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

Our long-term goals for this project are to develop economically and environmentally sustainable pest management practices for the brown marmorated stink bug (BMSB), Halyomorpha halys (Stål), in specialty crops and to implement a coordinated, rapid delivery system to disseminate critical information generated from this project to specialty crop end-users. USDA-NIFA SCRI # 2011-51181-30937

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 form and deliver practical outcomes.

PROJECT DIRECTORS

- Tracy Leskey, USDA-ARS
- George Hamilton, Rutgers University
- Cerruti Hooks, University of Maryland
- Grzegorz Krawczyk, Penn State University
- Jay Harper, Penn State University
- Chris Bergh, Virginia Tech
- Carrie Koplinka-Loehr, Northeastern IPM Center
- Peter Shearer, Oregon State University
- Jim Walgenbach, North Carolina State University
- Art Agnello, Cornell University
- Joanne Whalen, University of Delaware
- Jay Brunner, Washington State University
Researchers believe they have identified where brown marmorated stink bug (BMSB) gathers in natural landscapes during winter, and their findings could help farmers manage this invasive insect.

Doo-Hyung Lee, a postdoctoral research associate with USDA’s Agricultural Research Service, wants to understand precisely what the risks are to growers from BMSB overwintering in natural landscapes. Lee works with a team of scientists led by Tracy Leskey at the Appalachian Fruit Research Station in West Virginia.

“We know BMSB aggregate inside human-made structures in very high numbers,” Lee explains. “However, in the natural landscape, BMSB are spread out. They can be anywhere. They can remain unchecked by any management strategies, spreading randomly and building their population.”

If researchers could better understand stink bug behavior in the natural landscape, Lee reasoned, they would be able to develop a defense strategy for growers whose farms are located near woodlands. He and his colleagues ventured out into the woods to gather this information first-hand.

Treasure hunting

Lee began his search on a chilly, overcast, winter afternoon in a desolate Maryland forest. “I felt as though I was hunting for treasure with no map,” he recalls. He and his team randomly mapped out plots of Maryland and West Virginia forest, then explored these areas for BMSB hideouts. After searching among dead trees, both standing and fallen, as well as in leaf litter on the ground, they found 26 aggregations of BMSB, a 3% find rate.

Using what they had learned, the researchers developed a more specific profile of BMSB’s preferred winter setting: large, dry, dead standing trees, more than 60 cm in circumference, particularly oak and locust, with porous dead tissue and peeling bark that gives BMSB a place into which to crawl. Lee and his team then returned to the woods, targeting only trees that matched their profile. This time, they found BMSB in 33% of trees, a finding that seems to confirm a BMSB preference for this winter refuge.
From forest to farm

BMSB poses a huge risk to agriculture, Lee says, because 11 percent of trees in the natural landscape have the potential to harbor BMSB. Therefore, improving our ability to track BMSB movement from woodlands into agricultural areas is critical.

As Lee tracks the brown marmorated stink bug, he is deploying several high-tech tools, including a flight mill that measures the distance and speed a stink bug is able to fly. He hopes to publish detailed information about the insect’s flight capacity within the next year. For now, he cites Asian studies suggesting that BMSB is able to fly long distances and find new cultivated crops readily.

Lee is also pioneering use of harmonic radar to track stink bugs by mounting a tiny antenna to the back of the 17 mm-long insect. This device will relay signals to researchers wearing equipment that can reliably detect tagged bugs up to 50 meters away.

Humankind’s best friend soon will join the defense against its new pest, Lee predicts. Dogs trained to detect the scent of BMSB will make it easier to monitor and manage BMSB in agricultural areas.

Outbreak pest

BMSB is characterized in Asian studies as an outbreak pest, which means that the insect might go undetected for months or years before suddenly bursting on the scene in an agricultural area and causing much devastation. Now that we better understand the sites that provide winter refuge for BMSB, Lee believes, we will be better prepared to prevent future invasions of nearby farms.

Assisting Lee in his research were John Cullum, Sean Wiles, Starker Wright, Torri Hancock, Brent Short, and Cameron Scorza. The research is part of a broader Coordinated Agricultural Project entitled “Biology, Ecology and Management of the Brown Marmorated Stink Bug in Specialty Crops” that has been funded through the USDA-NIFA Specialty Crop Research Initiative.

“People are interested in our project because we are asking very basic questions about the biology of the insect that scientists have not looked at yet,” Lee said. “They are curious because our findings characterize the overwintering behavior of BMSB in the natural landscape. People are very excited.”

These words, while attempting scientific understatement, show the exhilaration of the entomologist who just found the keys to the BMSB hideout in the forest.

by CHRIS GONZALES

This research project supports objective 1: Establish biology and phenology of BMSB in specialty crops.
Native parasitoids hold promise in stink bug defense

Researchers suspect that our best defense against the brown marmorated stink bug (BMSB) could be a large group of parasitic wasps that would serve as natural control agents against the invasive pest. At a recent workshop in Newark, Delaware, entomologists shared critical information about native parasitoids that attack stink bugs in North America.

Kim Hoelmer, a USDA scientist who helped organize the event, is particularly interested in a group of tiny parasitic wasps that are very specialized in their choice of a host insect. Some types of parasitic wasps attack and develop inside spiders, beetles, or aphids; other groups are known to attack stink bugs.

The 24 researchers and graduate students who attended the workshop are expanding what is known about natural enemies of BMSB. They learned to distinguish the different kinds of natural enemies of BMSB so they would know whether parasitoids they encountered in the field were new or already reported elsewhere.

Each participant received a master key to identify native parasitoids of BMSB, which presented current observations previously scattered across different scientific journals. They practiced identification with unlabeled specimens—all known parasitoids of BMSB—and some brought unknown specimens they had collected in the field.

The parasitic wasp is very tiny, growing inside a host BMSB egg, emerging at maturity at 1.5 mm. Its small size presents challenges for researchers trying to study it, so workshop leaders shared special techniques for handling and mounting such small specimens. For example, Hoelmer explained, quality of microscope optics is an issue if you need to see whether or not a ridge on a part of the body is interrupted or runs from one side of the body to the other.

Armed with this information, researchers can use their knowledge to recognize locally important natural enemies of BMSB and to monitor the levels of parasitism in the field. Both are important parts of a strategy to control the invasive insect using natural means.
In a day and a half we presented tools and materials to help a keenly interested group of researchers identify natural enemies of BMSB," Hoelmer said. “I was amazed and astonished by the level of interest.”

The workshop, which Hoelmer led with colleagues Christine Dieckhoff, Kathy Tatman and Matt Buffington of USDA’s Agricultural Research Service, was part of a broader project entitled "Biology, Ecology, and Management of Brown Marmorated Stink Bug" that has been funded through the Specialty Crop Research Initiative. The University of Delaware let organizers use a teaching laboratory that was perfect for this event.

“We were expecting maybe 8 to 10 people would attend,” Hoelmer said, “but we found there was much greater interest. We had to turn away some due to lack of seats.” The group may plan another workshop to meet demand. To learn more, or to receive information about future workshops, contact Christine Dieckhoff.

by CHRIS GONZALES

An adult Trissolcus basalis female attacks an egg mass of the stink bug species Nezara viridula, similar in appearance to the eggs of brown marmorated stink bug. Several related Trissolcus species attack BMSB in its native Asian range and in North America. Source: M. Roche, USDA Agricultural Research Service European Biological Control Laboratory

This research project supports objective 2: Develop monitoring and management tools for BMSB.
Establishing parasitism and Predation Rates by Native Natural Enemies Attacking BMSB in Specialty Crops

Researchers from the University of Maryland and USDA-ARS have developed a brown marmorated stink bug (BMSB) natural enemy survey protocol for monitoring BMSB parasitism and predation using sentinel (colony-produced) and wild egg masses (laid in the field). The protocol was developed by Cerruti Hooks, an Assistant Professor in the Department of Entomology at the University of Maryland, and Kim Hoelmer, Research Entomologist currently serving as Director of the European Biological Control Laboratory, Montpellier, France, as a means to standardize procedures across the Biological Control team for the SCRI project.

Because biological control activity varies according to host plant and is influenced by location and surrounding landscapes, it is critical to obtain information from specialty cropping systems, neighboring field crops and natural landscapes. Surveys are being conducted across the country to determine levels of parasitism and predation and identify key species of natural enemies that are having an impact on BMSB survival.

Fifteen scientists from eight universities participated in the survey this year. Participants in this survey included: Christine Dieckhoff and Kathleen Tatman, USDA-ARS, working in natural landscapes; George Hamilton and Joyce Parker, Rutgers University, in peaches and blueberries; Doug Pfeiffer and Tom Kuhar, Virginia Tech, in grapes and vegetable crops, respectively; Paula Shrewsbury, Ashley Jones, and Cerruti Hooks, University of Maryland, in vegetables, field crops near vegetable systems, fruit and ornamentals; Mark Abney and Jim Walgenbach, North Carolina State University, in orchards, vegetable crops and natural landscapes; Shimat Joseph, Virginia Tech, in orchards and natural landscapes; Brian Kunkel and Joanne Whalen, University of Delaware, in ornamentals, sweet corn and Lima beans; Peter Shearer, Chris Hedstrom and Nik Wiman, Oregon State, in hazelnuts and wine grapes; and John Tooker and David Biddinger, Pennsylvania State University, in tomatoes and row crops.

The protocol required that participants use egg masses produced by laboratory-based colonies, and naturally laid wild egg masses in the field. Lab colony egg masses are deployed in the field as “sentinels”. Egg masses are attached to foliage for two to three days and then retrieved along with any wild egg masses, and returned to the laboratory. Presence and identity of predators and parasitoids seen on the egg masses are recorded during egg mass placement and retrieval. Any emerging parasitoids in the laboratory have been retained and sent to Kim Hoelmer’s laboratory for identification or identified by individuals trained at a two day parasitoid identification workshop sponsored by Kim Hoelmer, Christine Dieckhoff and other members of his Newark, DE Laboratory.
BMSB adults were also collected throughout the season to establish if they were attacked by tachinid flies. If tachinid eggs are found on adult BMSB, adults are taken to the laboratory to determine if eggs hatch, larvae successfully colonize BMSBs, and ultimately if adult flies emerge. Any BMSB life stages showing evidence of pathogen-infection also are being collected in field surveys for identification. In addition, David Biddinger has identified that predatory sand wasps, *Bicyrites quadrifasciatus*, are provisioning nests with BMSB nymphs in greater numbers compared with other stink bug species indicating these wasp are good predators of immature stages of BMSB. Some additional predators observed using BMSB eggs or nymphs as prey by Cerruti Hooks include the big-eyed (*Geocoris* sp.), minute pirate bug (*Orius* sp.), soft winged flower beetle and various spiders.

The following are results received to date from surveys conducted in 2011 and 2012. Using sentinel egg masses (Table 1), rates of parasitism ranged from 0.0% in tree of heaven in VA to as high as 6.2% in sweet corn in DE. Predation was higher, up to 34% in tree of heaven in VA. For wild egg masses (Table 2), parasitism rates were higher, as high as 32% in ornamentals. Notably, predation rates (combined with unknown mortality factors) in ornamentals also were very high (25.4%).

The preliminary results collected to date indicate that there are several species of stink bug natural enemies native to North America that are having an impact on BMSB populations. These results vary according to cropping systems and regions, but they offer another mechanism that can contribute to overall management of BMSB.

This research project supports objective 2: Develop monitoring and management tools for BMSB.
Table 1: Results of sentinel egg mass surveys in 2012

<table>
<thead>
<tr>
<th>System</th>
<th>Host</th>
<th>Institution</th>
<th>Deployment Location</th>
<th>Egg Masses</th>
<th>Eggs</th>
<th>Parasitism Total (%)</th>
<th>Predation Total (%)</th>
<th>BMSB Nymphs Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable</td>
<td>sweet corn</td>
<td>UDEL</td>
<td>Interior</td>
<td>11</td>
<td>323</td>
<td>20 (6.2)</td>
<td>49 (15.2)</td>
<td>81 (25.1)</td>
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<tr>
<td>Vegetable</td>
<td>Lima beans</td>
<td>UDEL</td>
<td>Interior</td>
<td>3</td>
<td>63</td>
<td>0</td>
<td>29 (46)</td>
<td>0</td>
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<tr>
<td>Orchard Crops</td>
<td>hazelnut cane-</td>
<td>OSU</td>
<td>Adjacent</td>
<td>72</td>
<td>1530</td>
<td>93 (6.1)</td>
<td>206 (13.5)</td>
<td>48 (3.1)</td>
</tr>
<tr>
<td>Small Fruit</td>
<td>berry blueberry</td>
<td>OSU</td>
<td>Adjacent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Fruit</td>
<td></td>
<td>OSU</td>
<td>Adjacent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild Host</td>
<td>Tree of Heaven</td>
<td>VT</td>
<td>Interior</td>
<td>22</td>
<td>538</td>
<td>0</td>
<td>185 (34)</td>
<td>168 (31)</td>
</tr>
<tr>
<td>Orchard Crops</td>
<td>Apple</td>
<td>PSU</td>
<td>Adjacent</td>
<td>243</td>
<td>6059</td>
<td>6 (0.1)</td>
<td>--</td>
<td>3867 (63.8)</td>
</tr>
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</table>

1 OSU results combined across crops

Table 2: Results of wild egg mass surveys in 2011 and 2012

<table>
<thead>
<tr>
<th>System</th>
<th>Host</th>
<th>Institution</th>
<th>Deployment Location</th>
<th>Egg Masses</th>
<th>Eggs</th>
<th>Parasitism Total (%)</th>
<th>Predation Total (%)</th>
<th>BMSB Nymphs Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable</td>
<td>sweet corn</td>
<td>UDEL</td>
<td>Interior</td>
<td>2</td>
<td>56</td>
<td>16 (28.6)</td>
<td>10 (17.9)</td>
<td>30 (53.6)</td>
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<tr>
<td>Vegetable</td>
<td>Eggplant²</td>
<td>UMD</td>
<td>Interior</td>
<td>2</td>
<td>522</td>
<td>121 (23.2)</td>
<td>180 (34.5)</td>
<td>221 (42.3)</td>
</tr>
<tr>
<td>Field Crop</td>
<td>field corn²</td>
<td>UMD</td>
<td>Interior</td>
<td>923</td>
<td>529</td>
<td>529 (57.3)</td>
<td>310 (33.6)</td>
<td>84 (9.1)</td>
</tr>
<tr>
<td>Ornamentals</td>
<td>Acer rubrum</td>
<td>UMD</td>
<td>Interior</td>
<td>–</td>
<td>5729</td>
<td>1089 (19)</td>
<td>1075 (18.8)</td>
<td>3565 (62.2)</td>
</tr>
<tr>
<td>Ornamentals</td>
<td>Prunus kwanzan</td>
<td>UMD</td>
<td>Interior</td>
<td>–</td>
<td>7435</td>
<td>2380 (32)</td>
<td>1850 (24.9)</td>
<td>3205 (43.1)</td>
</tr>
<tr>
<td>Ornamentals</td>
<td>Ulmus</td>
<td>UMD</td>
<td>Interior</td>
<td>–</td>
<td>10960</td>
<td>3791 (34.6)</td>
<td>2780 (25.4)</td>
<td>4389 (40)</td>
</tr>
<tr>
<td>Ornamentals</td>
<td>Acer rubrum</td>
<td>UMD</td>
<td>Interior</td>
<td>–</td>
<td>5729</td>
<td>1089 (19)</td>
<td>1075 (18.8)</td>
<td>3565 (62.2)</td>
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<td>Ornamentals</td>
<td>Prunus kwanzan</td>
<td>UMD</td>
<td>Interior</td>
<td>–</td>
<td>7435</td>
<td>2380 (32)</td>
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<td>3205 (43.1)</td>
</tr>
<tr>
<td>Ornamentals</td>
<td>Ulmus</td>
<td>UMD</td>
<td>Interior</td>
<td>–</td>
<td>10960</td>
<td>3791 (34.6)</td>
<td>2780 (25.4)</td>
<td>4389 (40)</td>
</tr>
<tr>
<td>Orchard Crops</td>
<td>hazelnut</td>
<td>OSU³</td>
<td>Adjacent</td>
<td>240</td>
<td>6333</td>
<td>257 (4)</td>
<td>226 (3.5)</td>
<td>4994 (78.9)</td>
</tr>
<tr>
<td>Small Fruit</td>
<td>caneberry</td>
<td>OSU</td>
<td>Adjacent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Fruit</td>
<td>blueberry</td>
<td>OSU</td>
<td>Adjacent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>Mixed²</td>
<td>VT</td>
<td>Interior</td>
<td>9</td>
<td>226</td>
<td>48 (21.2)</td>
<td>--</td>
<td>--</td>
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<tr>
<td>Wild Host</td>
<td>tree of heaven²</td>
<td>VT</td>
<td>Adjacent</td>
<td>96</td>
<td>2449</td>
<td>155 (6.3)</td>
<td>--</td>
<td>--</td>
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<tr>
<td>Vegetables</td>
<td>mixed</td>
<td>VT</td>
<td>Interior</td>
<td>13</td>
<td>208</td>
<td>82 (39.4)</td>
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<td>VT</td>
<td>Adjacent</td>
<td>111</td>
<td>2964</td>
<td>122 (4.1)</td>
<td>--</td>
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</table>

¹Includes other unascribed mortality factors in some locations; ²Results collected in 2011; ³OSU results combined across crops
Scientists draw maps to stop stink bug pirates

A monitoring system set up in the early 1980s to track common vegetable pests in New Jersey has led to a treasure trove of maps about a new invader, the brown marmorated stink bug (BMSB). Scientists are analyzing the maps to stop BMSB from pirating a wide range of fruit and vegetables in North America.

George Hamilton, an entomologist and extension specialist at Rutgers University, leads a team that is using this valuable store of historic information about BMSB movement to help them predict future BMSB activity across other regions.

The 2004 invasion

“In 1999, we first detected BMSB in New Jersey,” Hamilton said. “In 2004, Anne Nielsen and I monitored an invasion of BMSB as it came into Philipsburg, NJ, right across the river from Allentown, PA.” Nielsen is an extension specialist in fruit entomology at Rutgers who at the time was a PhD student studying BMSB. Since then, Hamilton and his team have followed the expansion of BMSB throughout New Jersey using a statewide network of black light traps. Growers, working with scientists, had installed a series of 70 or more black light traps on their farms in the early 1980s, sentinels against the European corn borer and corn earworm. This integrated pest management program has been running continuously, albeit with modifications such as new computer technology, for more than 30 years.

Hamilton’s group prepares weekly statewide maps of their BMSB catches in New Jersey. These maps signal to growers where hotspots—rising numbers of BMSB and other pests—are found.

In 2004, they did what they could to warn growers to check their crops, but at the time BMSB was not classified as an agricultural pest. “What we can do now,” Hamilton said, “is more accurate hotspot identification.”
How growers use this information

Scientists use the maps to track insect counts, distance, and time. This information helps them estimate how quickly BMSB reproduces and how far it travels. The predictions about what areas may be at risk are immensely valuable for growers. As Hamilton knows, it’s hard work to go into the field, collect samples, and update the database. Yet for growers who live in areas where BMSB is getting established, these reports could mean the difference between a healthy harvest and crop losses.

One of Hamilton’s PhD students, Noel Hahn, has been studying BMSB movement in and out of orchards. In 2012 he visited orchards weekly, sampling specific trees on the borders and in the middle, and noting land-use types. He analyzes landscape features and tries to determine statistically from where BMSB is invading. Adam Wallner, a post-doctoral researcher with Rutgers trained in geospatial relationships and statistics, is working on making forecasts and predicting trends.

Accurate maps, useful forecasting

Today scientists seek out the maps made from historical data, wanting to understand what it looks like when BMSB invades new territory.

Hamilton has created maps of his team’s data since 2010, but he can map any year by going back to the 1980s-era vegetable and pest monitoring system. “We can look at the [2004] invasion as if it were happening in real time. We can assess how fast BMSB mates, how far it can move every year. I’m aware of only a few invading pests—the emerald ash borer would be one—where we had such an extensive monitoring system already in place.”

Bringing maps to growers on the Internet

“Three years ago,” Hamilton said, “we started publishing these maps. We put them in our newsletters. Growers can receive our newsletters, go to the website, and find BMSB hotspots. If there is a BMSB hotspot in their area, they should go out in their fields, looking themselves. If they find BMSB, they will need to make their own management decisions.”

The map research is part of a broader Coordinated Agricultural Project entitled “Biology, Ecology and Management of the Brown Marmorated Stink Bug in Specialty Crops” that has been funded through the USDA-NIFA Specialty Crop Research Initiative.

“Other states are calling us about this program,” Hamilton said, with a touch of reserved pride. “Michigan, California, and Oregon have contacted us to learn more about it.”

by CHRIS GONZALES

A map shows the intense BMSB activity of July, 2011, illustrating the potential of mapping to warn growers about pest risk. Source: G. Hamilton, Rutgers University

This research project supports objective 2: Develop monitoring and management tools for BMSB.
The Race to Identify the BMSB Aggregation Pheromone

Monitoring tools are used to assess the presence, abundance, and seasonal activity of pest species to allow growers to make informed management decisions. Certainly, the need for a reliable monitoring tool for BMSB is critical based on their season-long activity and devastating damage to so many crops. Scientists at the ARS Invasive Insect Biocontrol and Behavior Laboratory (IIBBL) in Beltsville, Maryland have been leading research efforts to identify attractants for BMSB. Previously, researchers had demonstrated that methyl (2E, 4E, 6Z)-decatrienoate (MDT) was a sensitive late-season attractant for BMSB with adults actively responding to this stimulus beginning in mid-August. MDT, is in fact, the pheromone of another Asian stink bug species, *Plautia stali*, but is cross-attractive to BMSB adults late in the season. Unfortunately, this compound is not attractive to adults in the early- or mid-season—resulting in the critical need for a season-long attractant to increase the sensitivity of monitoring tools.

Led by efforts of Ashot Khrimian, the aggregation pheromone of BMSB was tentatively identified. In September 2011, field trials conducted in Kearneysville, WV and Beltsville, MD, revealed that male-produced compounds were very attractive to BMSB adults. However, the timing of this trial also led to a critical question of early-season attraction. Based on the positive responses from adults in a small pre-trial, a larger multi-state trial was initiated. In this case, standard black pyramid traps baited with 10mg lures of the BMSB aggregation pheromone—also known as #10 were compared with traps baited with Rescue MDT (Sterling) lures and unbaited traps.

Traps were deployed at the interface between agricultural production and wild, unmanaged habitat in mid-to-late April and left in place until late October. Trapping sites included tree fruit orchards, small fruit plantings such as blueberries, vineyards, ornamental nurseries, and vegetable plantings in DE, MD, MI, NC, NY, PA, NJ, OR, VA, WA, and WV.
Results are summarized in Table 1. Throughout the early season, traps baited with #10 reliably captured BMSB adults. By mid-summer, these same traps also were capturing nymphs, although numbers were low in many locations. Traps baited with #10 continued to attract BMSB in the late-season.

Traps baited with MDT were not attractive to BMSB adults in the early-season. However, as nymphal populations began to increase, traps baited with MDT captured these immature stages. Beginning in mid-August, adults also responded strongly to MDT. MDT is an extremely attractive stimulus to adults in the late-season. The MDT lures used in this study had ~10x more material per lure compared with #10 lures; this obvious difference in release rates was apparent in late-season captures. Unbaited traps captured very few BMSB season-long.

Overall, these results are encouraging and point to the promise of a sensitive monitoring tool for BMSB detection and monitoring in the near future. In addition, the potential for combining stimuli including light-based cues could further enhance our capacity to reliably detect BMSB. As the SCRI project continues, these approaches as well as questions of trap type, capture mechanism and deployment strategy will be addressed.

Table 1. Mean number and total (in parentheses) of BMSB adults and nymphs captured per trap per sampling period across all states and sampling sites.

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Sampling Period</th>
<th>#10</th>
<th>MDT</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>Early (mid-April to mid-June)</td>
<td>3.2 (280)</td>
<td>0.4 (34)</td>
<td>0.3 (22)</td>
</tr>
<tr>
<td></td>
<td>Middle (mid-June to mid-August)</td>
<td>7.2 (644)</td>
<td>5.4 (482)</td>
<td>0.7 (61)</td>
</tr>
<tr>
<td></td>
<td>Late (late-August to late-October)</td>
<td>50.4 (4489)</td>
<td>172.3 (15332)</td>
<td>7.7 (687)</td>
</tr>
<tr>
<td>Nymph</td>
<td>Early (mid-April to mid-June)</td>
<td>0.02 (2)</td>
<td>0.1 (11)</td>
<td>0.0 (0)</td>
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<td></td>
<td>Middle (mid-June to mid-August)</td>
<td>60.2 (5356)</td>
<td>144.5 (12856)</td>
<td>7.7 (687)</td>
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<tr>
<td></td>
<td>Late (late-August to late-October)</td>
<td>48.8 (4342)</td>
<td>166.8 (14849)</td>
<td>7.4 (663)</td>
</tr>
</tbody>
</table>

*This research project supports objective 2: Develop monitoring and management tools for BMSB.*
In September 2012, the Northeastern IPM Center launched the StopBMSB.org website to report the latest research findings and outreach efforts. Content also includes a photo identification guide and state-by-state map depicting the presence and pest status of BMSB across the country. StopBMSB.org provides information about our team's efforts to control brown marmorated stink bug (BMSB), through funds provided by the USDA's Specialty Crop Research Initiative.

This research project supports objective 4: Integrate stakeholder input and research findings to form and deliver practical outcomes.
Project Outputs

Research Publications


Research Talks


Leskey, T.C. and S.E. Wright. (2011). Entomological Society of America. Integrating olfactory and visual stimuli as attractants for BMSB. Reno, NV.


Wright, S.E. and T.C. Leskey. (2011). Cumberland-Shenandoah Fruit Workers’ Conference. Laboratory and field evaluations of insecticides for control of brown marmorated stink bug. Winchester, VA.

Research Posters


Research Workshops/Meetings/Symposia


Research Oriented Websites and Digital Products

Use of Citizen Science-based data to track BMSB throughout NYS.
http://imapinvasives.org/nyimi/map/ IPMNET website with BMSB fact sheets and section devoted to current BMSB research at University of Maryland BMSB Updates http://ipmnet.umd.edu/bmsb/index.htm

Scholar site for BMSB Working Group maintained at Virginia Tech (http://scholar.vt.edu) (by enrollment only)

ENY Brown Marmorated Stink Bug Project: http://hudsonvf.cce.cornell.edu/bmsb1.html (incorporates Flash and Vimeo movies of presentations on BMSB for tree fruit and small fruit growers, plus additional websites and online resources)

StopBMSB.org website. The Northeastern IPM Center, with input from collaborators, created the website. This fully searchable website offers original articles about BMSB research, state specific BMSB sites, updates on the impact of BMSB, RSS (syndication), feed alerts for updated material, and links to Facebook and Twitter.

Brown Marmorated Stink Bug in NC. Includes extension articles and a map of distribution in NC. http://www.ces.ncsu.edu/fletcher/programs/apple/entomology/BMSB/index.html

Oregon State University BMSB website: http://BMSB.hort.oregonstate.edu. The website was initiated in June has had ca. 1,037 page views from all 50 states and 17 countries.

PSU based web site: stinkbug-info.org to track BMSB populations PSU Department of Entomology, BMSB factsheet - 166,280 page views 138,650 were page views by first time viewers.


Rutgers BMSB Iphone/Ipad AP http://www.pestmanagement.rutgers.edu/IPM/Vegetable/Pest%20Maps/maparchive.htm#2011 http://njaes.rutgers.edu/stinkbug/


**Extension Workshops, Field Days, Trainings and Talks**

The extension outreach efforts of all institutes were combined to summarize all workshops, field days, training, and talks covering BMSB in specialty crops.

<table>
<thead>
<tr>
<th>Institute</th>
<th>Outreach/Education Events Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornell</td>
<td>17</td>
</tr>
<tr>
<td>NC State</td>
<td>12</td>
</tr>
<tr>
<td>Northeastern IPM Center</td>
<td>2</td>
</tr>
<tr>
<td>OSU</td>
<td>18</td>
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<tr>
<td>Penn State</td>
<td>33</td>
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<td>Rutgers</td>
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<td>UMD</td>
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<td>USDA-ARS</td>
<td>14</td>
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<tr>
<td>VT</td>
<td>18</td>
</tr>
<tr>
<td>WA State</td>
<td>42</td>
</tr>
</tbody>
</table>
Extension and Outreach Publications


Cornell "Grower Alerts" to Hudson Valley pome fruit growers (7 alerts sent to 317 Hudson Valley growers and extension staff in 6 states via email throughout the 2012 growing season, plus 2 additional more detailed "Pest Alerts" sent to growers and put onto ENY BMSB website).

Cornell Scaffolds article, "Update on the BMSB in the Hudson Valley" 25 June 2012.


New Leveraged/Complementary Resources


PSU. State Horticultural Association of Pennsylvania. Understanding biology and behavior of brown marmorated stink bug as a basis for development of management programs in fruit orchards. $24,922.

PSU. Pennsylvania Apple Marketing Board. 2012. Late season injury on fruit caused by brown marmorated stink bug: monitoring, management and prevention. $25,000)

Rutgers. Whole-farm Organic Management of BMSB and Endemic Pentatomids Through Habitat Manipulation. USDA-NIFA Organic Research and Extension Initiative. $2.6M. A. Nielsen, PD.


UMD. Butler, B.R., Sr. Northeastern SARE. BMSB control with surround on Peaches. $1,000.

UMD. Gill, S. K. Rane, B. Kunkel. Maryland Nursery and Landscape Association - $5000 grant to support trials on BMSB damage to herbaceous annuals and perennials.
2012 Summary Report Year 1

USDA-ARS. Identifying natural overwintering sites of BMSB using USDA-APHIS detector dogs. $15,000.

USDA-ARS and Rutgers. Northeastern IPM Center. BMSB IPM Working Group. $15,000.


Selected Media contacts and Press Coverage

Print


Oregonian “Oregon researchers sic a tiny wasp on crop-killing brown marmorated stink bug,”, By Eric Mortenson.


Pittsburgh Post Gazette. “Stink bugs return to Pittsburgh area” by Kaitlynn Reily, October 5, 2012.


Pittsburgh Post-Gazette. June 20, 2012. “Where have all the stink bugs gone?” by Emily Dobler.

Baltimore Sun, Miami Herald, Kansas City Star. February 5, 2012. “Storms may have killed off many stink bugs” by Candus Thomson.


An Unprecedented Threat: article written by Joy Drohan based on interview with BMSB NIFA SCRI participants. Published in Penn State AgScience Magazine. Summer /Fall 2012 pp: 26-31

**Broadcast**

WBAL TV, S. Gill, interview on BMSB for an episode of The Sunday Gardener on late March, 2012
KWG NEWS ‘Stink bug’ threatens NW farms, vineyards, Keeley Chalmers, Oregon
UDel Wilmington Radio Spots - B. Kunkel
VT WDBJ TV news 28 Sep 2012, "Stink bugs invading Virginia"

**Commodity Press**

Lancaster Farming. November 19, 2011 “Stink Bug Numbers Show Overall Decline “ by Ayleen Stelhorn
Growing Produce. August 31, 2011. “Beast of the East” by Brian Sparks
## PROJECT INVESTIGATORS

### USDA/ARS
- Tracy Leskey
- Starker Wright
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- Ashot Khrimian
- Aijun Zhang
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### Rutgers University
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- Shelby Fleischer
- Gary Felton
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- Vaughn Walton
- Silvia Rondon
- Jeffrey Miller

### Cornell University
- Art Agnello

### Washington State Univ
- Jay Brunner

### Northeastern IPM Center
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### North Carolina State Univ
- Jim Walgenbach
- Mark Abney

### University of Delaware
- Joanne Whalen
- Brian Kunkel
Stakeholder Advisory Panel

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

**Member Name, Affiliations, and State**

George Behling, Tree Fruit Grower and Owner, Nob Hill Orchards, WV
Robert Black, Fruit and Vegetable Grower, Catoctin Mt. Orchards; Treasurer, Maryland State Horticultural Society, MD
Steve Black, Nursery Owner, Raemelton Farm, MD
Bunky Dulin, Sweet Corn Processor, S.E.W. Friel, DE/MD
Dan Flick, Tree Fruit Grower; Chair, WTFRC Apple Crop Protection Committee; Business Development manager, Wilbur Ellis, WA
Susan Futrell, Director of Marketing, Red Tomato, MA
Art Galleta, Executive Chair, US Highbush Blueberry Council, NJ
Tom Green, President, IPM Institute of North America, WI
Ken Gauen, Lima Bean Processor, Pictsweet, DE/MD
Tom Haas, Tree Fruit Grower and Owner, Cherry Hill Orchards; Dir. of Field Operations, Cherry Hill Orchards Outlet; Member SHAP Executive Board, PA
Brad Hollabaugh, Tree Fruit Grower, General Manager and Co-Owner, Hollabaugh Bros, Inc., PA
Rick Hood, Organic Grower, Summer Creek Farm, MD
Doug Inkley, Senior Scientist, National Wildlife Federation, MD/DC
Tom Kelly, Vineyard Manager, Rappahannock Cellars, VA
Joseph Kovach, Associate Professor of Entomology, Ohio State University, OH
Christian Krupke, Associate Professor of Entomology, Purdue University, IN
Edith Lurvey, Northeast Region Field Coordinator, IR-4 Project, Cornell University, NY
Santo John Maccherone, Fruit Grower, Circle M Farms; Chair, New Jersey Peach Promotion Council, NJ
Clarissa Mathews, Vegetable and Ornamental Grower, Redbud Organic Farm; Professor of Environmental Studies, Shepherd University, WV
Nathan Milburn, Fruit and Vegetable Grower, Milburn Orchards, MD; Board of Directors, International Fruit Tree Association; National Berry Crop Initiative; Vice President, North American Raspberry and Blackberry Association, MD
Guy Moore, Fruit and Vegetable Grower, Larriland Farms; President, Maryland Vegetable Growers Association, MD
Phil Neary, Director of Operations and Grower Relations, Sunny Valley International, NJ
Rob Neenan, Vice President, California League of Food Processors, CA
Mark Orr, Fruit, Vegetable, and Ornamental Grower; President, Orr’s Farm Market & Orchard, WV
Kay Rentzel, Managing Director, National Peach Council, PA
John Saunders, Fruit and Vegetable Grower, Silver Creek Orchards, VA
Mark Seetin, Director, Regulatory and Industry Affairs, US Apple, VA
Rob Shenot, Fruit and Vegetable Grower, Shenot Farms; Vice President, Pennsylvania Vegetable Growers Association, PA
H. Lee Showalter, Grower Services and Food Safety Manager, Rice Fruit Co., PA
Chad Vargas, Vineyard Manager, Adelsheim Vineyards, OR
Tyler Wegmeyer, Director of Congressional Relations, American Farm Bureau Federation, WV/DC
John Wise, Associate Professor, Michigan State University; Research and Extension Coordinator, MSU Trevon Nichols Research Complex, MI