the bug tends to overwinter in homes and outbuildings. Although more research is required to better understand the ecology and biology of *H. halys*, we present its life history, host plant damage, and the management options available for this invasive pest species.

Key Words: biological control, chemical control, crop damage, invasive, Pentatomidae

Table 1. North American natural enemies of *Halyomorpha halys* reported from field surveys (D.J.B., C.R.R.H., A.L.J., T.P.K., P.M.S., N.G.W., and J. W., unpublished data)

Order	Family (subfamily if known)	Species	*H. halys* life stages attacked	Locality
Araneae	Arachnida		Eggs, nymphs, adults	Maryland, Oregon, Pennsylvania
Coleoptera	Coccinellidae	*Harmonia axyridis*	Eggs	Pennsylvania
Dermaptera	Forficulidae		Eggs	Pennsylvania
Diptera	Tachinidae	*Trichopoda pennipes*	Adult, late instars	Pennsylvania
Hemiptera	Anthocoridae	*Orius* sp.	Eggs	Maryland
	Geocoridae	*Geocoris* sp.	Eggs, nymphs	Maryland, Oregon, Pennsylvania
	Reduviidae	*Arilus cristatus*	Eggs, nymphs, adults	Maryland, Oregon, Pennsylvania
Hymenoptera	Crabronidae	*Astata* unicolor	Adults, late instars	Pennsylvania
		Astata bicolor	Late instars	Oregon
		Bicyrtes quadrafaciata	Late instars	Pennsylvania
	Encyrtidae	*Ooencyrtus* sp.	Eggs	Delaware, Maryland
	Eupelmidae	*Anastatus mirabilis*	Eggs	Delaware, Maryland
		Anastatus pearsalli	Eggs	Delaware, Maryland, Pennsylvania
		Anastatus reduvii	Eggs	Delaware, Maryland, Delaware
	Platygastridae (Scelioninae)	*Gryon obesum*	Eggs	Maryland
	Platygastridae (Telenominae)	*Telenomus podisi*	Eggs	Maryland, Pennsylvania
		Telenomus utahensis	Eggs	Virginia
		Trissolcus brochymenae	Eggs	Delaware, Maryland, Virginia
		Trissolcus edessae	Eggs	Delaware, Maryland, Virginia
		Trissolcus euschisti	Eggs	Delaware, Maryland, Oregon
		Trissolcus thyantae	Eggs	Virginia
		Trissolcus utahensis	Eggs	Oregon
Mantodea	Mantidae	*Tenodera sinensis*	Nymphs, adults	Maryland
Neuroptera	Chrysopidae	Unidentified larvae	Eggs, early nymphs	Maryland, Oregon, Pennsylvania

Journal of Extension
Sharing Knowledge, Enriching Extension

Brown Marmorated Stink Bug in the Mid-Atlantic States: Assessing Grower Perceptions, Economic Impact, and Progress

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Dellinger et al. (in press) published an article in the Journal of Extension detailing grower perceptions, impact and progress made addressing BMSB. Their results are based on surveys administered in in 2012 and 2014 to attendees at regional horticultural conferences. A summary of their findings can be found below.

1. Most respondents correctly recognized a BMSB adult, but not a BMSB nymph. More emphasis needs to be placed on the identification and awareness of BMSB nymphs so that growers can accurately assess BMSB populations for effective IPM.

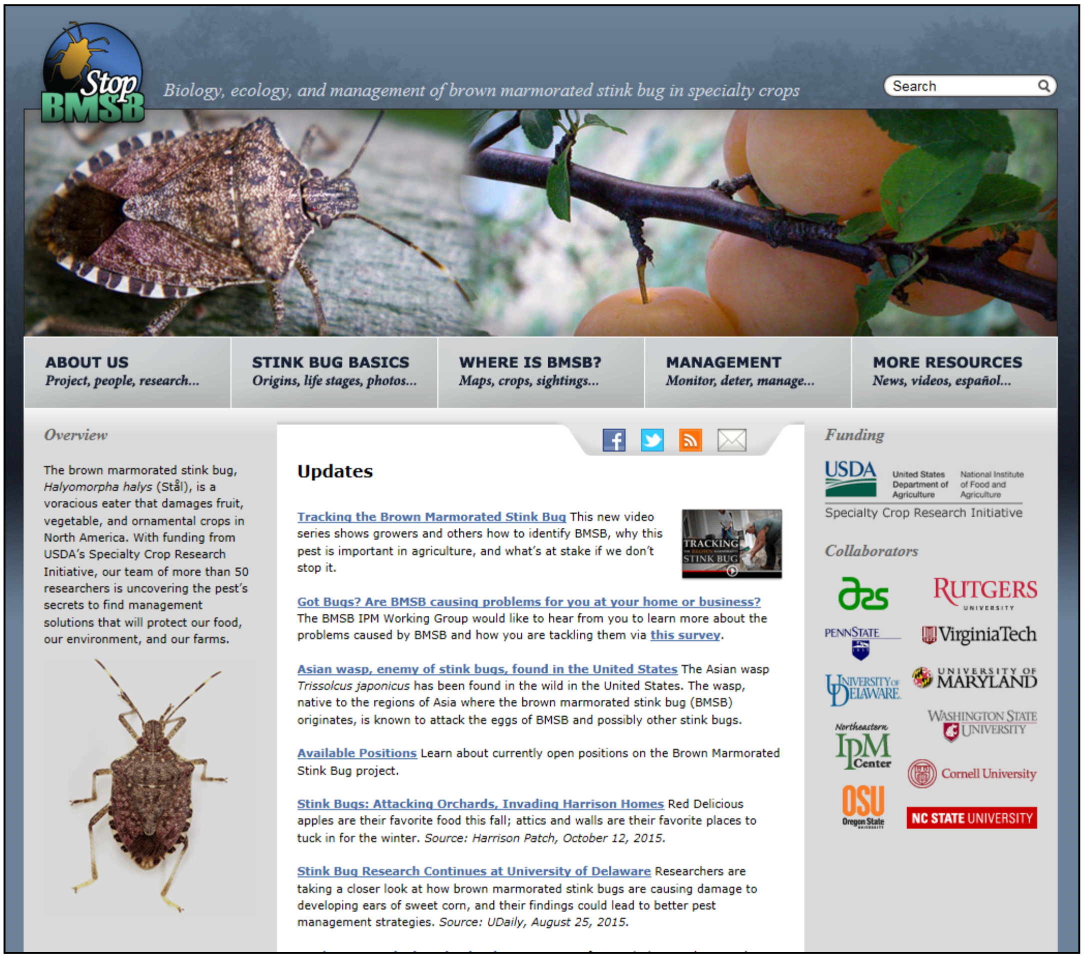
2. Most respondents did not know or could not state their economic losses due to BMSB as either percentage profit or crop loss. Growers could benefit from tools and information relating to estimating crop and profit loss.

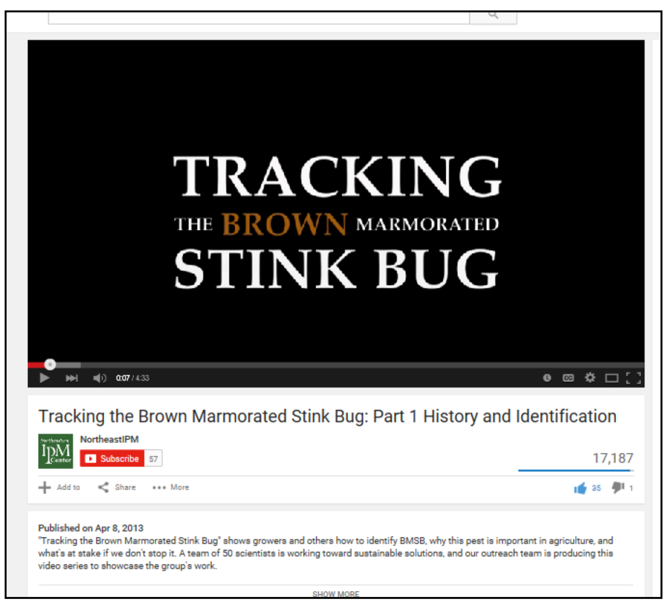
3. Respondents reporting economic loss due to BMSB indicated these losses are mostly as under 33% loss of profit or less than $10,000. BMSB remains a key pest with a broad impact on agriculture in the mid-Atlantic.

4. Respondents are mostly interested in insecticide choices for BMSB control, followed by scouting techniques for BMSB and BMSB biology. Timely information on these subjects will be needed for growers to remain resilient as BMSB continues to expand its range and impact.

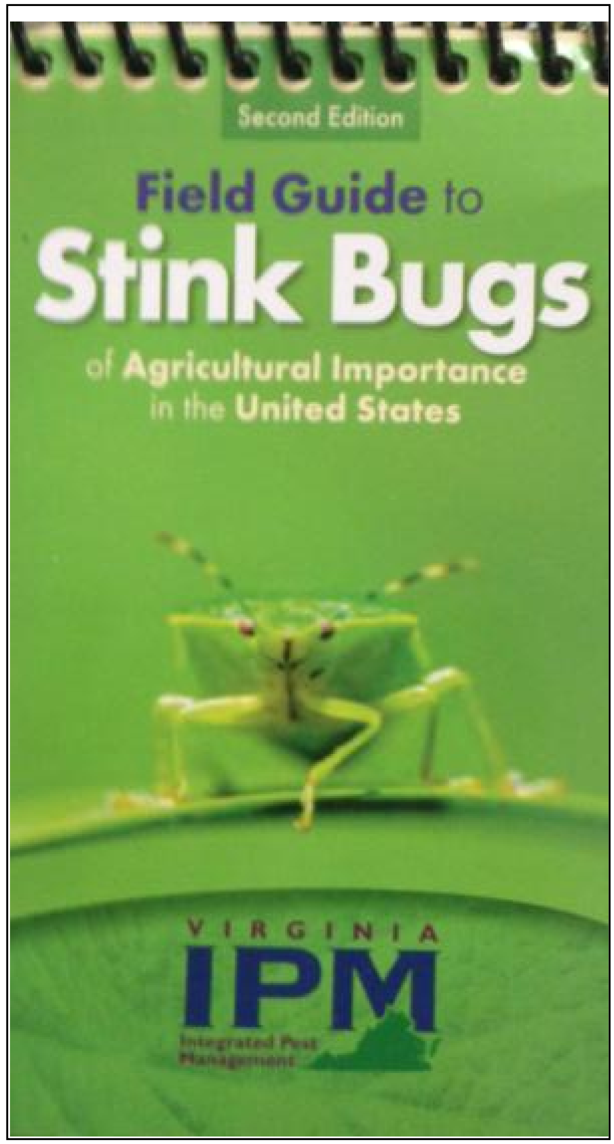
Lastly, the surveys revealed that respondents prefer to learn about BMSB from grower meetings, Extension publications, and Extension educators. Cooperative Extension remains a trusted source of valuable, timely information regarding BMSB.

The Northeastern IPM Center, in collaboration with Team members, created and has maintained the well-known website for the project, StopBMSB.org, as well as the YouTube video series, Tracking the Brown Marmorated Stink Bug.





Based on responses to surveys administered to growers and other stakeholders, the Northeastern IPM Center and collaborating team members developed an identification kit for stink bugs. This included updating and expanding a regional pocket stink bug guide originally published by Virginia Tech. to become a national guide as well as creating inexpensive BMSB specimens using hand sanitizer bottles that could be distributed easily.



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Hoelmer, C.*R.R. Hooks, A. Jones, G. Krawczyk,* T.P. Kuhar, H. Martinson, W.S. Mitchell, A.L. Nielsen, D.G. Pfeiffer, M.J. Raupp, C.R. Rodriguez-Saona, P.W. Shearer, P.M. Shrewsbury, P.D. Venugopal, J. Whalen, N.G. Wiman, T.C. Leskey, J.F. Tooker. 2014. Biology, ecology and management of brown marmorated stink bug (*Halyomorpha halys*). Journal of Integrated Pest Management 5(3) 1-13, http://jipm.oxfordjournals.org/content/5/3/A1, http://dx.doi.org/10.1603/IPM14002. *Supports Objective* 4.2

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Objective 2.2.

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2012

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Tests. Vol. AMT37. Sec. E72; DOI: 10.4182/amt.2012.E72, http://amt.oxfordjournals.org/content/37/1/E72. *Supports Objective 2.2.*

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2011

1. **Sargent, C., H.M. Martinson, and M.J. Raupp. 2011.** The Orient Express in Maryland: The Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae). The Maryland Entomologist 5(3): 2-21, http://www.mdentsoc.org/ sites/default/files/Phaeton/v5n3.pdf. *Supports Objective 4.1.*

Project Outputs

Research Talks

Acebes-Doria, A., T.C. Leskey and J.C. Bergh. 2014. Choice experiments examining host preference of *Halyomorpha halys* nymphs. Cumberland-Shenandoah Fruit Workers Conference. Winchester, VA. December 4-5.

Acebes-Doria, A., T.C. Leskey and J.C. Bergh. 2014. Seasonal movement patterns of *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) nymphs on wild and tree fruit hosts at the orchard-woodland interface. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Acebes-Doria, A., T.C. Leskey and J.C. Bergh. 2015. Influence of initial host on subsequent host choice by *Halyomorpha halys* (Hemiptera: Pentatomidae) nymphs. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth, DE. March 14-17.

Bergh, J.C. and T.C. Leskey. 2014. Emergence patterns of brown marmorated stink bug from overwintering shelters. IOBC Pome and Stone Fruit meeting. Vienna, Austria. October 6-9.

Bergh, J.C., T.C. Leskey, B.D. Short and J.P. Cullum. 2014. BMSB captures in traps & injury to apples: Effects of orchard border habitat. Cumberland-Shenandoah Fruit Workers Conference. Winchester, VA. December 4-5.

Bergh, J.C., T.C. Leskey, B.D. Short and J.P. Cullum. 2014. Effect of orchard border habitat on *Halyomorpha halys* captures in pheromone traps and fruit injury. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Bergmann, E.J. and H.M. Martinson. 2014. Designing the dreaded brown marmorated stink bugs out of residential landscapes. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Blaauw, B. and A. Nielsen. 2015. "Understanding dispersal behavior to enhance the sustainability of brown marmorated stink bug management". Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Bon, M.C., E. Talamas, M. Buffington, K. Hoelmer and T. Haye. 2014. "*Trissolcus* spp. as biocontrol agents of *Halyomorpha halys*: III. Molecular-based species delineation". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Buffington, M., E. Talamas, K. Hoelmer, C. Dieckhoff and N. Johnson. 2014. "Systematics and biological control: Past meets present in Project *Trissolcus*". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Cambridge, J. and G.C. Hamilton. 2014. Patterns and predictions for visual sampling of the brown marmorated stink bug. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Cambridge, J. and G.C. Hamilton. 2015. The spatial behavior of the brown marmorated stink bug (*Halyomorpha halys*) in peach trees. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Dieckhoff, C. and Hoelmer, K.A. 2015. "What lies beyond traditional host range testing: a closer look at host choice in *Trissolcus japonicus*". Eastern Branch of the Entomological Society of America . Rehoboth Beach, DE. March 14-17.

Dieckhoff, C. and K. Hoelmer. 2014. "Status of Host Range Tests with Asian Egg Parasitoids". BMSB SCRI SAP meeting. Kearneysville WV. December 3.

Dieckhoff, C. and K. Hoelmer. 2014. "*Trissolcus* as biocontrol agents of BMSB: Behavioral aspects of host choice". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Fraga, D.F., C. Rodriguez-Saona, A. Nielsen, G.C. Hamilton and A.C. Busoli. 2015. "O papel de voláteis de *Halyomorpha halys* na capacidade predação de ovos de Orius insidiosus". Siconbio, Rio de Janiero, Brazil.

Gorzlancyk, A., T.C. Leskey and J.C. Bergh. 2014. Improving and refining the utility of pheromone traps for monitoring brown marmorated stink bug, *Halyomorpha halys*. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Hahn, N. and G.C. Hamilton. 2014. Using citizen science to track the spread of brown marmorated stink bug (*Halyomorpha halys*). Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Hahn, N. and G.C. Hamilton. 2015. Using a Spatially Autoregressive Model to Identify Factors Influencing Clustering of *Halyomorpha halys*. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Hamilton, G.C. 2015. Management of of BMSB in Commercial Buildings. BMSB Working Group Meeting. Beltsville, MD. June 9.

Hoelmer, K. and C. Dieckhoff. 2014. "Control Biológico de 'Brown Marmorated Stink Bug'". Annual Course in Biological Control & Invasive Species Symposium, Annual Meeting, Mexican Society of Biological Control. Merida, Mexico, November 5-6.

Hoelmer, K. and C. Dieckhoff. 2015. "2.2.5 - Asian Parasitoids & 2.2.6 - Native Natural Enemies (updates)". SCRI annual planning meeting. Kearneysville, WV, February 4-5.

Hoelmer, K. and C. Dieckhoff. 2015. "Biological Control of *Halyomorpha halys* (BMSB) in North America" . Meiji University. Tokyo, Japan. July 14.

Hoelmer, K. and C. Dieckhoff. 2015. "Biological Control of *Halyomorpha halys* (BMSB) in North America". Fujian Agric. & Forestry University. Fuzhou, China. July 1.

Hoelmer, K. and C. Dieckhoff. 2015. "Biological Control of *Halyomorpha halys* (BMSB) in North America". Saga University. Saga, China. July 11.

Hoelmer, K. and C. Dieckhoff. 2015. "Biological Control of *Halyomorpha halys* (BMSB) in North America". Yunnan Academy of Agric. Science, Kunming, China June 28.

Hoelmer, K. and C. Dieckhoff. 2015. "Biological Control of *Halyomorpha halys* (BMSB) in North America". Kyushu University. Kyushu, China. July 13.

Hoelmer, K., C. Dieckhoff, et al. 2015. "Biological control programs for brown marmorated stink bug and spotted wing drosophila", 8th International IPM Symposium. Salt Lake City, UT. March 23-26.

Khrimian, A., S. Shirali, M.A. Siegler, F. Guzman and D.C. Weber. 2015. "Stereoisomeric Libraries for Pheromone Identifications: 1-Bisabolen-3-ols", International Society of Chemical Ecology Meeting. Stockholm, Sweden. June 29-July 3.

Krawczyk, G., D. Soergel, B. Lehman and T. Enyeart. 2015. Development of rational management options for invasive pest brown marmorated stink bug, *Halyomorpha halys* – lures, traps, barriers and…. . XVIII International Plant Protection Congress. Book of Abstracts p. 56. Berlin, Germany. August 24-27. http://www.ippc2015.de/abstracts/download-abstractbook/

Krawczyk, G., T. Enyeart and N. Ellis. 2015. Evaluation of insecticide sensitivities among brown marmorated stink bug populations. 89th Annual Orchard Pest and Disease Management Conference. Abstracts p.11. Portland OR. January 14-16. http://www.tfrec.wsu.edu/pdfs/P2951.pdf

Krawczyk, G., T. Leskey, T. Enyeart and L.A. Hull. 2014. Monitoring invasive pest, brown marmorated stink bug, *Halyomorpha halys* (Heteroptera: Pentatomidae) in fruit orchards. IOBC/WPRS Working Group Meeting. Vienna, Austria. October 06-

09. http://www.iobc-wprs.org/events/20141006_book_of_abstracts_IOBC-WPRS_Vienna.pdf

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Kuhar, T. and J. Aigner. 2015. “From bubble baths to baking bugs: A potpourri of our urban pest control research endeavors on BMSB in Virginia”, BMSB Working Group Meeting. College Park, MD. June 9.

Kuhar, T.P. and J.D. Aigner. 2015. Polar vortices: Can they really kill the stink bugs? Virginia Academy of Science 93rd Annual Meeting. Harrisonburg, VA. May 21-23.

Leskey T.C. and K. Hoelmer. 2015. Progress on development of sustainable solutions for managing the invasive brown marmorated stink bug and spotted wing drosophila. Invasive Terrestrial Animals and Pathogens Federal Interagency Committee (ITAP). Beltsville, MD.

Leskey, T.C. 2014. Integrated Plant Protection in Fruit Crops Meeting. Developing pheromone-based monitoring and management tools for brown marmorated stink bug in tree fruit. International Organization of Biological Control. Vienna, Austria.

Leskey, T.C. 2014. Biology, Ecology and Management of Brown Marmorated Stink Bug. National Gypsy Moth Management Board Meeting. Louisville, KY.

Leskey, T.C. 2015. Developing strategies to manage the invasive brown marmorated stink bug through cooperative, collaborative and integrated initiatives. Western BMSB SCRI Planning Meeting. Portland, OR.

Leskey, T.C. 2015. Developing strategies to manage the invasive brown marmorated stink bug through cooperative, collaborative and integrated initiatives. USDA-NIFA SCRI Specialty Crop Committee. Washington, DC.

Leskey, T.C. 2015. Developing strategies to manage the invasive brown marmorated stink bug through cooperative, collaborative and integrated initiatives. Plant Insect Ecosystems Networking and Business Session. Keynote Speaker. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Leskey, T.C. 2015. Biology, ecology and management of brown marmorated stink bug. National Integrated Pest Management Symposium. Salt Lake City, UT.

Leskey, T.C. 2015. What we have learned about the brown marmorated stink bug. Eco -Apple/Red Tomato Annual Meeting. Bard College. Annandale-on-Hudson, NY. March 10-11.

Martinson, H., P.D. Venugopal, E. Bergmann, P. Shrewsbury and M. Raupp. 2015. Drivers of host plant use for invasive stink bugs in heterogeneous habitats. Ecological Society of America National Meeting. Baltimore, MD. August 9-14.

Morrison, W.R. and T.C. Leskey. 2014. Manipulating the behavior of the brown marmorated stink bug (Hemiptera: Pentatomidae) using pheromonal stimuli in the field: Attraction, retention and active space. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Morrison, W.R. and T.C. Leskey. Symposium: Managing the Ongoing Threat Posed by Invasive Species in the Eastern U.S. Laying the foundation for an attract-and-kill strategy to manage *H. halys* (Pentatomidae: Hemiptera) in apple orchards in the mid-Atlantic. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Nielsen, A., S. Chen, S.J. Fleischer and N. Wiman. 2014. Voltinism and Phenology. Stakeholder Advisory Panel Meeting for the USDA NIFA CAPS project, Biology, Ecology, and Management of Brown Marmorated Stink Bug (BMSB) in Orchard Crops, Small Fruit, Grapes, Vegetables, and Ornamentals. Kearneysville, W.V. December 2.

Nielsen, A.L., B.R. Blaauw and D. Polk. 2014. “Steps towards a systems-level approach to invasive species management for brown marmorated stink bug” Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Nystrom-Santacruz, E., R. Koch, R. Venette, K. Hoelmer and C. Dieckhoff. 2014. "Cold tolerance of *Trissolcus japonicus*, an egg parasitoid of BMSB". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Pike, T., R.J. St. Leger and P.M. Shrewsbury. 2014. Potential fungistatic effects of the defensive compound of the brown marmorated stink bug, *Halyomorpha halys* (Stål), on entomopathogenic fungi. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Pote, J., A. Nielsen, D.M. Fonseca and R. Valentin. 2015. “Using Molecular Techniques to Identify Natural Enemies of BMSB” BMSB Working Group Meeting. Beltsville, MD. June 9.

Raupp, M.J. 2015. Turning the tables on invasive insect pests: Using wicked plant defenses in landscape ecosystems. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Rice, K.B., M. Gish, S.J. Fleischer, C.M. De Moraes, M.C. Mescher and J.F. Tooker. 2015. Shedding new light on a mark-release-recapture technique: Laser detection of fluorescently marked insects. 26th USDA Interagency Research Forum on Invasive Species. Annapolis, MD. January 13-16.

Rice, K.B., S.J. Fleischer, R. Troyer, K.W. Waltrous and J.F. Tooker. 2014. The influence of crop management and landscape diversity in damage in tomatoes by brown marmorated stink bug. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Rondon, S.I., N.G. Wiman, P.W. Shearer, V. Walton and J. Lee. 2015. Oregon efforts towards controlling the brown marmorated stink bug: an extension perspective. 99th Annual Meeting of the Pacific Branch Entomological Society of America. Coeur d'Alene, ID. April 12-15.

Rondon, S.I., M. R. Bush, N. Wiman, P. Shearer, V. Walton & C. Lee. 2015. Monitoring and Managing Brown Marmorated Stink Bug in the Pacific Northwest: An Extension Prospective. 99th Annual Meeting of the Pacific Branch Entomological Society of America. Coeur d'Alene Resort, Coeur d'Alene, ID. April 12 -15.

Shearer, P.W. 2015. Brown marmorated stink bug, an imminent pest. 2015 BC Tree Fruit Horticultural Symposium. Kelowna, BC, Canada. March 10.

Shrewsbury, P.M., A.L. Jones and C. Hooks. 2014. Biological control: Working towards sustainable management of the exotic brown marmorated stink bug, *Halymorpha halys*. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Shrewsbury, P., M. Raupp, H. Martinson, D. Venugopal and E. Bergmann. 2015. Designing stink bug-free landscapes. Brown Marmorated Stink Bug Working Group Meeting. College Park, MD. June 9.

Talamas, E., M. Buffington, N. Johnson. 2014. "*Trissolcus* as biocontrol agents of brown marmorated stink bug: II. Species-level taxonomy". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Thompson, D.I., C. Mills, N. Wiman and SI. Rondon. 2015. Brown marmorated stink bug in eastern Oregon. 74th Annual Pacific Northwest Insect Management Conference. Portland, OR. January 12-13.

Venugopal D., H. Martinson, P. Shrewsbury and M. Raupp. 2015. Abundance patterns of the invasive *Halyomorpha halys* in adjacent tree nurseries and field crops. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Walgenbach, J.F. 2014. Update on the status of brown marmorated stink bug in the southeastern US. Winter Meeting of the BMSB IPM Working Group. Winchester, VA. December 3.

Walgenbach, J.F. 2014. Status of BMSB in the southern Region. Summer Meeting of the BMSB IPM Working Group. College Park, MD. December 9.

Walgenbach, J.F., AJ. Bakken, S.C. Schoof and E.C. Ogburn. 2014. Biology of the brown marmorated stink bug in relation to apples in North Carolina. IOBC Working Group Meeting on IPM in Tree Fruits. Vienna, Austria. October 6.

Walgenbach, J.F., D.A. Tussey and S.C. Schoof. 2014. Chemigation as a risk reduction tool in fruiting vegetable production. Annual meeting of the Entomological Society of America. Portland, OR. November 16.

Wiman, N.G. 2015. BMSB Research update and its impact on berry crops. Annual meeting of the Oregon Horticultural Society (berry day). Canby, OR. January 15.

Wiman, N.G. 2015. Brown marmorated stink bug research in Oregon. Annual meeting of IR4 Western Region. Portland Oregon. April 22.

Wiman, N.G., V.M. Walton and D.T. Dalton. 2015. Survival Analysis of Brown Marmorated Stink Bug on Field-Aged Insecticide Residues in Hazelnut. Orchard Pest and Disease Management Conference. Portland OR. November 16-19.

Wiman, N.G., V.M. Walton and D.T. Dalton. 2015. Survival Analysis of Brown Marmorated Stink Bug on Field-Aged Insecticide Residues in Hazelnut. Orchard Pest and Disease Management Conference. Portland, OR. January 14.

Wiman, N.G., V.M. Walton, P.W. Shearer, S.I. Rondon. 2015. Current issues with brown marmorated stink bug in the western US. 8th International Integrated Pest Management Symposium. Salt Lake City, UT. March 25.

Wiman, N.G., V.M. Walton, P.W. Shearer, J. Lee and S.I. Rondon. 2014. Addressing the threat: Brown Marmorated Stink Bug Research in Oregon. Utah State University Seminar Series. Logan, UT. December 8.

Research Posters

Aigner J., T. Kuhar. 2014. Using citizen scientists to evaluate light traps for catching brown marmorated stink bug, *Haylomorpha halys*, in homes in Virginia. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Aigner, B. L., T. P. Kuhar, D. A. Herbert and J. Hogue. 2015. A comparison of methods in detecting brown marmorated stink bug (*Halyomorpha halys*) and how wooded borders affect populations in soybeans. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Aigner, J.D., J.F. Walgenbach, J. Whalen, K. Rice, S.J. Fleischer and T.P. Kuhar. 2015. IPM decisions in the management of brown marmorated stink bug, *Halyomorpha halys* Stål (Hemiptera: Pentatomide), using pheromone-baited pyramid traps in vegetables. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Bush, M. R. and P. Landolt. 2015. Exotic "Stinky" Bugs of the PNW. 99th Annual Meeting of the Pacific Branch Entomological Society of America. Coeur d'Alene Resort. Coeur d'Alene, ID.

Bush, M. R. 2015. In Search of Invasive Bugs. 100th Annual Meeting and Professional Improvement Conference. Sioux Falls, SD. July 12-16.

Bush, M., S.I. Rondon, N.G. Wiman, P.W. Shearer, V. Walton and J. Lee. 2015. Monitoring and managing brown marmorated stink bug in the Pacific Northwest: an extension perspective. 99th Annual meeting of the Entomological Society of America Pacific Branch. Exotic and invasive pests symposium. Coeur d'Alene, ID. April 12-15.

Colavecchio, A.M, C. Dieckhoff and K.A. Hoelmer. 2014. "Classical biological control of brown marmorated stink bug (*Halyomorpha halys*): an update". Annual Meeting of the Delaware Invasive Species Council. Dover, DE. October 22.

Fraga, D.F., C. Rodriguez-Sanoa, G.C. Hamilton, A.L. Nielsen and A.C. Busoli. 2014. "The role of volatiles from brown marmorated stink bug, *Halyomorpha halys*, on host location and egg predation by minute pirate bug, *Orius insidiosus*". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19

Hoelmer, K., C. Dieckhoff, A. Colavecchio and K. Tatman. 2015. "Parasitism of *Halyomorpha halys* by Indigenous Parasitoids: An Update". Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Hoelmer, K., C. Dieckhoff, K. Tatman and A. Colavecchio. 2014. "Parasitism of *Halyomorpha halys* by indigenous natural enemies in landscape hosts in the mid-Atlantic states". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Morehead, J.A. and T.P. Kuhar. 2015. Efficacy of Organic Insecticides Against Brown Marmorated Stink Bugs (Hemiptera: Pentatomidae). Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Morrison, W.R., C. Mathews and T.C. Leskey. Using harmonic radar to measure the retention capacity of trap crops for the invasive brown marmorated stink bug (Hemiptera: Pentatomidae) in organic pepper plantings. Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Mathews, C., W.R. Morrison III, and T. Leskey. CSI egg mass damage: Tracking down unexplained predation of brown marmorated stink bug egg masses by native natural enemies. 100th Annual Meeting of the Ecological Society of America, Baltimore, MD.

Nielsen, A.L. 2015. "Impact of Invasive Pests on NJ Wine Grapes". Annual meeting of the Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. March 14-17.

Ogburn, E.C. and J.F. Walgenbach. 2014. Impact of natural enemies on brown marmorated stink bug (*Halyomorpha halys*) in North Carolina agroecosystems. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Rice, K.B., M. Gish, S.J. Fleischer and J.F. Tooker. 2014. Non-destructive detection across landscapes of mass marked insects. Ecological Society of America. Sacramento, CA. August 10-15.

Trope T., D. Pfeiffer and T. Kuhar. 2014. Trap cropping: Controlling brown marmorated stink bug (Hemiptera: Pentatomidae) (*Halyomorpha halys* (Stål) in organic cropping systems with pheromone lures, sorghum and pollenless sunflowers. Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Research Workshops/Meetings/Symposia

Dieckhoff, C. and K. Hoelmer. 2014. "Parasitoids of the brown marmorated stink bug: 4th specialized training workshop", in conjunction with the BMSB IPM working group meeting. College Park, MD. June 10-11.

Hoelmer, K. and C. Dieckhoff. 2014. Control Biológico de 'Brown Marmorated Stink Bug'. Annual Course in Biological Control & Invasive Species Symposium. Annual Meeting Mexican Society of Biological Control. Merida, Mexico. November 5-6.

Hoelmer, K. and E. Delfosse. 2014 "Classical Biological Control of BMSB". Annual meeting of the Entomological Society of America. Portland, OR. November 16-19.

Research Oriented Websites and Digital Products

Blog, Bug of the Week. 2014. Stink bugs on the move: Brown Marmorated Stink Bug, *Halyomorpha halys*. September 22. http://bugoftheweek.com/blog/2014/9/22/stink-bugs-on-the-move-brown-marmorated-stink-bug-ihalyomorpha-halysi

Blog, Bug of the Week. 2015. Stinky exodus underway: Brown Marmorated Stink Bug, *Halyomorpha halys*. April 6. http://bugoftheweek.com/blog/2015/4/3/stinky-exodus-underway-brown-marmorated-stink-bug-ihalyomorpha-halysi

Deployment of updated EDDMaps website for on-demand access to threshold-based tree fruit producer assistance in BMSB management decision-making. https://www.eddmaps.org/bmsbny/

www.StopBMSB.org

Use of Citizen Science-based data to track BMSB throughout NYS. http://imapinvasives.org/nyimi/map/

Accepted Research Publications

Acebes-Doria, A., T.C. Leskey, and J.C. Bergh. 2015. Development and comparison of trunk traps to monitor movement of *Halyomorpha halys* (Hemiptera: Pentatomidae) nymphs on host trees. Entomologia Experimentalis et Applicata. (In press).

Aigner, J.D., J. Wilson, L. Nottingham, J. Morehead, T. Dimeglio, and T. Kuhar. 2015. Bioassay evaluation of IKI-3106 (cyclaniliprole) for control of brown marmorated stink bug and harlequin bug, 2014. Arthropod Management Tests 2015 40: (L) (In press).

Aigner, J.D., J.F. Walgenbach, and T.P. Kuhar. Toxicities of neonicotinoid insecticides for systemic control of brown marmorated stink bug (Hemiptera: Pentatomidae) in fruiting vegetables. Journal Agricultural and Urban Entomology. 31: (Accepted).

Aigner, J.D., T.P. Kuhar, and J. Walgenbach. Relative toxicity and field efficacy of soil-applied neonicotinoids for control of *Halyomorpha halys* (Stål) in fruiting vegetables. Journal of Agricultural and Urban Entomology. (Accepted).

Aigner, JD and TP Kuhar. 2015. Lethal High Temperature Extremes of the Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) and Efficacy of Commercial Heat Treatments for Control in Export Shipping Cargo. Journal of Agricultural and Urban Entomology. (Accepted).

Bakken, A.J., S.C. Schoof, M. Bickerton, K.L. Kamminga, J.C. Jenrette, S. Malone, M.A. Abney, D.A. Herbert, D. Reisig, T.P. Kuhar and J.F. Walgenbach. 2015.

Occurrence of brown marmorated stink bug (Hemiptera: Pentatomidae) on wild hosts in nonmanaged woodlands and soybean fields in North Carolina and Virginia. Environmental Entomology: 44: 1011-1021. URL: http://www.bioone.org/doi/full/10.1093/ee/nvv092

Basnet, S., T.P. Kuhar, C.A. Laub, and D.G. Pfeiffer. 2015. Seasonality and Distribution Pattern of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) in Virginia Vineyards. Journal Economic Entomology. 1–8 DOI: http://dx.doi.org/10.1093/jee/tov124

Cira, T.M., R.C. Venette, J. Aigner, T. Kuhar and D.M. Mullins, S.E. Gabbert, W.D. Hutchison. Cold tolerance across geographic and temporal scales of brown marmorated stink bug (*Halyomorpha halys* (Stål)). Environmental Entomology. (Accepted).

Cissel, W.J., C.E. Mason, J. Whalen, J. Hough-Goldstein and C.R. Hooks. 2015. Effects of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) Feeding Injury on Sweet Corn Yield and Quality. Journal of Economic Entomology. doi: http://dx.doi.org/10.1093/jee/tov059

Haye T., T. Gariepy, K.A. Hoelmer, J.P. Rossi, J.C. Streito, X. Tassus and N. Desneux. 2015. Range expansion of the invasive brown marmorated stinkbug, *Halyomorpha halys*: an increasing threat to field, fruit and vegetable crops worldwide. Journal Pest Science. 88:4 665-673. http://dx.doi.org/10.1007/s10340-015-0670-2

Jentsch, P.J. 2015. A New Threshold-Based Management Tool for the Brown Marmorated Stink Bug. NY Fruit Quarterly, Vol. 23, No.3 Fall.

Joseph, S.V., M. Nita, T.C. Leskey, and J.C. Bergh. 2015. Temporal effects on the incidence and severity of brown marmorated stink bug (Hemiptera: Pentatomidae) feeding injury to peaches and apples during the fruiting period in Virginia. Journal Economic Entomology. 108: 592-599 http://www.bioone.org/doi/abs/10.1093/jee/tou059

Kuhar, T.P., H. Doughty, C. Philips, J. Aigner, L. Nottingham, and J. Wilson. 2014. Evaluation of foliar insecticides for the control of foliar insects in bell peppers in Virginia, 2013. Arthropod Management Tests 2014 39 (1) E19. doi: http://dx.doi.org/10.4182/amt.2014.E19

Lee, D-H. and T.C. Leskey. 2015. Flight behavior of foraging and overwintering brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae). Bulletin of Entomological Research. 105: 566-573. DOI: http://dx.doi.org/10.1017/S0007485315000462

Leskey, T.C., A. Khrimian, D.C. Weber, J.C. Aldrich, B.D. Short, D-H. Lee and W.R. Morrison. 2015. Behavioral Responses of the Invasive *Halyomorpha halys* (Stål) to Traps Baited with Stereoisomeric Mixtures of 10, 11-Epoxy-1-bisabolen-3-oL. Journal of Chemical Ecology. 41:418–429. DOI: http://dx.doi.org/10.1007/s10886-015-0566-x

Leskey, T.C., A. Agnello, J.C. Bergh, G.P. Dively, G.C. Hamilton, P. Jentsch, A. Khrimian, G. Krawczyk, T.P. Kuhar, D-H. Lee, W.R. Morrison III, D.F. Polk, C. Rodriguez-Saona, P.W. Shearer, B.D. Short, P.M. Shrewsbury, J.F. Walgenbach, D.C. Weber, C. Welty, J. Whalen, N. Wiman, F. Zaman. 2015. Attraction of the invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) to traps baited with semiochemical stimuli across the United States. Environmental Entomology: 44(3): 746–756. http://dx.doi.org/10.1093/ee/nvv049

Leskey, T.C., D-H. Lee, D.M. Glenn and W.R. Morrison. 2015. Behavioral responses of the invasive *Halyomorpha halys* (Stal) (Hemiptera: Pentatomidae) to light-based stimuli in the field. Journal of Insect Behavior. (Accepted).

Leskey, T.C., D-H. Lee, J.C. Bergh, D.G. Pfeiffer, T. Kuhar, G. Dively, P. Shrewsbury, G.C. Hamilton, C. Rodriguez-Saona, D. Polk, G. Krawczyk, J. Walgenbach, J. Whalen, P. Shearer, and N.G. Wiman. 2015. Season-long response of *Halyomorpha halys* (Stål). (Hemiptera: Pentatomidae) to black pyramid traps baited with attractive pheromonal stimuli in diverse landscapes and cropping systems. Environmental Entomology. DOI: http://dx.doi.org/10.1093/ee/nvv049

Martinson, H., D.P. Venugopal, E. Bergmann, P. Shrewsbury, and M. Raupp. 2015. Fruit availability influences the seasonal abundance of invasive stink bugs in ornamental tree nurseries. Journal of Pest Science. DOI http://dx.doi.org/10.1007/s10340-015-0677-8

Morehead, J., J. Aigner, J. Wilson, L. Nottingham, T. Dimeglio, and T. Kuhar. 2015. Efficacy of organic insecticides for control of brown marmorated stink bug on peppers in Virginia. 2014. Arthropod Management Tests 2015 40: (E) (In press).

Morrison, III W.R., D.-H. Lee, B. Short, A. Khrimian, and T.C. Leskey. 2015. Establishing the behavioral basis for an attract-and-kill strategy to manage the invasive *Halyomorpha halys* in apple orchards. Journal of Pest Science. DOI http://dx.doi.org/10.1007/s10340-015-0679-6

Morrison, W.R., J.P. Cullum, and T.C. Leskey. 2015. Evaluation of trap design and deployment strategy for capturing *Haylomorpha halys* (Hemiptera: Pentatomidae). Journal of Economic Entomology. DOI: http://dx.doi.org/10.1093/jee/tov159

Rice, K.B., S.J. Fleischer, C.M. De Moraes, M.C. Mescher, J.F. Tooker and M. Gish. 2015. Handheld lasers allow efficient detection of fluorescent marked organisms in the field. PLOS ONE. June 2. DOI: http://dx.doi.org/10.1371/journal.pone.0129175

Soergel, D.C., N.Ostiguy, S.J. Fleisher, R.R. Troyer, E.G. Rajotte and G. Krawczyk. 2015. Sunflower as a potential trap crop of *Halyomorpha halys* (Hemiptera: Pentatomidae) in pepper fields. Environmental Entomology. DOI: http://dx.doi.org/10.1093/ee/nvv136

Talamas E.J., M.V. Herlihy, C. Dieckhoff, K.A. Hoelmer, M.L. Buffington, M.C. Bon and D.C. Weber. 2015. *Trissolcus japonicus* (Ashmead) emerges in North America. Journal of Hymenoptera Research 43:119-128. DOI http://dx.doi.org/10.3897/JHR.43.4661

Venugopal, D.P., H.M. Martinson, E.J. Bergmann, P.M. Shrewsbury, and M.J. Raupp. 2015. Edge Effects Influence the Abundance of the Invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) in Woody Plant Nurseries. Environmental Entomology. doi: http://dx.doi.org/10.1093/ee/nvv061

Wilson, J., J. Aigner, L. Nottingham, and T. Kuhar. 2015. Bioassay evaluation of sulfoxaflor for control of harlequin bug, brown marmorated stink bug and kudzu bug, 2013. Arthropod Management Tests 2015 40: (L) (in press).

Wiman, N.G., J. Parker, C. Rodriguez-Saona, and V.M. Walton. 2015. Characterizing damage of *Halyomorpha halys* on blueberries in Oregon and New Jersey. Journal of Economic Entomology. DOI: http://dx.doi.org/10.1093/jee/tov036.

Extension Talks and Meetings

2014 Ecological Entomology. Anne Arundel Master Gardeners. Crownsville, MD. October 14.

2014 Ecological Entomology. Carroll County Master Gardeners. Oregon Ridge Park. Cockeysville, MD. October 9.

2014 Hands on field training for field guides. Oregon Ridge Park. Cockeysville, MD. September 4.

2014 How bugs make the world go around. Audubon Naturalist Society. Chevy Chase, MD. October 23.

2014 Insect Management in Lima Beans, including BMSB monitoring and management, in Processing Lima Beans. Lima Bean Industry Meeting. December.

2014 Introduction to insects and ecosystem services. Baltimore County Public School Teachers. Oregon Ridge Park, Cockeysville, MD. November 3.

2014 Introduction to insects and ecosystem services. Master Naturalists of Baltimore County. Eden Mill Nature Center. Pylesville, MD. August 28.

2014 Introduction to insects and ecosystem services. Master Naturalists of Frederick County. Middletown, MD. October 13.

2014 Introduction to insects and ecosystem services. Master Naturalists of Montgomery County. Chevy Chase, MD. October 21.

2015. A Short Review of Insecticide Timing, Gloucester/Salem/Cumberland County Twilight Fruit Meeting. April 7. (31 attended).

2015 Brown Marmorated Stink Bug: Field Confusion. Scaffolds No.19, August 3.

2015. Early Season IPM and Scouting, Gloucester/Salem/Cumberland County Twilight Fruit Meeting. March 26. (24 attended).

2015 Ecological Entomology. Prince George's Howard County Master Gardeners. College Park, MD. March 23.

2015 Ecological Entomology. Talbot County Master Gardeners. Wye Mills, MD. April 2.

2015 Ecological IPM. Baltimore Master Gardeners. Baltimore, MD. February 9.

2015 Ecological IPM. Howard County Master Gardeners. Ellicott City, MD. March 2.

2015 Ecological IPM. Master Gardeners of Washington, DC. Washington, DC. June 9.

2015 Emerging Insect Problems of Tree Fruit in Eastern NY, Long Island Agricultural Forum. Suffolk County Community College. Eastern Campus Riverhead, New York. January 8.

2015 Emerging Invasive Insects in Eastern NY, ICS Full Scale Exercise, Fire Training Center. New Hampton, NY July 21.

2015 How bugs make the world go around. Maryland Horticultural Society. Baltimore, MD. April 14.

2015 How bugs make the world go around. Mercer County Master Gardeners. Princeton, NJ. March 21.

2015 Insect Management Fresh Market Vegetables, including BMSB. Delaware Ag Week. Fresh Market Veg Session. January 13.

2015 Insect Management in Tree Fruit, including BMSB. Delaware Ag Week. Fruit Session. January 12.

2015 Insect Management Processing Veg, including BMSB. Delaware Ag Week. Processing Veg Session. January 14.

2015 Insecticide Programs for 2015. South Jersey Fruit Meeting, February 10. (27 attended).

2015 Insects and hands on field training for identification. Oregon Ridge Park, Cockeysville, MD. May 4.

2015 Introduction to insects and ecosystem services. Calvert County Master Naturalists. Prince Frederick, MD. March 9.

2015 Introduction to insects and ecosystem services. Fairfax County Master Gardeners. Fairfax, VA. February 4.

2015 Introduction to insects and ecosystem services. Master Naturalists of Montgomery County. White Oak, MD. May 8.

2015 Invasive species, Monarchs and more. Howard County Conservancy, MD. August.

2015 IPM Working Group Meeting. College Park, MD. June.

2015 Onion Bulb Mite & Brown Marmorated Stink Bug in Hudson Valley Vegetable Crops. CCE Orange County, Middletown, February.

2015 Organic Pesticide Applicator Training for Fruit and Vegetable Growers; 'IPM in Organic Pest Management Programs' Cornell Cooperative Extension. Hudson Valley Research Laboratory. September 10.

2015 Overview of Three Years of ARDP Funded Research in Brown Marmorated Stink Bug, in NY Annual Reporting Session to the Advisory Board of the New York State Apple Research and Development Program (ARDP) NYSAES. November 26.

2015 Review of the 2014 Pest Management Season in ENY; 2015. Hudson Valley Commercial Fruit Growers' School. Garden Plaza Hotel. Kingston, NY. February 11-13.

2015 Rise of Secondary Pests in Peaches. Mid Atlantic Fruit and Vegetable Conference. Hershey, PA. January 29. (300 attended).

2015 Strategies for Late Season Invasives Management in Berries and Grapes. 2015 Hudson Valley Commercial Fruit Growers' School. Garden Plaza Hotel. Kingston, NY. February 11-13.

2015 Strategies for Total Insect Management With and Without BMSB. North Jersey Fruit Meeting. March 4. (110 attended).

Acebes-Doria, A., T.C. Leskey and J.C. Bergh. 2014. Host plant effects on *Halyomorpha halys* (Hemiptera: Pentatomidae) development and survival. BMSB SCRI Stakeholder Advisory Panel meeting. Kearneysville, WV. December 2.

Bergh, J.C. 2015. Brown marmorated stink bug research update for 2015. Winter Fruit Schools. 5 counties in Virginia. February 10-14.

Bergh, J.C. 2015. Woolly apple aphid outbreaks in relation to brown marmorated stink bug management. Mid-Atlantic Fruit and Vegetable Conference. Hershey, PA. January 27-29.

Biddinger, D., E. Rajotte, and N. Joshi. 2015. Apples. Moving towards ecologically-based IPM in eastern apple orchards. Ontario Fruit and Vegetable Convention and Trade Show. Niagara Falls, Ontario, Canada. February 18-19.

Biddinger, D., E. Rajotte, N. Joshi and M. Vaughan. 2015. Tree Fruit IPM. Ecologically-Based IPM for Apples. Illinois Specialty Crop, Agrotourism, and Organics Conference. Springfield, IL. Jan. 7-8.

Bush, M.R. 2014. Brown Marmorated Stink Bug Update. Pacific Northwest Vegetable Association's Annual Conference. Three Rivers Convention Center. Kennewick, WA. November 12- 13. (110 attended).

Bush, M.R. 2014. Extension Outreach for Exotic Pests of the Pacific Northwest. Exotic Pest Grant Advisory Workshop. Puyallup, WA. October 14. (25 attended).

Bush, M.R. 2015. A Passion for Roses with a Dose of Pest Management and Extension Outreach for Exotic Pests in the PNW. Walla Walla Master Gardener Training Program. Walla Walla Extension. Walla Walla, WA. February 26. (15 attended).

Bush, M.R. 2015. Emerging Pests in the PNW and Bugs and Pests on Fruit Trees (including orchard walk). WSU Pierce County Master Gardener Program's Continuing Education Summer Workshop. Franklin Pierce High Scholl East. Tacoma, WA. August 1. (65 attended).

Bush, M.R. 2015. Exotic Pest Outreach and Resources from the WSU Extension Garden Team. Yakima County Master Gardener Training Program. Ahtanum Youth Park. Union Gap, WA. February 4. (82 attended).

Bush, M.R. 2015. Hands-on Insect ID and Host Crops. Brown Marmorated Stink Bug Training for Pest Boards. Yakima Area Arboretum. Yakima, WA. August 21. (20 attended)

Bush, M.R. 2015. Keep Your Eyes Open for Invasive Insects. Urban IPM and Pesticide Safety Education Recertification Program. Highline Community College. Des Moines, WA. February 5. (122 attended).

Bush, M.R. 2015. Keep Your Eyes Open for Invasive Insects. Urban IPM and Pesticide Safety Education Recertification Program. Mill Creek Country Club. Mill Creek, WA. February 23. (116 attended).

Bush, M.R. 2015. Keep Your Eyes Open for Invasive Insects. Urban IPM and Pesticide Safety Education Recertification Program. Whatcom Community College. Bellingham, WA. April 1. (173 attended)

Bush, M.R. 2015. Pest Control Tools and Education. Leadership Yakima Ag Day Yakima Chamber. Yakima, WA. April 8. (15 attended).

Butler, Sr., B.R. 2015. Brown Marmorated Stink Bug, Spotted Wing Drosophila, Kudzu Bugs. Invasive species effects on IPM programs. Presented three times for Maryland Private Applicator Pesticide Training. Carroll County, Md. (76 attended).

Dieckhoff, C. and K. Hoelmer. 2015. Invited to present and consult on status and prospects for biological control of brown marmorated stink bug by western US workgroup preparing SCRI proposal. April 29-30.

Dieckhoff, C. and K. Hoelmer. 2015. Participated in ARS-BIIR public awareness booth at University of Delaware Ag Day and represented BMSB research program. April 25.

Dieckhoff, C. and K. Hoelmer. 2015. Presented update on BMSB biological control programs at ITAP-INVERT (Invasive Terrestrial Animals and Plants-Invertebrates) interagency meeting. Beltsville, MD. August.

Dieckhoff, C. and K. Hoelmer. 2015. Received visit to BIIR biocontrol laboratory in Newark of Chinese Academy of Agricultural Science (Beijing) cooperator to consult on BMSB lab and field research methods, May 12-13.

Gilrein, D. and F. Zaman. 2014. Farmingdale State University class on perennials. Farmingdale, NY. November 12. (5 attended).

Gilrein, D. and F. Zaman. 2014. Long Island Arboricultural Association. Cornell Entomology Update: Notes and Noteworthy Landscape Pests. Farmingdale, NY. November 11. (48 attended).

Gilrein, D. and F. Zaman. 2014. Suffolk County Community College biology class. Riverhead, NY. December 3. (17 attended).

Gilrein, D. and F. Zaman. 2015. Central Park Conservancy. Manhattan, NY. August 18. (44 attended).

Gilrein, D. and F. Zaman. 2015. CNLP training: Insects and mites of landscape plants. Holtsville, NY. March 3. (14 attended).

Gilrein, D. and F. Zaman. 2015. Farmingdale State College class: Pests of landscape plants. Farmingdale, NY. April 9. (19 attended).

Gilrein, D. and F. Zaman. 2015. LIHREC Plant Science Day: Entomology Program Projects at LIHREC. July 15. (18 attended).

Gilrein, D. and F. Zaman. 2015. LIHREC Plant Science Day: Updates on spotted wing drosophila and brown marmorated stink bug. Riverhead, NY. July 15. (64 attended).

Gilrein, D. and F. Zaman. 2015. Long Island food conference: What (else) is eating your vegetables? Hempstead, NY. April 25. (8 attended).

Gilrein, D. and F. Zaman. 2015. Long Island Horticulture Conference: A good year for pest after all. Ronkonkoma, NY. January. (158 attended).

Gilrein, D. and F. Zaman. 2015. NSLGA, Ornamental and nuisance pests in and around the home. Uniondale, NY. February 2. (207 attended).

Gilrein, D. and F. Zaman. 2015. NY Entomological Society: Cornell's Entomology program on Long Island. Manhattan, NY. April 21. (18 attended).

Gilrein, D. and F. Zaman. 2015. NYS Arborists: Southern pine beetle and others to expect in. Suffern, NY. January 22. (132 attended).

Gilrein, D. and F. Zaman. 2015. Outbreaks and invasions: New pest on Long Island. Eastern branch of the Entomological Society of America. Rehoboth Beach, DE. March 16. (23 attended).

Gilrein, D. and F. Zaman. 2015. PCA of Long Island: What's bugging you. Islandia, NY. January 29. (109 attended).

Gilrein, D. and F. Zaman. 2015. Update to CCE Suffolk board of directors. Riverhead, NY. May 20. (19 attended).

Hamilton, G.C. 2015. The Brown Marmorated Stink Bug and Its Impact in Ornamentals. Eastern Pennsylvania Turfgrass Conference & Trade Show. January 7. (100 attended)

Hoheisel, G. 2015. BMSB overview. BMSB Training for Pest Boards. Yakima, WA. September 21.

Hoheisel, G. BMSB – The biology, identification, and current control methods being researched in Eastern WA. QFC/McGregor Grower Meeting. Quincy, WA. February 2.

Krawczyk, G. 2014. Seasonal orchard IPM updates. Adams County Twilight IPM meeting. Biglerville, PA. May 7. (120 attended).

Krawczyk, G. 2015. Update on managing tree fruit insects including BMSB. 2015 New Holland Vegetable day. New Holland, PA. January 19.

Krawczyk, G. 2015. Brown marmorated stink bug management and monitoring update for stone fruit crop. PSU FREC Plant Protection Day, Biglerville, PA. September 16. (45 attended).

Krawczyk, G. 2015. Insect IPM options for orchards including those with minimal crops. Erie County Tree Fruit IPM meeting. North East, PA, May 12. (23 attended).

Krawczyk, G. 2015. Insect IPM update. Western PA Twilight IPM meeting. Homer City, PA. May 11. (15 attended).

Krawczyk, G. 2015. Revisiting management options for codling moth and oriental fruit moth (with plenty of BMSB around). Mid-Atlantic Fruit and Vegetable Convention. Hershey, PA. January 27-29.

Krawczyk, G. 2015. Seasonal orchard IPM updates. Central Susquehanna Twilight IPM meeting. Berwick, PA, May 21. (65 attended).

Krawczyk, G. 2015. Seasonal orchard IPM updates. Franklin County Twilight IPM meeting. Waynesboro, PA. May 8. (35 attended).

Krawczyk, G. 2015. Seasonal orchard IPM updates. Multi-State Fruit Growers twilight educational meeting. Smithsburg, MD, June 02. (60 attended).

Krawczyk, G. 2015. Seasonal orchard IPM updates. Southeast Region Orchard Twilight IPM meeting. Boyertown, PA, May 20. (57 attended).

Krawczyk, G. Seasonal orchard IPM updates. Appalachian Fruit Growers Twilight IPM meeting. Fishertown, PA, May 19. (45 attended).

Kuhar, T. 2015. An IPM approach to managing the major pests of vegetables including stink bugs. Richmond Area Vegetable Growers Meeting. Henrico, VA. March 10.

Kuhar, T. 2015. Insect Management in Vegetable Crops, Tri-County Vegetable and Small Fruit Growers Meeting, Cumberland Valley Produce Auction. Shippensburg, PA. January 7.

Kuhar, T. 2015. Integrated pest management approaches for vegetable pest management. 2015 Winter Vegetable School. Northern Piedmont. Warrenton, VA. February 23.

Kuhar, T. 2015. Integrated pest management approaches for vegetable pest management. 2015 Winter Vegetable School. Shenandoah Valley. Dayton, VA. February 24.

Kuhar, T. 2015. New Insecticides for Vegetable Crops. Pest Management Session: 2015 New Jersey Agricultural Convention and Trade Show. Atlantic City, NJ. February 3.

Kuhar, T. 2015. Update on brown marmorated stink bug and spotted wing drosophila. 2nd Annual Foothills Specialty Crop Growers Roundtable Meeting. Pilot Mountain, NC. February 13.

Kuhar, T. 2015. Update on Tomato Insect Pest Management. Tomato Session: 2015 New Jersey Agricultural Convention and Trade Show. Atlantic City, NJ. February 4.

Morehead, J.A. and T.P. Kuhar. 2015. Organic control options for stink bugs on vegetables. Virginia Cooperative Extension New River Valley Agriculture Field Day at Kentland. Whitethorne, VA. August 13.

Murray, T.A. 2014. Brown Marmorated Stink Bug Update. GS Long Consulting. Hood River, OR.

Murray, T.A. 2014. Exotic Pests of Urban Forests. International Association of Arborists: PNW Chapter Annual Conference. September 30.

Murray, T.A. 2014. The Bugs that Ate the PNW: Exotic Pests of Concern. Master Gardener Advanced Training. Hood River OR.

Murray, T.A. 2015. Exotic Insect Pests in Washington State. Pesticide Education Program Training. Puyallup, WA. September 22.

Murray, T.A. 2015. Exotic Insect Pests in Washington State. Pesticide Education Program Training. Puyallup, WA. December 4.

Murray, T.A. 2015. Exotic Insect Pests in Washington State. Pesticide Education Program Training. Tacoma, WA. January 14.

Murray, T.A. 2015. Exotic Insect Pests in Washington State. Pesticide Education Program Training. Tumwater, WA. February 2.

Murray, T.A. 2015. Exotic Insect Pests in Washington State. Pesticide Education Program Training. Vancouver, BC. January 8.

Murray, T.A. 2015. The Bugs that Ate the PNW: Exotic Pests of Concern. Master Gardener Advanced Training. Hood River, OR. January 28.

Murray, T.A. 2015. The Bugs that Ate the PNW: Exotic Pests of Concern. Master Gardener Advanced Training. The Dalles, OR. March 11.

Murray, T.A. and R. Suits. 2015. Double Trouble: New Pests on Small, Diversified Farms. Hood River, OR.

Nielsen, A.N. 2015.South Jersey Twilight1. May. (35 attended).

Nielsen, A.N. 2014. "Management of Brown Marmorated Stink Bug in Peaches". Great Lakes Fruit and Vegetable EXPO. Grand Rapids, MI. December. (200 attended).

Nielsen, A.N. 2015. "Old and new pests in the orchard". South Jersey Fruit Meeting. February. (35 attended).

Nielsen, A.N. 2015. "Bringing IPM Back to Peaches in the Face of BMSB". Mid-Atlantic Fruit and Vegetable Convention. Hershey, PA. January. (100 attended).

Nielsen, A.N. 2015. "Insect Pests in the Vineyard". NJ Agricultural Convention. Atlantic City, NJ. February (45 attended).

Nielsen, A.N. 2015. "Understanding and Management of Brown Marmorated Stink Bug on Organic Farms". NOFA-NJ Winter Conference. Lindcroft, NJ. January.

Nielsen, A.N. 2015. North Jersey Twilight. May. (40 attended).

Nielsen, A.N. 2015. South Jersey Twilight 2. May. (25 attended).

Nielsen, A. 2015. Rutgers Grape IPM School A workshop to identify identify key vineyard pests and discuss available IPM tactics. March. (50 attended).

Shearer, P.W. 2014. Brown Marmorated Stink Bug in the PNW and How Eastern IPM Programs are Evolving to Deal With It. Annual Meeting of the Washington State Horticultural Society. Kennewick, WA. December 3.

Shearer, P.W. 2015. Brown marmorated stink bug and spotted wing drosophila update. G. S. Long Grower meeting. Hood River, OR. January 8.

Shrewsbury, P. 2015. Bugs, Aphids, Adelgids, Thrips. Advanced Landscape IPM Shortcourse. Department of Entomology, University of Maryland. College Park, MD. January.

Shrewsbury, P. 2015. Demonstration of Hemiptera pests – Laboratory (w/ John Davidson, UMD). Advanced Landscape IPM Shortcourse. Department of Entomology, University of Maryland. January.

Shrewsbury, P. 2015. Impact of Invasive Insects and Plants on our Ecosystems. Montgomery County Master Gardeners University of Maryland Extension. Derwood, MD. February.

Shrewsbury, P. 2015. Insect Pests of Ornamentals. Continuing Professional Education Short Course, Rutgers University. New Brunswick, NJ. January.

Walgenbach, J.F. 2015. Insect management in vegetable crop systems. Winter Vegetable Conference. Asheville, NC. February 19.

Walgenbach, J.F. 2015. Insect update for NC Apples. Henderson County Apple Meeting. Hendersonville, NC. February 4.

Walgenbach, J.F. 2015. Insect update for NC Apples. Wilkes County Apple Meeting. Wilkesboro, NC. March 31.

Walgenbach, J.F. 2015. What's new in the world of IPM? New Products and Monitoring Tools. Southeastern Apple Growers Meeting. Asheville, NC. January 14.

Walton V. M. 2015. BMSB in commercial wine grapes in Oregon. LIVE annual field scouting workshop. Rickreal, Oregon, August. (211 attended).

Walton, V.M. 2015. BMSB in commercial Agricultural crops in Oregon. Blue Mountain Horticultural Society. Milton Freewater, Oregon. February. (30 attended).

Walton, V.M. 2015. BMSB in commercial Agricultural crops in Oregon. Umpqua Growers association. Roseburg, Oregon. March. (50 attended).

Walton, V.M. 2015. BMSB in commercial wine grapes. Rogue Valley wine grape growers summer tour. Medford, Oregon. August. (48 attended).

Walton, V.M. 2015. BMSB in the Willamette Valley in Oregon. Willamette Valley Grape growers Technical Meeting. Oregon, January. (63 attended).

Walton, V.M., N.G. Wiman, P.W. Shearer and S.I. Rondon. 2015. BMSB and SWD in Oregon. Blue Mountain Horticultural Society. February 2. (31 attended)

Walton, V.M., N.G. Wiman, P.W. Shearer and S.I. Rondon. 2015. BMSB and SWD in Oregon. Southern Oregon Pesticide Applicators Conference. Medford, OR. January 12. (250 attended)

Wilson, J., J. Aigner, H. Wantuch, T. Dimeglio, and T. Kuhar. 2015. Integrated Pest Management Strategies with Case Studies Pertinent to Virginia. Virginia Private and Commercial Applicator Recertification Course. Blacksburg, VA. January 7.

Wiman, N.G. 2015. Brown marmorated stink bug and the home orchardist. Home orchard society all about fruit show. Canby, OR. October 17.

Wiman, N.G. 2015. Brown marmorated stink bug in perennial crops in Oregon. Oregon State University orchard and vineyard pest management workshop. Roseburg, OR. October 28.

Wiman, N.G. 2015. Brown marmorated stink bug management in hazelnuts. Pratum Co-Op Workshop. Canby, OR. November 17.

Wiman, N.G. 2015. Brown marmorated stink bug management in hazelnuts. Wilbur Ellis Workshop. Canby, OR. November 15.

Wiman, N.G. 2015. Brown marmorated stink bug management in hazelnuts. Willamette Hazelnut Growers Workshop. Canby, OR. November 18.

Wiman, N.G. and E. Tomasino. 2015. Brown marmorated stink bug impacts on the wine industry. Columbia Gorge Winemakers Association meeting. Analemma Winery. Mosier, OR. May 6.

Wiman, N.G., V.M. Walton and I. Zasada. 2015. Insects and nematodes. Oregon State University Blueberry School. Corvallis, OR. March 15. (305 attended)

Extension oriented Websites and Digital Products

2015 BMSB Update: Bifenthrin Use recommendations, Section 18 Labels Available. August 6. http://blogs.cornell.edu/jentsch/

2015 BMSB Update: Increasing Damage to Pink Lady Apple Observed In Columbia County. August 6. http://blogs.cornell.edu/jentsch/

2015 BMSB Update: Nymphs Increasing in Traps & Found on Peach. August 17. http://blogs.cornell.edu/jentsch/

2015 BMSB: Bifenthrin Section 18 Renewal Includes Columbia County. August 6. http://blogs.cornell.edu/jentsch/

2015 Brown Marmorated Stink Bug in North Carolina. http://entomology.ces.ncsu.edu/brown-marmorated-stink-bug-in-north-carolina-3/

2015 Brown Marmorated Stink Bug in Oregon. http://horticulture.oregonstate.edu/group/brown-marmorated-stink-bug-oregon

2015 Maintaining Fall Stink Bug Management in Apple. September 14. http://blogs.cornell.edu/jentsch/

2015 Stink Bug Management in Red Delicious. September 22. http://blogs.cornell.edu/jentsch/

2015 Weekly reporting of BMSB captures on entomology section of blog. http://blogs.ext.vt.edu/tree-fruit-pest/

Krawczyk, G. 2015. Insect Bytes. Weekly fruit insect pest web updates from April to October. Penn State University, College of Agricultural Sciences. University Park, PA. http://extension.psu.edu/plants/tree-fruit/news/2015

Krawczyk, G. 2015. Monthly entomology updates. The Fruit Times Newsletter, monthly issues from April to October. Penn State University, College of Agricultural Sciences. University Park, PA. http://extension.psu.edu/plants/tree-fruit/news/2015

Walgenbach, J.F. and S.C. Schoof. 2015. Current Western NC Orchard Pest Conditions. NC Coop. Ext. Service IPM Portal. https://www.ces.ncsu.edu/current-pest-populations-henderson-and-polk-counties/.

www.StopBMSB.org

Extension and Outreach Publications

2014 Common Insects, Mites & Vertebrates: Brown marmorated stink bug. WSU Extension Hortsense. May 22. http://hortsense.cahnrs.wsu.edu/Search/MainMenuWithFactSheet.aspx?CategoryId=13&ProblemId=6047

2014 Brown marmorated stink bug. WSU Extension Pestsense. June 13. http://pestsense.cahnrs.wsu.edu/Search/MainMenuWithFactSheet.aspx?CategoryId=2&ProblemId=849

2015 "Fruit and Vegetable Newsletter". Cornell Cooperative Extension of Suffolk County.

2015 Newsletter articles: Rutgers Plant and Pest Advisory, Fruit IPM section. 22 articles. http://plant-pest-advisory.rutgers.edu/category/fruit/

2015 Vegetables - Weekly Crop Update Electronic Newsletter - Seasonal Occurrence Posted to our website and reported weekly throughout the summer of 2015

Biddinger, D. and T. Baugher. 2014. How fall BMSB sprays can affect your next growing season and some IPM strategies to minimize them: Woolly apple aphid. Fruit Times. September 26. http://extension.psu.edu/plants/tree-fruit/news/2014/how-fall-bmsb-sprays-can-affect-your-next-growing-season-and-some-ipm-strategies-to-minimize-them-woolly-apple-aphid

Gonzales, C. 2014. From Asia: Sustainable Insights into Stink Bugs StopBMSB.org; A collection of articles originally published in Asia yields a bounty of insights into the brown marmorated stink bug. September 29.

Gonzales, C. 2015. Asian wasp, enemy of stink bugs, found in the United States StopBMSB.org; The Asian wasp *Trissolcus japonicus* has been found in the wild in the United States. The wasp, native to the regions of Asia where the brown marmorated stink bug (BMSB) originates, is known to attack the eggs of BMSB and possibly other stink bugs. March 26.

Hilton, R., P. Shearer and N. Bell. 2015. Pear Pests. in Hollingsworth, C. (ed). Pacific Northwest Insect Management Handbook. Pacific Northwest Extension Publication. Corvallis, OR. pp. J54-J65.

Krawczyk, G., T.R. Enyeart and B. Lehman. 2015. Reintroducing of IPM principles into management programs for brown marmorated stink bug and other fruit pests. Pennsylvania Fruit News Vol. 95(1): 16-21.

Morehead, J., J. Aigner, J. Wilson, L. Nottingham, T. Dimeglio and T. Kuhar. 2015. Efficacy of organic inseticides for control of brown marmorated stink bug on peppers in Virginia, 2014. Arthropod Management Tests 2015 40: E19. doi: http://dx.doi.org/10.1093/amt/tsv072 (E19)

Pscheidt J.W., Peachey E. and V. Walton 2015. Hazelnut 2015 Pest Management Guide for the Willamette Valley. Oregon State University Extension Service. EM 8328. 370

Pscheidt J.W., Peachey E. and V. Walton 2015. Walnut 2015 Pest Management Guide for the Willamette Valley. Oregon State University Extension Service, EM 8421. 192

Shearer, P.W. and N.G. Wiman. 2014 EMERGING PEST: Brown Marmorated Stink Bug-A Pending Threat to Pacific Northwest Agriculture. March. http://insect.pnwhandbooks.org/pnw-insect-management-handbook/emerging-pest-brown-marmorated-stink-bug

Skinkis P., J. Pscheidt, V.M. Walton, A.J. Dreves, E. Peachey, N. Allen and J. Sanchez. 2007-2015. Pest Management Guide for Wine Grapes in Oregon. OSU Extension Service EM8413E. (updated annually) 3861.

Streito, J.C., J.P. Rossi, T. Haye, K. Hoelmer and X. Tassus. 2014. La Punaise diabolique (*Halyomorpha halys*): nouveau ravageur à la conquête de la France. Phytoma no. 677: 26-29. 2014. (non-peer-reviewed journal article, in French)

Whalen, J., D.A. Herbert, G. Dively, D. Venugopal, B. Cissel, C. Hooks, T. Kuhar, T. Patton, B. Aigner, S. Malone, J. Hogue, and E. Seymore. 2015. Brown marmorated stink bug biology and management in mid-Atlantic soybeans. United Soybean Board Publication.

Weiford, L. 2014. BMSB coming for Northwest fruit crops. Fruit Grower News (v. 53, no. 4), pp 20-21. (Interviewed and quoted by reporter) https://news.wsu.edu/2014/03/04/scientist-swat-team-combats-stink-bug-invasion/

Zaman, F. 2015. “Brown Marmorated Stink Bug (BMSB) Update”. Fruit and Vegetable Newsletter. August 20.

Zaman, F. 2015. "Brown Marmorated Stink Bug (BMSB) Update". Fruit and Vegetable Newsletter. April 9.

Zaman, F. 2015. "Brown Marmorated Stink Bug (BMSB) Update". Fruit and Vegetable Newsletter. June 8.

Zaman, F. 2015. "Brown Marmorated Stink Bug (BMSB) Update". Fruit and Vegetable Newsletter. September 17.

Zaman, F. 2015. "Brown Marmorated Stink Bug (BMSB) Update". Fruit and Vegetable Newsletter. September 8.

New Leveraged/Complementary Resources

Blaauw, B. and A, Nielsen. "Identifying Movement and Distribution Patterns of the Brown Marmorated Stink Bug in Peach Orchards". NJ Hort Society. $3,500.

Coffey, P. and C.R.R. Hooks. 2015. The effect of cover crops on the abundance and survival of beneficial stink bugs. USDA-NIFA Northeast Sustainable Agriculture Research and Education (NESARE). $11,916.

Hoelmer, K. USDA ARS Beneficial Insect Introduction Research laboratory in Newark, DE, have been facilitated with APHIS FY15 Farm Bill funds totaling $603,574 to a consortium of researchers in Delaware, Florida, Michigan, California, and Oregon under the direction of the ARS BIIR laboratory in Newark.

Hooks, C.R.R., G. Chen, T. Kuhar and S. Tubene. 2014. Using an integrated management approach to mitigate multiple pest constraints and improve profits in snap beans. Delmarva Land Grant Institution Collaborative Research Seed Funding Program. $30,000.

Jentsch , P. 04/15/15 to 03/31/17. Increasing the Efficacy and Economic Viability of Trap and Kill Systems for Spotted Wing Drosophila Management and Brown Marmorated Stink Bug in NY Vegetable and Fruit Production. New York Farm Viability Institute. $99,614.

Jentsch , P. 09/15/13 to 10/31/14. Studies Determining Risk Factors Associated With BMSB in Food Product Contamination. Confidential Consulting to Private Firm. $7,400

Jentsch , P. and T. Lampasona. 04/01/14 to 3/31/15 Monitoring and Management Strategies for the Invasive Spotted Wing Drosophila and Brown Marmorated Stink Bug in the Hudson Valley of NY. NYS Ag & Mkts CCE Columbia County. $64,740.

Jentsch, P. 03/01/14 to 11/30/15 Field Insecticide Trials with Apple, Pear, Small Fruit. Agricultural Company Gifts/Grants. $35,000.

Jentsch , P. and T. Lampasona. 04/01/13 to 3/31/14 Tree Host Survey, Monitoring and Management Strategies for the Invasive Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål): (Pentatomidae), Along Borders of NY Tree Fruit. NYS Ag & Mkts ARDP. $14,900.

Jentsch , P. and T. Lampasona. 04/01/14 to 3/31/15 Development of Pest Management Thresholds and Management Strategies for the Invasive Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål): (Pentatomidae) In Commercial Tree Fruit in the Hudson Valley of NY. NYS Ag & Mkts ARDP. $16,456

Jentsch, P. 10/01/11 to 09/30/15 Smith-Lever BMSB Evaluations.

Krawczyk, G. Re-introducing of IPM principles into management programs for brown marmorated stink bug and other fruit pests. 2015 State Horticultural Association of Pennsylvania. $ 23,726.

Krawczyk et al. 2015 State Horticultural Association of Pennsylvania. Effect of Exclusion Netting on Integrated Pest and Disease Management and Fruit Quality of Apples. $19,554.

Lee, Jana. Examine biological control of BMSB eggs in nursery fields. Schmidt grant. $5000.

Leskey, T. Amplifying Natural Enemy Impacts: Enhancing Attraction of Brown Marmorated Stink Bug (*Halyomorpha halys*) and its Natural Enemies with Semiochemicals to Flower Patches. State Horticultural Association of Pennsylvania. $25,000.

Nielsen, A. CPPM. IPM-CPR. Systems-Level Approach To Manage Brown Marmorated Stink Bug And Conserve Beneficial Insects In Tree Fruit. $299,952.

Nielsen, A., D. Polk and L Coia. “Survey of vineyard pest insects in New Jersey”. NJ Dept of Ag Specialty Crop Block Grant. $39,309.

Nielsen, A., B. Blaauw, D. Polk, T. Leskey and C. Bergh “IPM-CPR: A Systems-Level Approach To Manage Brown Marmorated Stink Bug And Conserve Beneficial Insects In Tree Fruit “. USDA CPPM. $299,952.

Tomasino, E and NG Wiman. 2015. Contamination of small fruits and wine by brown marmorated stink bug. USDA-ARS Northwest Center for Small Fruits Research. $34,314.

Venugopal, D., K. Hamby and C.R.R. Hooks. 2015. Multitasking marigold to strengthen organic IPM in lima bean and other bean crops. USDA-NIFA Northeastern IPM Competitive Grants Program. $25,000.

Walton, VM, NG Wiman, K Daane, Frank Zalom, Monica Cooper, and Lucia Varela. Brown marmorated stink bug risk and its impacts in western vineyards. California Department of Food and Agriculture Pierce's Disease and Glassy-winged Sharpshooter Board. $215,635.

Whalen, J., D.A. Herbert, G. Dively, D. Venugopal, B. Cissel, C. Hooks, T. Kuhar, T. Patton, B. Aigner, S. Malone, J. Hogue, and E. Seymore. 2015. Brown marmorated stink bug biology and management in mid-Atlantic soybeans. United Soybean Board Publication.

Wiman, NG. 2015. Evaluating candidate feeding deterrents for brown marmorated stink bug as an alternative management strategy. Oregon Agricultural Research Foundation. $12,000.

Wiman, N.G., M. Hoddle and P.W. Shearer. 2015. Addressing the threat of brown marmorated stink bug in the western US. USDA NIFA SCRI Planing Grant. $50,000.

Selected Media Contacts and Press Coverage

Print

Democrat & Chronicle. September 30, 2015. Sarah Taddeo. Stink bugs smell up Rochester homes.

East Oregonian. February 24, 2015. George Plaven. Mild winter wakes nuisance pests early.

Entomology Today. June 30, 2015. Kevin Fitzgerald. Stink Bugs' Tree Host Preferences May Provide Management Clues. http://entomologytoday.org/2015/06/30/stink-bugs-tree-host-preferences-may-provide-management-clues/

Harrison Patch. March 14, 2015. Lanning Taliaferro. Stink Bug Population Re-Emerging in the Hudson Valley. http://patch.com/new-york/harrison/stink-bug-population-re-emerging-hudson-valley-0

Hort. Matters. OMAFRA. July 29, 2015. Hannah Fraser. Brown marmorated stink bug update. http://www.omafra.gov.on.ca/english/crops/hort/news/hortmatt/2015/17hrt15a5.htm

Good Fruit Grower. March 2015. Lehnert, R. and D. Biddinger. Is biocontrol beating the bug? http://www.goodfruit.com/is-biocontrol-beating-the-bug/

New York Times. October 22, 2015. AP. Wasp that kills stink bugs found; could help fruit orchards.

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Stakeholder Advisory Panel

More than 30 independent growers, association directors, and business leaders from across the United working in our Stakeholder Advisory Panel. This group reviews project accomplishments, provides feedback on re-search plans, and guides the execution of objectives.

Member Name, Affiliations, and State

Current Members

David & Jeanne Beck, Owners, Crawford Beck Vineyard, LLC, OR
George Behling, Tree Fruit Grower and Owner, Nob Hill Orchards, WV
Robert Black, Fruit and Vegetable Grower, Catoctin Mt. Orchards, MD
Steve Black, Nursery Owner, Raemelton Farm, MD
Sam Doane, Production Horticulturist, J.S. Schmidt, OR
Susan Futrell, Director of Marketing, Red Tomato, MA
Ken Gauen, Lima Bean Processor, Pictsweet, DE/MD
Tom Green, President, IPM Institute of North America, WI
Tom Haas, Tree Fruit Grower and Owner, Cherry Hill Orchards, PA
Scott Hoffman, Field Representative, Furmano Foods, PA
Brad Hollabaugh, Tree Fruit Grower, General Manager and Co-Owner, Hollabaugh Bros, Inc., PA
Doug Inkley, Senior Scientist, National Wildlife Federation, MD/DC
Gene Klimstra, Crop Consultant, Agricon Consulting, NC
Edith Lurvey, Northeast Region Field Coordinator, IR-4 Project, Cornell University, NY
Santo John Maccherone, Fruit Grower, Circle M Farms; Chair, NJ Peach Promotion Council, NJ
Bill MacKintosh, Consultant and Owner, Mackintosh Fruit Farm, VA
Wayne Marston, Owner, Adam's Apple Farm, VA
Clarissa Mathews, Redbud Organic Farm; Professor of Environ. Studies, Shepherd Univ., WV
Nathan Milburn, Fruit and Vegetable Grower, Milburn Orchards, MD
Guy Moore, Fruit and Vegetable Grower, Larriland Farms, MD
Mark Orr, Fruit, Vegetable, and Ornamental Grower; Orr's Farm Market & Orchard, WV
Polly Owen, Executive Director, Oregon Hazelnut Commission, OR
Tom Peerbolt, Senior Consultant, Peerbolt Crop Management, OR
Kay Rentzel, Managing Director, National Peach Council, PA
Michael Rozyne, Executive Director, Red Tomato, MA
Jennie Schmidt, Vineyard Manager & Jane of all trades, Schmidt Farms, MD
Michael Seagraves, Entomology Lead, Driscoll Strawberry Associates, Inc., CA
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Previous Members

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Rick Hood, Organic Grower, Summer Creek Farm, MD
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