# Whole-farm Organic Management of BMSB and Endemic Pentatomids through Behavior-Based Habitat Manipulation

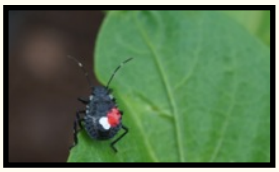
# 2013-2014 PROJECT UPDATE

A multi-state project funded by the

**Organic Research and Extension Initiative**

USDA United States Department of Agriculture National Institute of Food and Agriculture











# Whole-farm Organic Management of BMSB and Endemic Pentatomids through Behavior-Based Habitat Manipulation

# YEAR 2 STAKEHOLDER UPDATE

## Introduction

This integrated project utilizes a multi-regional, transdisciplinary approach for the development and dissemination of whole-farm organic management for the brown marmorated stink bug (BMSB). BMSB is an invasive insect causing severe economic loss in Mid-Atlantic States, with damage increasing in Southern states. It is an especially devastating pest for organic farmers. Current organic management tactics have not mitigated damage because BMSB is highly mobile, feeds on a diverse number of crops. and occupies a large geographic area. Thus, whole-farm management is required for effective organic control. Our approach will aid growers in the selection and planning of trap crops,

"Farmers are eager to adopt new tactics sustainable BMSB management"

enhancing natural enemies, and cultural control, all of which will be researched in this project.

We are currently investigating the behaviors for dispersal and identifying movement patterns that will be integrated into applications for proactive stink bug management. We have partnered with *e*Organic to aid in the novel dissemination of research findings. The results of our project as well as the basic biology and identification of BMSB have been disseminated widely to communities of interest in 11 states throughout the country. This has been done through the combined utilization of grower meetings, field days, and social media, such as Facebook. We have also worked directly with organic growers in these states by conducting research at their farms.

## Training and Professional Development

To date this project has helped support the training of 6 post-doctoral researchers, 12 graduate students, and 15 undergraduate student interns. Project members have provided training to over 240 master gardeners. The USDA conducted a parasitoid identification workshop to identify key characteristics of native species. The 'Great Stink Bug Count' trained over 200 participants in 2013 and 2014 on identification of BMSB. Data from this are being utilized to identify key characteristics of houses that serve as overwintering structures for BMSB.

The training these individuals received was essential for the completion of the objectives from the first and second years of this OREI project. The education and experience everyone received while participating has also been important for their advancement in their careers and/or development as future scientists.

## Results: Habitat Manipulation

A trap crop is the planting of an attractive host plant surrounding a cash crop with the goal of preventing or delaying injury of the cash crop. Year 1 field trials indicated that sorghum and sunflower were the most attractive trap crop evaluated to BMSB. In 2014 a field-scale experiment was conducted on the management potential of trap crops to protect bell peppers from stink bug pests. We evaluated a combination of sunflower and sorghum as a trap crop for BMSB at 11 farms in

8 states. Two farms in states with low BMSB pressure did not record any stink bug injury and were not included in analysis. The trap crop was attractive to BMSB and native stink bugs and delayed colonization of the pepper crop. Pepper injury was classified as "Class 1" if two or less feeding sites were visible externally, and "Class 2" for >2 feeding sites. There was no significant difference in the percent of harvested fruit that were free of damage, as well as peppers considered “Class 1” or “Class 2” damage between the control and trap crop surrounded peppers (Fig. 1). When BMSB abundance was low, early in the season at farms like Rutgers’, damage was lower in the trap crop peppers. However, later in the season as BMSB abundance increased, the trap crops may have failed in their effectiveness at protecting the peppers (Fig. 2).

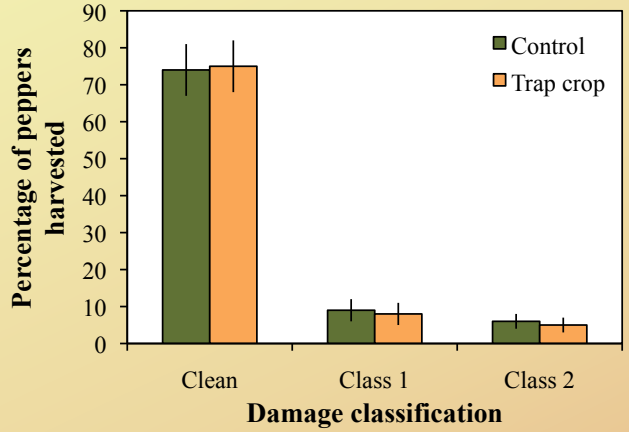



Figure 1. Average percentages of harvested bell peppers damaged from stink bugs among 9 farms.

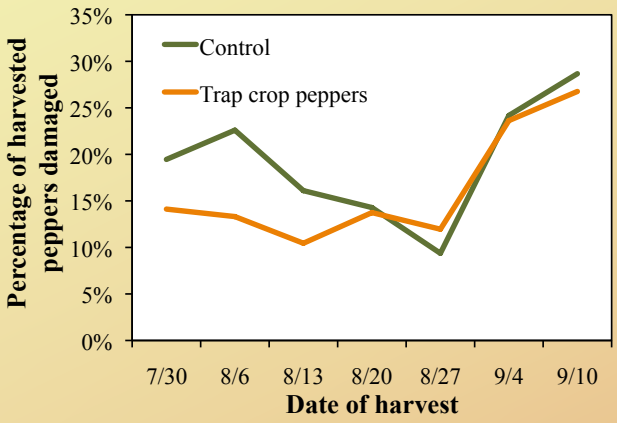
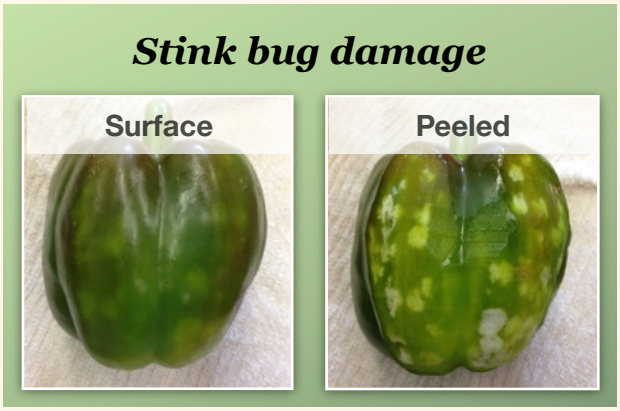



Figure 2. Seasonality of pepper damage at Rutgers due to stink bugs.

Given the broad host range of BMSB, management within the trap crops may be needed, especially in high BMSB pressure areas. For organic farms, management goals must be in line with the holistic approach frequently taken by organic farmers. Thus, a management method that has minimal impact on natural enemies, which are highly attracted to the sunflower trap crop, is key. As a continuation from Year 1, Rutgers investigated within trap crop management options for BMSB: flaming, OMRI insecticides, and a trap baited with BMSB aggregation pheromone. The trap removed the highest number of BMSB from the trap crop and will have minimal impact on natural enemies. The organic insecticide Azera also showed promise for knocking down BMSB populations within the trap crop.




We investigated behavior of BMSB within the trap crop to measure dispersal and utilization via inexpensive protein markers and harmonic radar in WV and NJ. Results suggest BMSB are retained longer and move less in the trap crop compared to the cash crop (Fig. 3). Additionally, the trap crop may pull BMSB from the cash crop and prevent the influx of new adults.

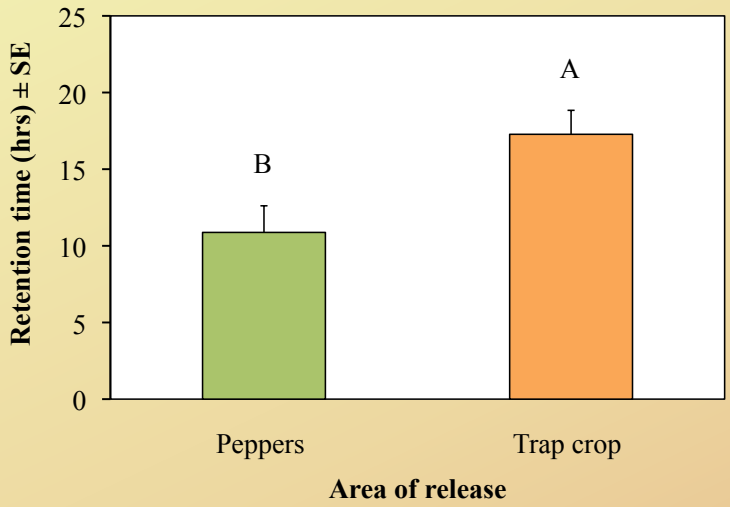



Figure 3. Retention time of harmonically tagged BMSB released in either bell peppers or the surrounding trap crop of sunflower and sorghum. $F_{1,74}$=11.4, P<0.0012.


Monitoring trap crops


BMSB on Sorghum

***Important Findings:***

- *Sorghum and sunflower are attractive trap crops.*
- *Deployment of these trap crops surrounding peppers slowed the injury to peppers.*
- *The next step for this objective is to evaluate the integration of a trap crop management tactic on farm to enhance the prevention of BMSB pepper damage.*

## Results: Whole Farm Movement

We are investigating whole-farm movement for BMSB hotspots, nymphal dispersal, host plant choice, and overwintering behaviors that will lead to management opportunities. Analysis at 3 organic farms identified hotspots in ornamental and fruit trees, typically in the

family Rosacea. Crop hosts in 2014 showed BMSB favored peppers, black-eyed peas, tree fruit, and golden beets. The seasonality of host choice determined that BMB colonized crops from the woods edge and/or human-made structures, like barns and farm houses.

We utilized a mark-release-recapture experiment to track movement of nymphs among four host plants at progressive phenological stages. Following the same trend from the first year's data, in Year 2 we also found that BMSB nymphs are making feeding choices and disperse to a more suitable crop depending on plant phenology. Based on host choice, we calculated an attraction index, which we used to determine that corn and soybean become more attractive as they flower and set fruit (Fig. 4). Headspace volatiles from each host plant were collected over progressive phenological stages to determine if there is an olfactory component to host attractiveness to BMSB nymphs. The collected volatiles are currently being quantified using gas chromatography.

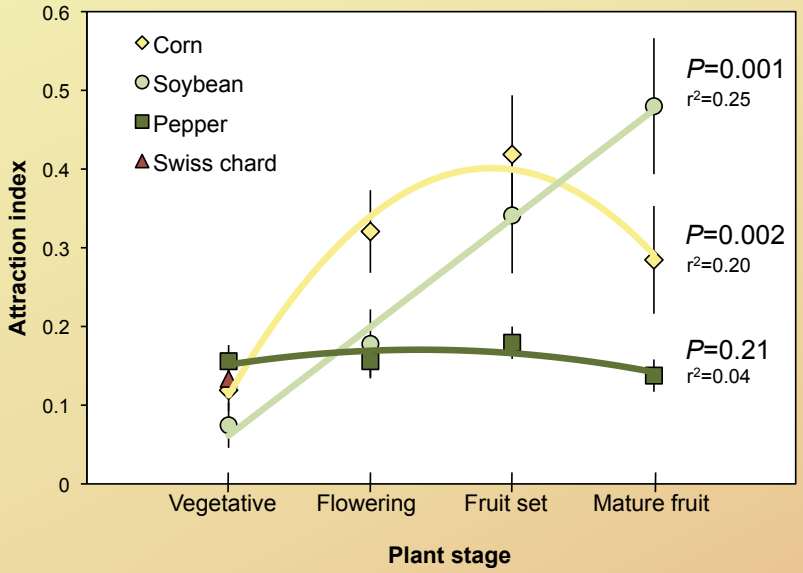



Figure 4. Regression of BMSB nymphal attraction to progressive phenological stages of host plants.


USDA, UFL, Rodale and Rutgers evaluated an overwintering trap to "trap out" fall populations of immigrating BMSB to help reduce the overall threat posed to crops the following spring. The traps were small, white wooden boxes and were designed to mimic an overwintering habitat. In Year 1, though, the boxes were filled with row cover cloth (Reemay) and resulted in low numbers of captured overwintering bugs. In Year 2 the participating organizations decided to replace the row cover cloth with slats of cardboard. Additionally, Mizell at UFL compared different colored traps, as well as plastic plant pots with rolled-up cardboard inside. Dark traps generally caught more BMSB than lighter colored traps, and the plant pots were

similarly effective at collecting BMSB compared to the standard wooden boxes.

In fall 2013, a citizen science project was initiated to identify characteristics of human-made structures that promote their use as overwintering sites by BMSB, and the second year of data collection is currently underway. 300 participants counted BMSB on their homes, and results suggest agricultural with woodland habitats and brown colored houses (Fig. 5) have the highest populations. Similar to the findings of Mizell's trap data, BMSB oriented mostly towards the North and East directions. In 2014, there were 225 participants, and those data are currently being assessed.




Figure 5. Mean number of BMSB counted per household on homes of various colors from 2013 citizen science survey.

***Important Findings:***

- *BMSB nymphs make host plant choices.*
- *Host plant selection follows host plant phenology and crops are most attractive during fruit set and fruit maturation.*
- *Looking at the whole-farm, host plant choices create population "hot spots."*
- *BMSB adults seeking overwintering sites can be trapped out using covered traps with slats of or rolled up corrugated cardboard.*
- *BMSB overwintering adults are highest on houses bordering agricultural and woodland habitats on dark colored houses.*

## Results: Impact of Natural Enemies

Natural enemy populations and activity in various organic crops were evaluated through either sticky cards or sentinel egg masses, which indicate biological control activity. The identity of predators and parasitoids of BMSB and native stink bug egg masses was conducted through multiple approaches, ranging from molecular diagnostics to 48h monitoring of egg masses, to understand the

impacts of natural enemies in the organic agroecosystem. Nearly 32,000 BMSB eggs were placed in 8 states to assess predation in 2014. Predation was low, averaging at 4% with feeding by chewing and sucking predators. Parasitism was very low at 0.15%, but some unhatched eggs may contain un-emerged parasitoids (Fig. 6). We are now dissecting these egg masses to determine whether the unhatched eggs were parasitized. Surveys in KY indicate higher parasitism rates of the native brown stink bug eggs compared to BMSB eggs. Parasitoid species identification is still in progress.

Day/night video cameras recorded predator visits to sentinel egg masses in NJ and MI, and identified katydids and earwigs as an important predator of BMSB eggs. Lab feeding trials performed by Redbud Farm and USDA-ARS documented BMSB egg feeding behavior of various arthropods. Preliminary results are similar to the video data with katydids, spiders, grasshoppers, and earwigs having the greatest impact on BMSB eggs. These two methods indicate that "missing" egg masses may be a result of predation. Thus, these trials will continue in Year 3 of this project in order to increase our understanding of the impact of these predators on BMSB populations.

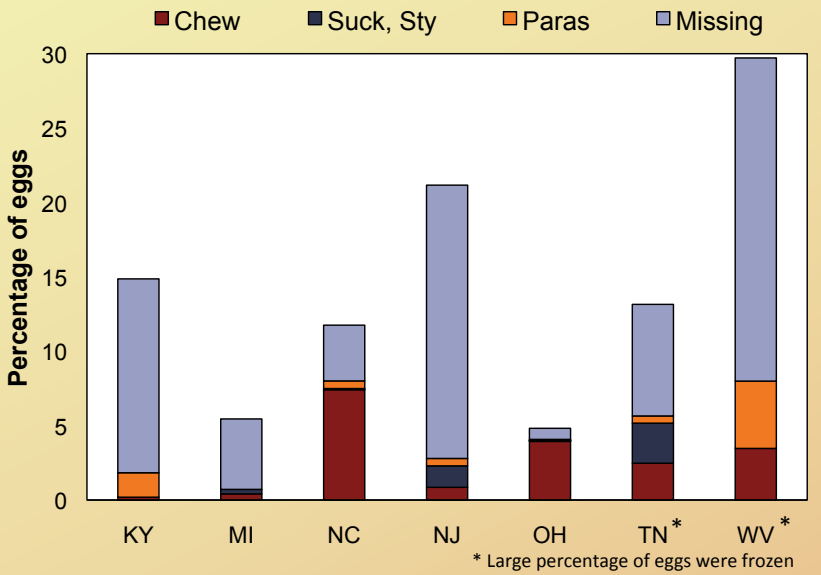
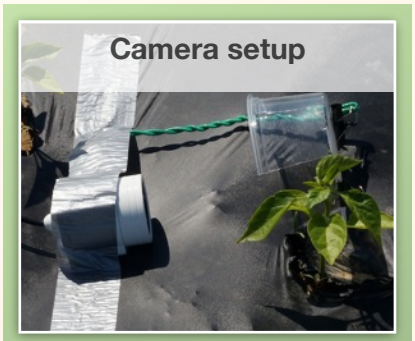



Figure 6. Natural enemy impact (chewing predation and sucking w/ stylet sheath, parasitization, and missing egg masses) BMSB eggs.





***Examples of the different types of natural enemy feeding damage done to BMSB eggs and nymphs.***



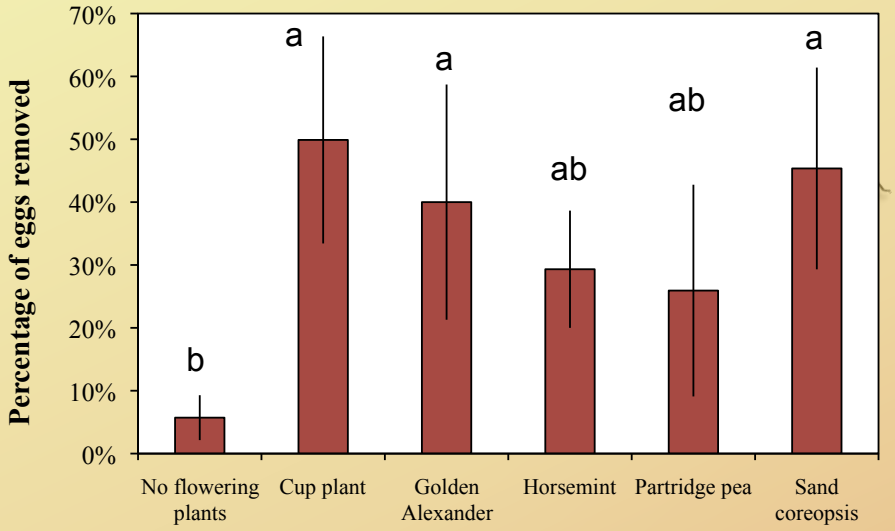



Figure 7. Comparison of natural enemy impact through egg removal from sentinel BMSB egg cards in 2014.

Insectary plantings are designated areas of annual and/or perennial flowering plants that are known to be attractive to and provide essential resources for bees and/or natural enemies, such as parasitoids. Plantings of partridge pea were studied in organic field corn and blackberry crops focusing on the enhancement of parasitoids of BMSB in MD and OH. Similar levels of parasitism was found in crops adjacent to plantings of partridge pea and those without flowers. Although the increased floral resources did not have a significant impact on egg parasitism, similar techniques have produced promising results. At Rutgers, 25 small scale ($3m^2$) perennial wildflower plots were established to compare five native flowering plants for their provision of resources for BMSB predators and parasitoids. Natural enemy abundance and their impact on sentinel BMSB eggs were quantified over the course of the season. There were no successful parasitization off eggs within the plots, but despite being a first year planting with few blooms, there was a significant increase in predation in BMSB egg masses that were placed in flower plots when compared to plots that were not planted with flowering plants ($F_{5,24}$=1.54, P=0.021, n=280 Fig. 7).

As an additional method of identifying the importance of extant natural enemies in Objective 3, researchers at Rutgers began a new project in Year 2 to collect a variety of natural enemies to analyze the contents of their guts to determine whether or not they have fed on BMSB. Along with the continuation of feeding trials and video surveillance, this will help identify predators of BMSB and quantify the prevalence of BMSB predation in the wild.


Hoverfly on golden Alexander


Lady beetle on sand coreopsis

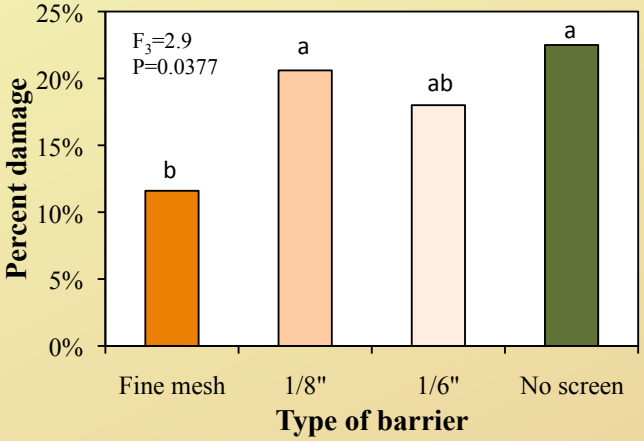

Parasitoid wasp on cup plant

***Important Findings:***

- *Although predation and parasitism levels are low, sentinel BMSB eggs are being attacked by extant natural enemies.*
- *Video surveillance and lab feeding trials have determined that "traditional" generalist predators may not be the major players in BMSB biological control, but rather that katydids, spiders, grasshoppers, and earwigs may have the greatest impact on BMSB eggs.*
- *Supporting natural enemies through the provision of floral resources through insectary strips has the potential to enhance the biological control of BMSB eggs.*

# Results: Integrated Management

Mechanical exclusion of stink bugs was studied using various sizes of mesh netting over organic bell peppers. Laboratory studies indicated that netting smaller than 1⁄4" was needed to impede adult BMSB movement. Field studies evaluated sizes of 1/6", 1/8", and 1 mm ("fine") mesh as a full season management tactic. Measurements on total yield, stink bug injury, and natural enemy populations were made. There was a correlation between netting size and the proportion of the stink bug injury and all netting sizes reduced damage compared to the open controls (Fig. 8). However, the finest mesh cages had secondary outbreaks of aphids due to exclusion of natural enemies. Even with the increased secondary pest outbreaks, the peppers enclosed by white fine mesh had the highest proportion of marketable fruit.



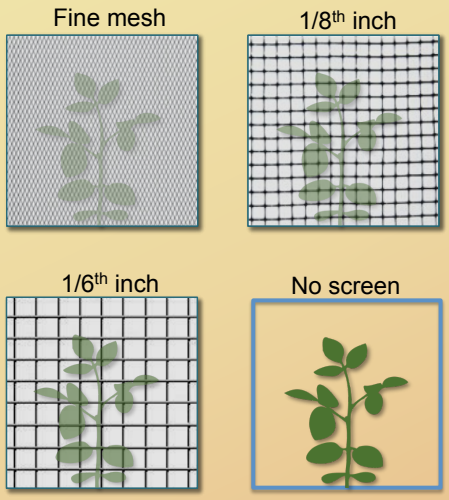
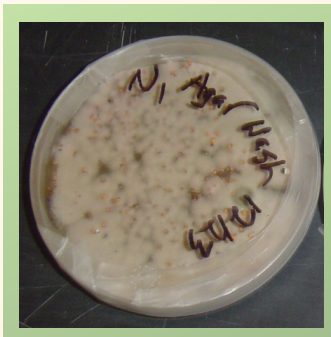




Figure 8. From UTK, comparison of stink bug damage on bell peppers under four different row cover treatments: fine mesh, 1/8", 1/6", and a no screen control.

Lab experiments at WVU demonstrated that BMSB can acquire spores of the fungus *Colletotrichum* from infected tomatoes and may be able to transport them to uninfected fruits, spreading anthracnose injury. This means that beyond initial feeding damage, BMSB has the potential to spread disease amongst a crop.

Field trials on pepper and tomato evaluated the efficacy and rate of organic insecticides for control of stink bugs. BMSB was the most predominant species in pepper, and the most effective treatments included Veratran D at 15 lbs/acre (93% control of adults) and Azera at 56 oz/acre (68%). On tomato, the predominant stink bugs were native species, causing overall 50.6% damage to the harvestable fruit. Veratran D at 15 lbs/acre mixed with Azera at 16 oz/acre provided 46% control.

Additionally, as insecticides used for BMSB management could have negative effects on non-target insects, field and laboratory trials evaluated the impact of four OMRI insecticides on egg parasitoids and the predator community in soybean. Field trials demonstrated that Azera had the lowest impact on the predator community. Conversely, Pyganic and Entrust disrupted the natural enemy complex. Entrust decreased parasitic hymenopteran abundance in MD. In multiple trials, Azera appears to have the lowest impact on natural enemies and moderate control (or knockdown) of pest species. Laboratory samples are currently being processed and the data will be analyzed to show possible impacts on individual taxa of natural enemies as well as overall community effects.



***Important Findings:***

- *Fine mesh row covers successfully prevented stink bugs from feeding on peppers.*
- *High costs and a reduction in natural enemies may reduce adoption of this tactic.*
- *Organic insecticides have varying efficacy on BMSB and native stink bug management, with Veratran D having the greatest impact on adult BMSB.*
  - *These insecticides had no significant impact on the natural enemy community.*

# Results: Extension and Outreach

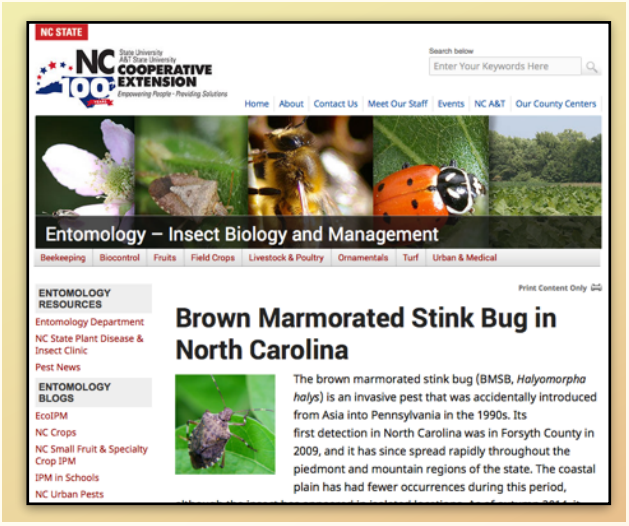
The results of our project as well as the basic biology and identification of BMSB have been disseminated widely to communities of interest in 11 states throughout the country. We have also worked directly with 7 organic growers in these states by conducting research at their establishments. A Facebook community page, Brown Marmorated Stink Bug in Organic Farming Systems, was created to inform and update growers and the public on the status and results from this project. Participants from all cooperating states contributed pictures and cooperating growers were tagged in photos. Participants gave extension training sessions or talks. A handout was developed with eOrganic summarizing the project and distributed to 25 organic growers in NJ during a discussion about trap crops and biological control for BMSB. NCSU gave 2 training sessions on BMSB in organic systems to 75 people and participated in a field day at a cooperating farm with 35 extension professionals. Trap crop trials were highlighted at field days in MD, OH, KY, WV and PA for over 400 people. Our project's trap crop work was featured in Vegetable Growers Times following a presentation at the Mid-Atlantic Fruit and Vegetable Convention.

Many of these experiments were conducted on organic farms, including Muth Family Farm (NJ), Rodale Institute (PA), Redbud Farm (WV), Crane Creek Valley Farm (NC), Bridgman Farm (OH), Stratford Ecological Center (OH), and Three Brothers Orchards (MI), where we were able to communicate results directly to the stakeholders. Additionally, the two years of results results and BMSB identification information have been distributed to target audiences, primarily organic farmers, through an online resources and farm field days. Specific extension and outreach activities include:


## Online resources

- A Facebook community page, Brown Marmorated Stink Bug in Organic Farming Systems, was created to inform and update growers and the public on the status and results from this project. The Facebook page also gave us an outlet to post interesting entomological and BMSB related news. The page currently has 115+ followers.

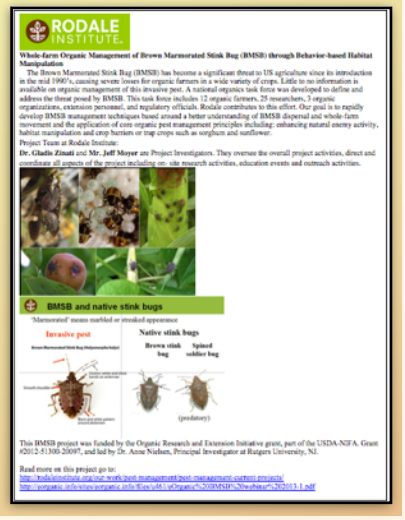
- Investigators at North Carolina State University developed a website dedicated BMSB that highlights work from this project. (http://entomology.ces.ncsu.edu/brown-marmorated-stink-bug-in-north-carolina-3/).




## Field Days and Twilight Meetings

- North Carolina State University held two, two-hour training session on the biology of BMSB and management in organic systems was conducted at the NC Organic School. The school was attended by >1000 individuals, and 75 attended the stink bug session. March 8 and 9, 2014.

- North Carolina State University also sponsored a BMSB Trap Crop Field day at the Cane Creek Organic Farms to discuss BMSB biology and management in organic vegetable systems. This event was attended by 35 county extension agents on June 18, 2014.




- West Virginia University held a field day on August 6, 2014, which highlighted their organic BMSB field research with a wagon tour of their trap crop experiment. This event was attended by approximately 100 growers and extension personnel.

- The experiment from Objective 1 investigating trap crops for the management of BMSB was highlighted by Rodale Institute at the Women in Agriculture field day held at their research farm on June 6th, 2014. This event had 28 attendees.

- At their annual on-farm field day, Rodale Institute show-cased their research and outreach activities. This event included a presentation about their participation in the trap crop experiment and was presented to 86 attendees on July 20, 2014. Attendees also received a handout highlighting this OREI BMSB project.


Jeff Moyer discussing organic research at Rodale Institute

- Project investigators at The Ohio State University delivered a presentation organic growers that focused on stink bug management at the Ohio Ecological Food and Farm Association's Annual Meeting on February 16, 2014.

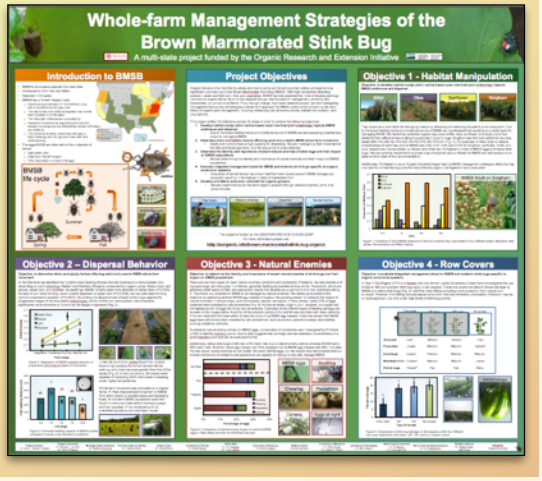
- The topic of stink bug management was included in presentations to vegetable and fruit growers by investigators at The Ohio State University at nine winter and summer meetings in Ohio. These field days were used to inform growers and other members of the community on organic stink bug management.

## Presentations

- Park, C., J. Ahn, and Y.-L. Park. 2014. Brown Marmorated Stink Bugs in Korea: Insight from Historical and Current Data. Annual Meeting of Eastern Branch Entomological Society of America, Williamsburg, VA.

- Ahn, J, and Y.-L. Park. 2014. Development of Sampling Plans for Brown Marmorated Stink Bugs on Corn. Presented at Annual Meeting of Eastern Branch Entomological Society of America, Williamsburg, VA.

- Blaauw BR and AL Nielsen "Whole-Farm Management Strategies for the Brown Marmorated Stink Bug" 2014 MOSES Organic Farming Annual Conference, WI.




- Pote J and AL Nielsen "Determining the predators of Brown Marmorated Stink Bug: a multidisciplinary approach" 2014. Presentation at Annual Entomological Society of America Eastern Branch.

- Deroshia, K. and M. Grieshop. 2013. Observing natural enemies of Brown Marmorated Stink Bug (Halyomorpha halys) using video surveillance in south- central Michigan. Presented at the Annual Meeting of the Entomological Society of America. November 11, 2013. Austin Texas.

- Goldner, J. and Y.-L. Park. 2013. Assessment of spined solider bug (Hemiptera: Pentatomidae) as a predator of brown marmorated stink bug (Hemiptera: Pentatomidae). Presented at Annual Meeting of Entomological Society of America, Austin, TX.

- Baek, S., M. McKinney, J. Goldner, C. Park.B. Seo, and Y.-L. Park. 2013. Non-target effects of organic insecticides on *Podisus maculiventris* (Hemiptera: Pentatomidae). Presented at Annual Meeting of Entomological Society of America, Austin, TX.

- Goldner, J., S. Baek, M. McKinney, and Y.-L. Park. 2014. Non-target effects of organic insecticides on *Podisus maculiventris* (Hemiptera: Pentatomidae). Annual Meeting of Eastern Branch Entomological Society of America, Williamsburg, VA.

- Mathews,C.R, Leskey, T.C., and Hallack, M.H. 2014. Biological Control of Hemipteran Pests in Organic Vegetable Crops with an Integrated Trap Crop and Pheromone Trap System. Talk presented at the Entomological Society of America, Eastern Branch Meeting, Williamsburg, VA.

- Nielsen, A.L., Mathews, C.R., Dively, G., Hooks, C.R.R., Blaauw, B.R., Pote, J., and Zinati, G. 2014. The potential of trap crops for BMSB management on organic farms. Talk presented at the Entomological Society of America, Eastern Branch Meeting, Williamsburg, VA.

- Extension Talk: "Damage and Organic Control Options for Brown Marmorated Stink Bug and Native Stink Bugs" Proceedings at the annual UT Steak and Potatoes Field Day, Aug 5, 2014. (60 attendees)

- Extension Talk: Walgenbach, J.F. 2014. Organic management of BMSB and an overview of OMRI approved insecticides. Organic Growers School. Asheville, NC. March 8 and 9. (75 participants)

- Extension Talk: Walgenbach, J.F. 2014. Good bugs and bad bugs - BMSB. Burke County Master Gardners. July 27, 2014. Morganton, NC. (45 participants)

- Extension Talk: Walgenbach, J.F. 2014. BMSB Trap Crop Field Day. Cane Creek Valley Farm, Fairview, NC. 35 participants. July 27, 2014.

- Extension Talk: Zinati, G. 2014. Managing Brown Marmorated Stink Bug Organically. Mid-Atlantic Vegetable Convention. Hershey, PA. (98 participants)

- Extension Talk: Pfeiffer, D. G. 2013. Organic pest management in caneberries and blueberries – Old friends and new. Organic berry production conference, Eastern Mennonite University, Dayton VA. October 2013.

- Extension Talk: Bessin, R. 2014. KY Fruit and Vegetable Conference (120 participants)

- Field Day: Bessin, R. UK Horticulture Farm field days and walks demonstration netting experiments (4 for a total of 305 participants)

- UK Master Gardener Training on BMSB biology and organic management. (240 total participants)

### Identification Workshop

- PI Hoelmer from the USDA co-led a parasitoid identification workshop sponsored by the Northeast IPM Center. Several members of our project participated to learn the identification of BMSB parasitoids. Held June 17-18, 2013 at the Carvel Research & Education Center at the University of Delaware in Georgetown, Delaware.

## Outputs from the Second Year of Research

In addition to the extension outputs from the work from our first and second years of this project, three journal articles have been published in peer-reviewed journals, and investigators associated with this OREI funded project have been featured in numerous news articles. Furthermore, initial results from the first year of this project have helped team members at the University of Maryland, West Virginia University, Michigan State University, Redbud Farms, LLC., and Rutgers to leverage funding to obtain additional funding or fellowships for BMSB research. The following is a detailed list of these outputs:

### Journal articles

- Lee, D-H, A.L. Nielsen, and T.C. Leskey. 2014. Dispersal capacity and behavior of nymphal stages of Halyomorpha halys (Hemiptera: Pentatomidae) evaluated under laboratory and field conditions. Journal of Insect Behavior 27: 639-651.

- Baek, S., Y. Son, and Y.-L. Park. 2014. Temperature-Dependent Development and Survival of Podisus maculiventris (Hemiptera: Pentatomidae): Implications for Mass Rearing and Biological Control. Journal of Pest Science. 87: 331-340.

- Mathews, C.R. and Barry, S. 2014. Compost tea reduces egg hatch and early-stage nymphal development of Halyomorpha halys (Hemiptera: Pentatomidae). Florida Entomologist 97(4):1726-1732.

## Press coverage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Shutdown Raises a Stink—But Not the Kind You Think
In the Capital, Odorous Bugs Flourish During Government Hiatus

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By ELIZABETH WILLIAMSON

WASHINGTON—The reopening of the federal government couldn't come soon enough for the war on stink bugs, whose reeking legions used the shutdown to solidify their grip on the nation's capital.

The brown marmorated stink bug is a costly, invasive pest currently concentrated in the vicinity of the federal government. First discovered in Allentown, Pa., in the mid-1990s, the insects advanced on the orchards, legume crops and gardens in states surrounding D.C., where they're sucking the juice from one of the greenest capital cities in the world.

The Asian species has few American predators, except for the U.S. Department of Agriculture, which leads a

- Research conducted by Tracy Leskey at the USDA-ARS was covered by the Wall Street Journal on October 20, 2013. The article, "Shutdown Raises a Stink," by Elizabeth Williamson highlighted work from Dr. Leskey's participation in this OREI funded project. (http://www.wsj.com/articles/SB10001424052702304384104579143212962343326)

- The OREI project and work from Anne Nielsen's lab at Rutgers University was featured in an article by Matt Milkovich titled, "Researchers seeking strategies for the brown marmorated stink bug." This article was posted by the Fruit Growers News on November 27, 2013.

- On May 19, 2014, NewsWorks aired a story titled, "Right on time for spring, the malodorous stink bug arises once again," by Richard Koenig, which, amongst other things, covered work from Tracy Leskey at the USDA-ARS on organic management of BMSB. (http://www.newsworks.org/index.php/local/essayworks/67989-right-on-time-for-spring-the-malodorous-stink-bug-arises-once-again)

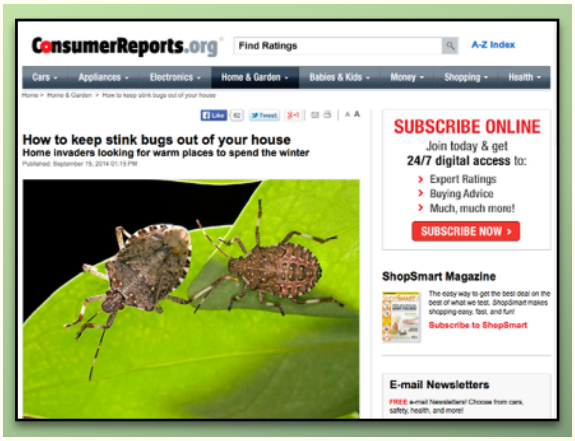
- The Dominion Post in West Virginia published a two-page newspaper article covering research done by OREI project investigator Park on BMSB and spined soldier bugs. This article titled, "Causing a Stink," was printed on July 13, 2014.

- Research conducted by Tracy Leskey at the USDA-ARS was highlighted by the Frederick News-Post in an article titled, "Study: Stink bugs prefer homes in woody, agricultural areas," by Ike Wilson on September 1, 2014. (http://www.fredericknewspost.com/news/economy_and_business/business_topics/agriculture/study-stink-bugs-prefer-homes-in-woody-agricultural-areas/article_8382df5f-f177-5429-9bfd-45dca9f4bb5f.html)

- The Washington Post on September 14, 2014, published the article, "Stink bug Census Underway in Washington," by Martin Weil. This article was about research conducted by Tracy Leskey at the USDA-ARS as part of this OREI funded project. (http://www.washingtonpost.com/local/stink-bug-census-under-way-in-washington/2014/09/14/f83fffa8-3c75-11e4-9587-5dafd96295f0_story.html)

- Research conducted by Tracy Leskey at the USDA-ARS was highlighted by Consumer Reports in an article titled, "How to keep stink bugs out of your house," by Mary H.J. Farrell, September 15, 2014. (http://www.consumerreports.org/cro/news/2014/09/how-to-keep-stink-bugs-out-of-your-house/index.htm)

- On September 16, 2014, West Virginia Public Radio aired the story, "Help the USDA count stink bugs in West Virginia," by Liz McCormick. This story described organic BMSB research conducted by Tracy Leskey from the USDA-ARS. (http://wvpublic.org/post/help-usda-count-stink-bugs-west-virginia)




- The Columbus Dispatch published an article on September 21, 2014, "Feds start second annual census of invasive brown marmorated stink bugs," by Laura Arenschield that described current research from Tracy Leskey at the USDA-ARS. (http://www.dispatch.com/content/stories/science/2014/09/21/01-counting-stinkers.html)

## Leveraged Funding

- Lebron-Rosario, A. and C.R.R. Hooks, 2013-2014. Using molecular methods to identify parasitoids and assess parasitism of the brown marmorated stink bug: deciphering the cause of unknown mortality, Maryland Grain Producers Utilization Board, $15,000.

- C.R.R. Hooks, Chen, G. and Rosario-Lebron, A. 2013-2014. Barley Residue and Herbicide Management Practices: Effects on Insects, Weeds, Soil Moisture Content and Soybean Yield. Maryland Soybean Board, $26,000.

- Lebron-Rosario, A. and C.R.R. Hooks, 2013-2014. Using marigold as a flowering plant to attract natural enemies of the brown marmorated stink bug in soybean fields. Maryland Soybean Board, $5,000.

- C.R.R. Hooks and Chen, G, 2013-2014. Designing a more sustainable weed and insect pest management system for vegetable producers. Maryland Agriculture Experiment Station Competitive Grants Program, $30,000.

- C.R.R. Hooks, Chen, G and Buchanan, A. 2013-2014. Developing economic and ecological sustainable pest management practices for growers of leguminous and solanaceous crops. USDA-NIFA Northeastern IPM Competitive Grants Program, $83,058.

- C.R.R. Hooks, et al. 2013-2014. Moving IPM in Maryland to Greater Economic and Ecological Sustainability. USDA-NIFA EIPM CS Competitive Grants Program, $135,000.

- Dively, G. 2014. Maryland Department of Agriculture. Specialty Crop Block Grant Program. Monitoring and Management of Brown Marmorated Stink Bug in Processing and Fresh Market Sweet. $16,000.

- Dively, G. 2014. United Soybean Board. Biology, Distribution, and Management of the Brown Marmorated Stink Bug in Soybean. $93,000.

- Dively, G. 2014. MGK Inc. Field Efficacy Evaluations of Botanical Insecticides. $25,000

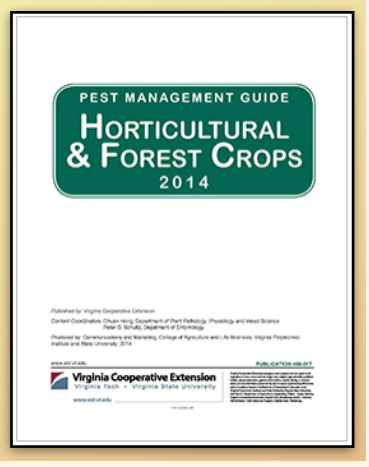
- Funding for international stink bug research. Funded by Rural Development Administration, South Korea ($150,000/3 years). This study includes (1) spatial ecology of stink bugs including BMSB, (2) searching for natural enemies for BMSB in South Korea, (3) population genetics of stink bugs including BMSB.

- At Michigan State University, a graduate student received a one year graduate fellowship based in part on her past work on this project.

- Redbud Farm, LLC was awarded $3,000 by NASA West Virginia Space Grant Consortium Research Enhancement Award to leverage work on "Effects of Compost-derived Microbial Spray on Brown Marmorated Stink Bug (*Halyomorpha halys*) Nymphal Development"

- Blaauw, B. R. and A. Nielsen were award $5,000 from the New Jersey Horticultural Society Research Grants to study the movement and distribution patterns of the brown marmorated stink bug (2014-2015).

## Additional Outputs




- UK Fact Sheet: PR-673. 2014. Managing brown marmorated stink bug on organic peppers with exclusionary screening materials. R. Dobson, R. Bessin. KY Ag Exp. Station.

- Handout. Hancock, T., and T.C. Leskey. 2013 Great Stink Bug Count preliminary results. USDA handout, pp 1-3.

- Production Guide: Pfeiffer, D. G., C. Johnson, K. S. Yoder and C. Bergh. 2014. Commercial Small Fruits: Disease and Insects. p. 2-1 – 2-16. In: 2014 Pest Management Guide for Horticultural and Forest Crops. Virginia Cooperative Extension Publication. 456-017.

- Production Guide: Pfeiffer, D. G., A. B. Baudoin, J. C. Bergh and M. Nita. 2014. Grapes: Diseases and Insects in Vineyards. p. 3-1 – 3-18. In: 2014 Pest Management Guide for Horticultural and Forest Crops. Va. Coop. Ext. Pub. 456- 017.

- Handout: Nielsen, A. and Blaauw, B. “Whole-farm Management Strategies for Brown Marmorated Stink Bug.” Distributed to growers at meetings.

- Morrison, R "Carrot and Stick: Luring the Brown Marmorated Stink Bug to an Early Demise" (http://www.youtube.com/watch?v=cjKqGf6esI4)


## Plans for Year Three

As the second year of our project finishes we are preparing for the third year of exciting research. In addition to the continuation of current research, in the third year we will:

- Objective 1: Trap cropping - In 2014 we conducted trap cropping trials at 11 sites at cooperating grower farms or research farms. Preliminary data looks promising but suggests that a killing agent may be needed under high population pressure. In Year 3 we will continue the same project, with the addition of a killing agent at high pressure sites; specifically baited pheromone traps to develop a 'pull-pull' system.

- Objective 2: Dispersal behavior - Whole-farm movement on-farm studies will be continued. Host plant volatiles that may contribute to nymphal host plant selection will be analyzed. Results from 2014 Great Stink Bug Count will be tabulated and analyzed.
- Objective 3: Natural Enemies - Surveys of egg mass predation and parasitism will continue. Instead of focusing video on egg mass predation, in NJ we will identify feeding guilds of various BMSB life stages. Molecular markers for identify of BMSB predators will be completed. Impact of insecticides on natural enemies will be conducted for a second year.
- Objective 4: Integration - Exclusion netting experiments are completed. Recommendations on the integration of key tactics such as trap cropping, insectary plantings and trap crop management, nymphal dispersal behavior will be developed.
- Objective 5: Extension and Outreach - In the final project year, we will develop and publish webinars, videos, factsheets on BMSB dispersal behavior, organic insecticides, trap cropping methods and impact by natural enemies.

## The OREI BMSB Team

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Dr. Tracy Leskey
**Virginia Tech**
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**West Virginia University**
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## Key personnel trained in 2014

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Jessica Blanchard
Alex Podosek
Cody Fust
Caleb Johnson
Bonnie Craighead
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Justin Leduc
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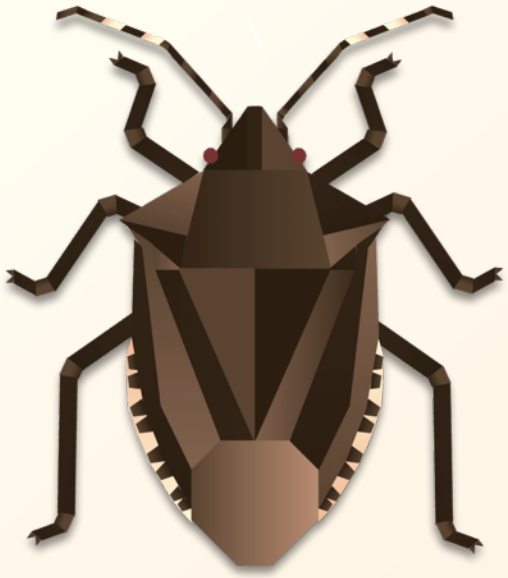

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United States Department of Agriculture
National Institute of Food and Agriculture

This document was created by Anne L. Nielsen and Brett R. Blaauw. January 2015.