Developing Strategies to Manage the Invasive Brown Marmorated Stink Bug Through Cooperative, Collaborative and Integrated Initiatives

Tracy C. Leskey
USDA- ARS
Appalachian Fruit Research Station
Kearneysville, WV 25430 USA

USDA

Stop BMSB

My Introduction to BMSB on October 8, 2003

SEL
Service
Information
Research
Systematic Entomology Laboratory

BMSB Confirmation

The enclosed identifications have been provided by Research Entomologists of the Systematic Entomology Laboratory, USDA, and represent a complete report on the specimens submitted with your request of 2003-10-09

The specimens except as noted, will be returned under separate cover. Thank you for any specimens kept for the U.S. National Collection.

Please send SEL/CTSU copies of publications in which the following identifications are reported. In reporting idenifications in publications, please cite the names of taxonomists, the taxon (e.g. family) or groups of taxa each was responsible for, and the employer affiliation. The following suggested formats are for SEL employees and employees of the Smithsonian Institution; a similar format should be used for our Cooperating Scientists at other institutions:

Name of Taxonomists (taxon), Systematic Entomology Laboratory, Agriculture Research Service, US Department of Agriculture

Name of Taxonomists (taxon), Department of Entomology, Smithsonian Institute

---IDENTIFICATIONS---

Hemiptera
Heteroptera
Pentatomidae
Halyomorpha halys Stal
Note: Apparent new state record for Maryland.
---Determined October 9, 2003 by Thomas J. Henry
Research Entomologist, SEL

Are There More?

Are There More?

None in Our Trapping Studies or On Crops

Early Research Efforts

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

J. Agric. Food Chem. 2008, 56, 197–203 197

Field Trapping of the Invasive Brown Marmorated Stink Bug, *Halyomorpha halys*, with Geometric Isomers of Methyl 2,4,6-Decatrienoate

ASHOT KHRIMIAN,*,[†] PETER W. SHEARER,[‡] AIJUN ZHANG,[†] GEORGE C. HAMILTON,[§] AND JEFFREY R. ALDRICH[†]

Invasive Insect Biocontrol and Behavior Laboratory, United States Department of Agriculture, Agricultureal Research Service, Beltsville Agricultural Research Center, Bldg. 007, Rm. 301, 10300 Baltimore Avenue, Beltsville, Maryland 20705, Agricultural Research and Extension Center, Rutgers University, 121 Northville Rd., Bridgeton, New Jersey 88302-5919, and Department of Entomology, Rutgers University, Blake Hall, 93 Lipman Drive, New Brunswick,

INSECTICIDE RESISTANCE AND RESISTANCE MANAGEMENT

Toxicity of Insecticides to *Halyomorpha halys* (Hemiptera: Pentatomidae) Using Glass-Vial Bioassays

ANNE L. NIELSEN,[1] PETER W. SHEARER, AND GEORGE C. HAMILTON

Department of Entomology, Rutgers University, 93 Lipman Drive, New Brunswick, NJ 08901

J. Econ. Entomol. 101(4): 1439–1442 (2008)

ECOLOGY AND POPULATION BIOLOGY

Life History of the Invasive Species *Halyomorpha halys* (Hemiptera: Pentatomidae) in Northeastern United States

ANNE L. NIELSEN[1] AND GEORGE C. HAMILTON

Department of Entomology, Rutgers University, 93 Lipman Drive, New Brunswick, NJ 08901

Ann. Entomol. Soc. Am. 102(4): 608–616 (2009)

PHYSIOLOGICAL ECOLOGY

Developmental Rate Estimation and Life Table Analysis for *Halyomorpha halys* (Hemiptera: Pentatomidae)

ANNE L. NIELSEN,[1] GEORGE C. HAMILTON, AND DEEPAK MATADHA

Department of Entomology, Rutgers University, 93 Lipman Dr., New Brunswick, NJ 08901

Environ. Entomol. 37(2): 348–355 (2008)

HORTICULTURAL ENTOMOLOGY

Seasonal Occurrence and Impact of *Halyomorpha halys* (Hemiptera: Pentatomidae) in Tree Fruit

ANNE L. NIELSEN[1] AND GEORGE C. HAMILTON

Department of Entomology, Rutgers University, 93 Lipman Dr., New Brunswick, NJ 08901

J. Econ. Entomol. 102(3): 1133–1140 (2009)

SEMIOCHEMICALLY BASED MONITORING OF THE INVASION OF THE BROWN MARMORATED STINK BUG AND UNEXPECTED ATTRACTION OF THE NATIVE GREEN STINK BUG (HETEROPTERA: PENTATOMIDAE) IN MARYLAND

J. R. ALDRICH[1],*, A. KHRIMIAN[1], X. CHEN[3]** AND M. J. CAMP[2]

[1]Invasive Insect Biocontrol & Behavior Laboratory, Agricultural Research Service, United States Department of Agriculture, B-007, rm 313, Agricultural Research Center-West, Beltsville, MD 20705

[2]Biometrical Consulting Service, Agricultural Research Service, United States Department of Agriculture, B-005, Agricultural Research Center-West, Beltsville, MD 20705

[3]Department of Entomology, University of California, Riverside CA 92521

*To whom correspondence should be addressed. E-mail: Jeffrey.Aldrich@ars.usda.gov

**Present address: Small Molecule Synthesis Facility, Chemical Biology Program, Department of Chemistry, Duke University, Durham, NC 27708-0354

Photos from AFRS Late 2008

2008-2009 Late Season Problems Detected Four Years After First Detections

Some growers already losing

10% of crops

First Sample From First Trapping Study October 11, 2009

Over 2000 adults captured in a single day

First Reports of Widespread Early Season Activity in Orchard CRops April – June 2010



Widespread BMSB Injury in Stone Fruit Identified Late June 2010


Many Mid-Atlantic
Growers Experienced
Catastrophic Damage
Levels of
>50%
in Stone Fruit Crops

Widespread Severe Damage

In Fruit, Vegetables, and Row Crops

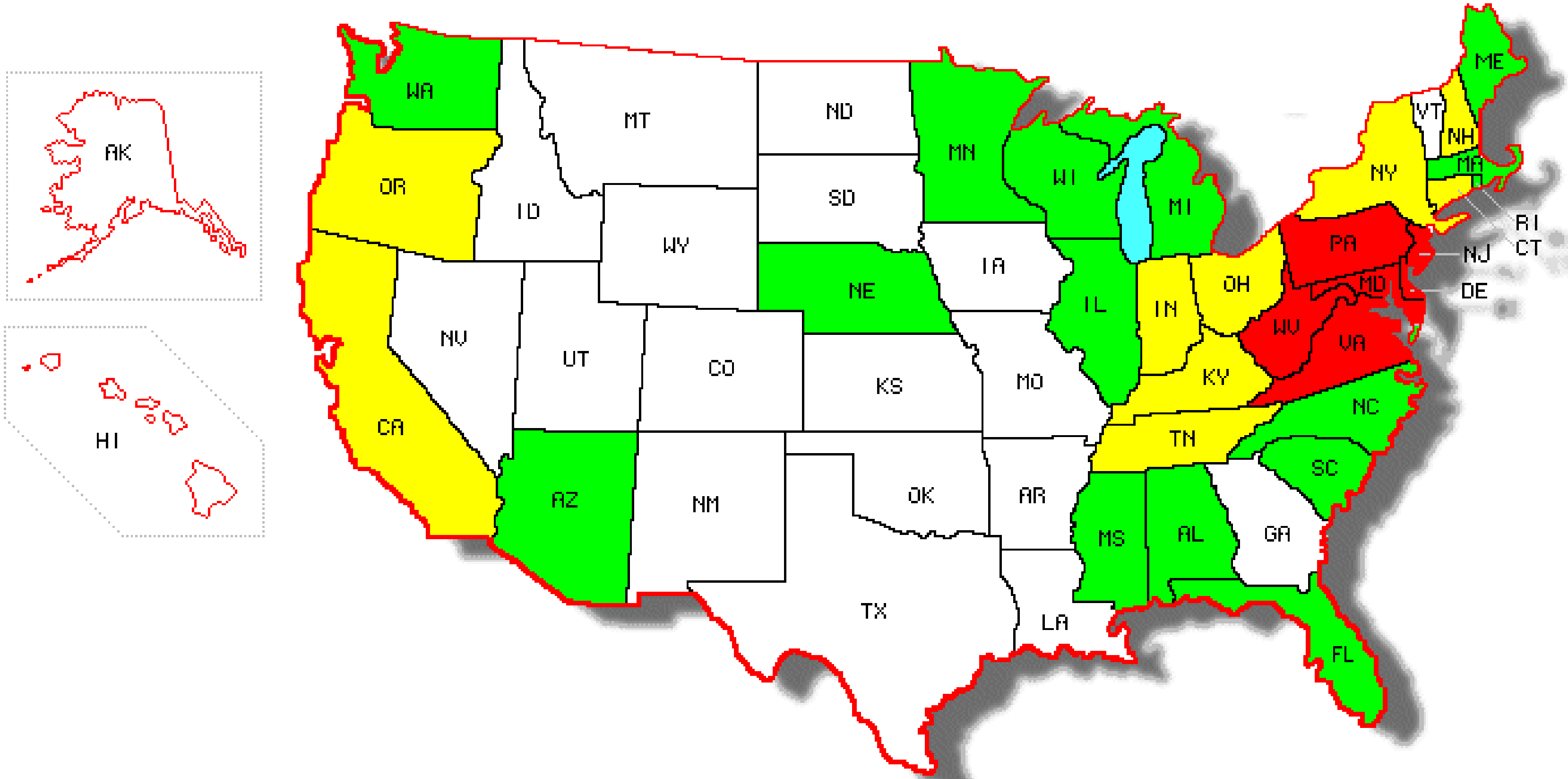
2010 BMSB Outbreak in Mid-Atlantic


$37 Million
In Losses For
Mid-Atlantic Apple
Growers
Leskey et al. 2012 a,b

Catoctin Mountain and Gardenhour Orchards
Emergency BMSB Meeting
September 3, 2010

Photos courtesy of Doug Pfeiffer

Congressional Briefings



- Severe Agricultural and Nuisance Problems Present
- Nuisance Problems Only
- Detected

BBC WORLD SERVICE

The New York Times

THE DIANE REHM SHOW

One of her guests is always you.

WAMU 88.5 | npr

The Washington Post

science friday npr

THE WALL STREET JOURNAL

TIME

CNNMoney

C-SPAN

CBS NEWS

CBC news

USA TODAY

GOOD MORNING AMERICA

VOA Voice of America

The Philadelphia Inquirer

NATIONAL GEOGRAPHIC

THE SUN

www.baltimoresun.com

FOX NEWS channel

abc NEWS

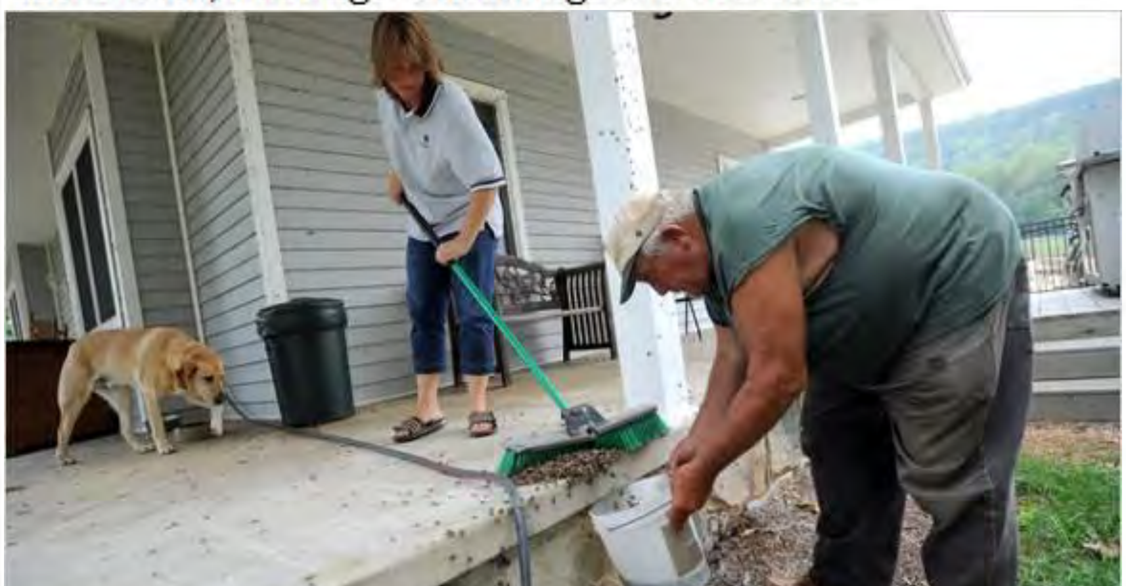
Los Angeles Times

Widespread Nuisance Problems For Homeowners and Businesses

The New York Times

U.S.

Move Over, Bedbugs: Stink Bugs Have Landed



Kelli Wilson and her father, Richard Lee Pry, cleared stink bugs from her porch Friday in Burkittsville, Md. The shield-shaped invaders have damaged fruit and vegetable crops.

One Homeowner's Plight

"This weekend I vacuumed up more than 8,000 stink bugs (vast majority were alive) in my attic, to add to the now more than 4,000 I've removed from my living space since 1/1/2011.

I have now destroyed 12, 348 stink bugs in my home in 45 days since January 1, 2011.

After all the effort this weekend, another 100+ found their way into my kitchen (a two year old addition) Sunday afternoon."

-near Harpers Ferry, WV

Building A Collaborative Team

Northeastern IPM Center

Search

We promote and fund integrated pest management for environmental, human health, and economic benefits.

Got Pests? Need Funding?

- HOME
- ABOUT US
- IPM IN ACTION
- GRANT PROGRAMS
- WORKING GROUPS
  - Marmorated Stink Bug
  - Pollinator
  - Spotted Wing Drosophila
  - More Working Groups
- PARTNERS IN IPM
- IPM PLANNING

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HOME » WORKING GROUPS » Marmorated Stink Bug » Membership

Membership - BMSB IPM Working Group

Members of the BMSB IPM Working Group met at Virginia Tech in December 2013.

LEADERS

Tracy Leskey
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Appalachian Fruit Research Station
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Kearneysville, WV 25430
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George Hamilton
Extension Specialist in Pest Management
Professor of Entomology and Chair
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New Brunswick, NJ 08901
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Apple growers George Behling, Bill Gardenhour, and Bob Black tell researchers at the BMSB Task Force Meeting of the damage caused by the BMSB in their orchards and the difficulty they experienced in trying to control the pest.

Grower And Consultant Experiences

Tree Fruit Grower

- BMSB had become their most important pest by 2008.
- Extreme damage to peaches, apples, Asian pear and raspberries.

Crop Consultant

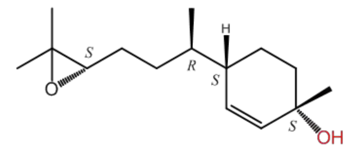
- Relying on mid- and late-season pyrethroids, creating a treadmill effect.
- Need a monitoring tools and control options that do not disrupt beneficials.

Organic Grower

- Severe damage on a range of fruiting vegetables including snap peas, green beans, heirloom and hybrid tomatoes, peppers, and raspberries.

Research Priorities

Studies of BMSB Biology, Behavior and Ecology



Identification of Aggregation Pheromone

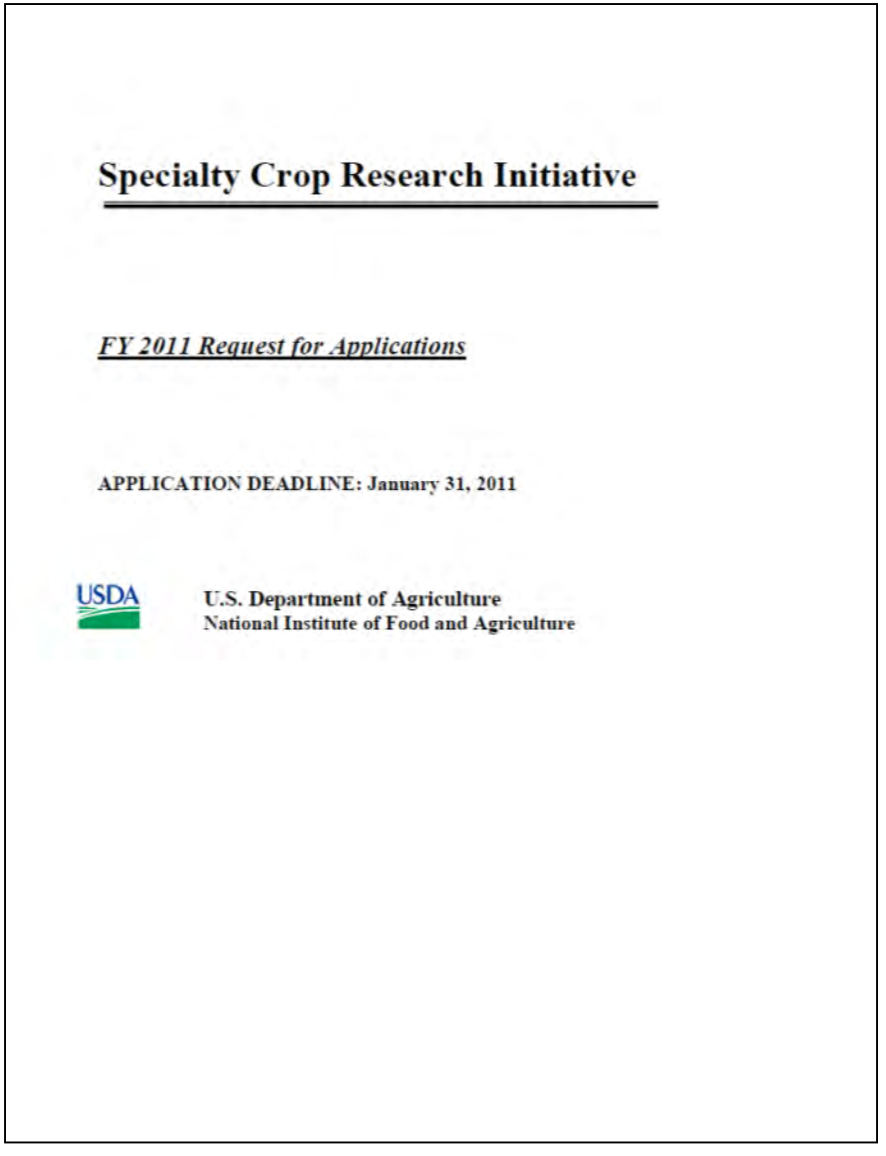
Identification of Effective Biological Control Agents

Identification of Effective Insecticides

Standardized Sampling/Monitoring Techniques

Landscape-Level Threat To Crops

USDA NIFA SCRI CAP



Specialty Crop Research Initiative

FY 2011 Request for Applications

APPLICATION DEADLINE: January 31, 2011

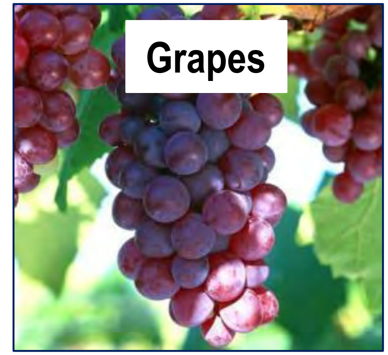
USDA

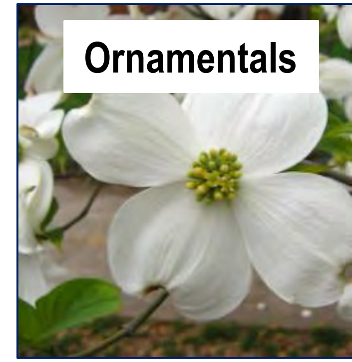
U.S. Department of Agriculture
National Institute of Food and Agriculture

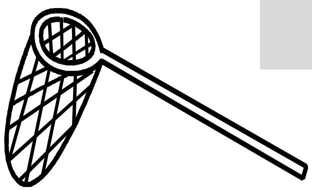
- Bring together a multi-state, multi-institutional, trans-disciplinary team to integrate scientific discoveries with practical application; and provide complementary extension efforts to bring science-based information to relevant audiences.

- Reduce duplication of efforts and integrate activities among individuals, institutions, states, and regions.

Building A Team With Broad Expertise







IPM

Insect Behavior

Horticulture

Field Ecology

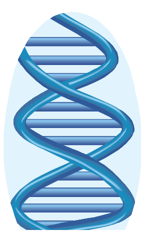
Biological Control

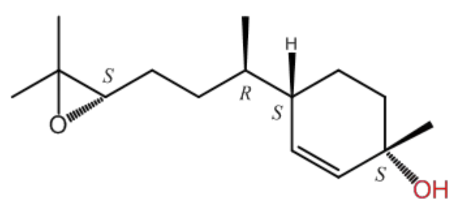
Economics

Taxonomy

Chemical Ecology

Plant Pathology





Molecular Genetics

Sociology

Host Plant Resistance

Extension/ Outreach

BMSB SCRI CAP Team

USDA ARS

Tracy C. Leskey
Doo-Hyung Lee
Kim Hoelmer
Aijun Zhang
Ashot Khrimian
Christine Dieckhoff
Rob Morrison
Jana Lee
Peter Landolt

VT

Tom Kuhar
Chris Bergh
Doug Pfeiffer
Eric Day

Northeastern IPM Center

Carrie Koplinka-Loehr
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Greg Krawczyk
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Jay Brunner
Betsy Beers
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Arthur Agnello

THE STATE UNIVERSITY OF NEW JERSEY RUTGERS

George Hamilton
Anne Nielsen
Cesar Rodriguez-Saona
Dean Polk

NCS

Jim Walgenbach
Mark Abney
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OSU Oregon State University

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Vaughn Walton
Silvia Rondon
Yan Wang
Nik Wiman
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Cerruti Hooks
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William Lamp
Jian Wang
Holly Martinson
Mike Raupp
Paula Shrewsbury
Leslie Pick
Ray St. Leger
Bryan Butler
Gerry Brust
Karen Rane
Amanda Buchanan
Guihua Chen
Dennis van Englesdorp
Dilip Venugopal

UNIVERSITY OF DELAWARE

Joanne Whalen
Brian Kunkel

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

Funding

USDA United States Department of Agriculture

National Institute of Food and Agriculture

Specialty Crop Research Initiative
Grant #2011-01413-30937

Collaborating Institutions

University of Delaware
ARS
Penn State
Rutgers, The State University of New Jersey
Northeastern IPM Center
Washington State University
Cornell University
OSU Oregon State University
University of Maryland
Virginia Tech
NC State University

StopBMSB.org

Goals of the BMSB SCRI CAP Team

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.

Notification of Award

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

The review panel grouped proposals into one of the relative categories below. The percentage indicates the final distribution of proposals in each category.

Recommended for Funding:

Outstanding %	18
High Priority %	26
Medium Priority %	18
Low Priority %	22

Not Recommended for Funding:

Some Merit %	14
Do Not Fund %	4

This proposal was placed in : Outstanding and ranked as : 1

Specialty Crop Research Initiative - PANEL SUMMARY

The panel decision regarding your proposal is based on the input provided by the reviews and the collected expertise and judgment of the individual panel members. This panel summary reflects the consensus opinion of the panel regarding your proposal.

Proposal Number: 2011-01413 Project Director: Leskey

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

Positive Aspects of the Proposal
The review panel felt this is an important issue that needs to be urgently addressed. The research and extension team is impressive and with adequate expertise, with as much experience as can be expected when dealing with a relatively new pest. There is evidence of strong stakeholder and political support, as well as a strong advisory panel. The team is well organized, which made the panel confident that this team can be successful.

The proposal covers several disciplines and aspires to integrate them in a systems approach. This proposal should produce valuable information currently lacking, about the biology, extent of damage, and the efficacy of a wide array of management strategies in a potentially large number of commodities. The panel liked that the team included a list of potential limitations and pitfalls, and reasonable ways to address them if necessary.

Funded Project

- USDA-NIFA Specialty Crop Research Initiative Program
- Title: Biology, Ecology, and Management of Brown Marmorated Stink Bug in Orchard Crops, Small Fruit, Grapes, Vegetables, and Ornamentals.
- Written as a 5-Year Coordinated Agricultural Project.
- Funded for 3 years with opportunity for renewal. Renewed for additional two years.
- Total Federal Award $10.7 million.

Original Grant Objectives

1. Establish biology and phenology of BMSB in specialty crops.
2. Develop monitoring and management tools for BMSB.
3. Establish effective management programs for BMSB in specialty crops.
4. Integrate stakeholder input and research findings to form and deliver practical outcomes.

Original Grant Objectives

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

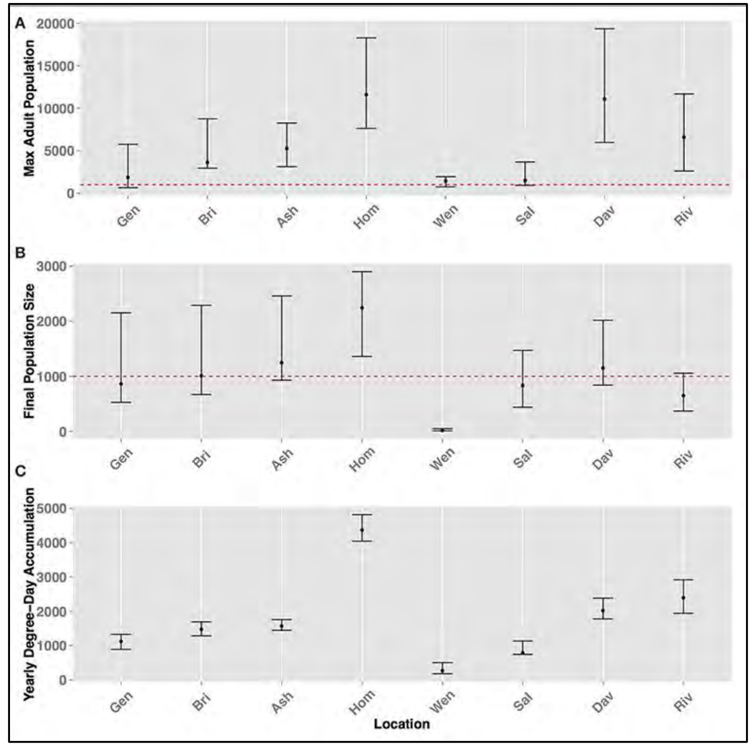
Survivorship, Population Growth, and Phenology of BMSB

ORIGINAL RESEARCH ARTICLE
Front. Physiol., 18 May 2016 | http://dx.doi.org/10.3389/fphys.2016.00165

CrossMark

Coupling Developmental Physiology, Photoperiod, and Temperature to Model Phenology and Dynamics of an Invasive Heteropteran, *Halyomorpha halys*

Anne L. Nielsen[1*], Shi Chen[2] and Shelby J. Fleischer[3]



Environmental Entomology, 45(2), 2016, 484–491
doi: 10.1093/ee/nvv220
Advance Access Publication Date: 7 January 2016
Research article

Physiological Ecology

Cold Tolerance of *Halyomorpha halys* (Hemiptera: Pentatomidae) Across Geographic and Temporal Scales

Theresa M. Cira,[1,2] Robert C. Venette,[3] John Aigner,[4] Thomas Kuhar,[4] Donald E. Mullins,[4] Sandra E. Gabbert,[4] and W. D. Hutchison[1]

[1]Department of Entomology, University of Minnesota, 219 Hodson Hall 1980 Folwell Ave., St. Paul, MN 55108 (c hutch002@umn.edu), [2]Corresponding author, e-mail: cirax002@umn.edu, [3]Northern Research Station, Fores States Department of Agriculture, 1992 Folwell Ave., St. Paul, MN 55108 (rvenette@fs.fed.us), and [4]Departme Virginia Tech, 170 Drillfield Dr., Blacksburg, VA 2406 (daigner@vt.edu; tkuhar@vt.edu; mullinsd@vt.edu; sgabbert

Lethal High Temperature Extremes of the Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) and Efficacy of Commercial Heat Treatments for Control in Export Shipping Cargo[1]

J. D. Aigner[2] and T. P. Kuhar[2,3]

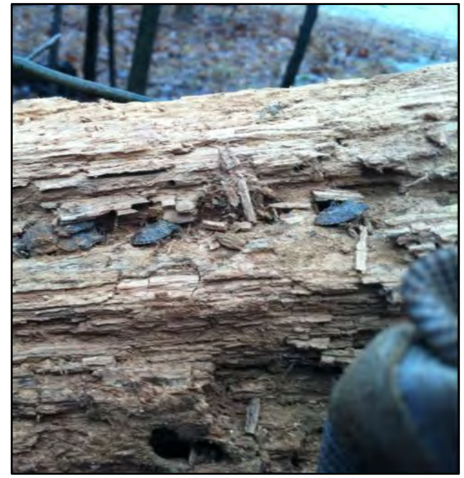
Overwintering Biology and Behavior

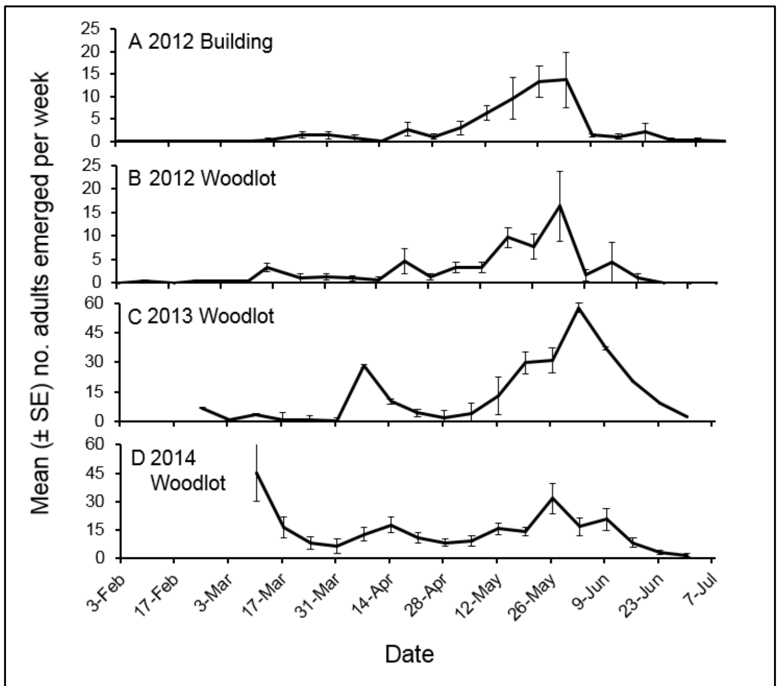
OPEN ACCESS Freely available online — PLOS | ONE

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

Doo-Hyung Lee[1*¤], John P. Cullum[2], Jennifer L. Anderson[3], Jodi L. Daugherty[3], Lisa M. Beckett[3], Tracy C. Leskey[1]

1 U.S. Department of Agriculture – Agricultural Research Service, Appalachian Fruit Research Station, Kearneysville, West Virginia, United States of America, 2 Department of Entomology, Virginia Tech, Winchester, Virginia, United States of America, 3 U.S. Department of Agriculture – Animal and Plant Health Inspection Service, National Detector Dog Training Center, Newnan, Georgia, United States of America





Characterizing Spring Emergence of Adult *Halyomorpha halys* (Hemiptera: Pentatomidae) Using Experimental Overwintering Shelters and Commercial Pheromone Traps¶

ACCEPTED

¶

J. CHRISTOPHER BERGH[1], WILLIAM R. MORRISON III[2], SHIMAT V. JOSEPH[3], AND TRACY C. LESKEY[2]¶

Risk Factors and Spread

OPEN ACCESS Freely available online PLOS | ONE

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

Adam M. Wallner[1]*, George C. Hamilton[2], Anne L. Nielsen[2], Noel Hahn[2], Edwin J. Green[3], Cesar R. Rodriguez-Saona[2]

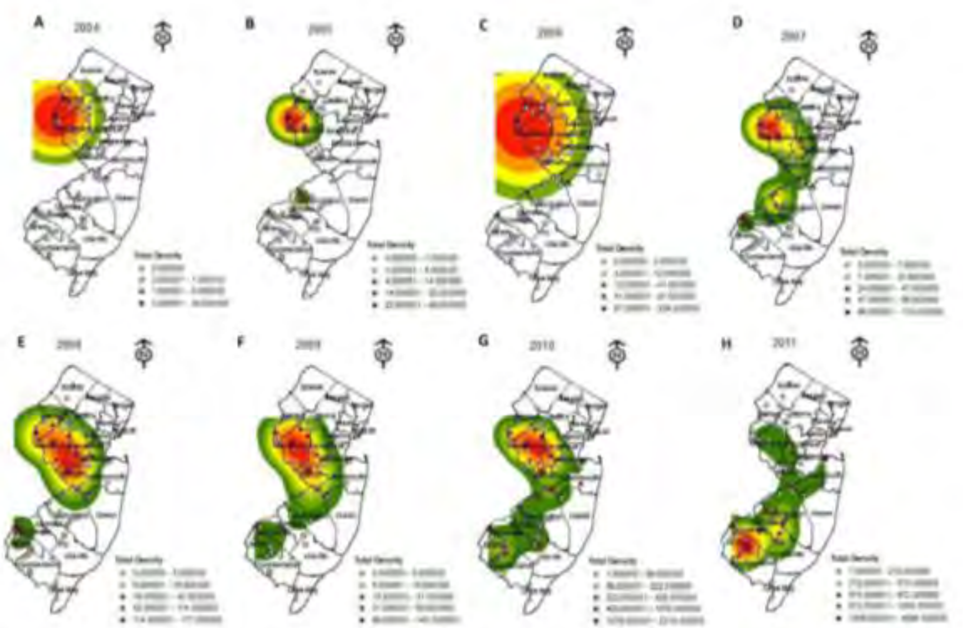


Figure 2. Kernel Density Estimation (KDE) graphs of the density of *Halymorpha halys* captured from black light traps placed throughout New Jersey from (A) 2004, (B) 2005, (C) 2006, (D) 2007, (E) 2008, (F) 2009, (G) 2010, (H) 2011. KDE are based on actual and predicted density of *H. halys* where green reflects lowest population density, orange moderate to high population density, and red predicts highest population of *H. halys*. Total density of *H. halys* for year black lights were monitored is also provided.
doi:10.1371/journal.pone.0095691.g002

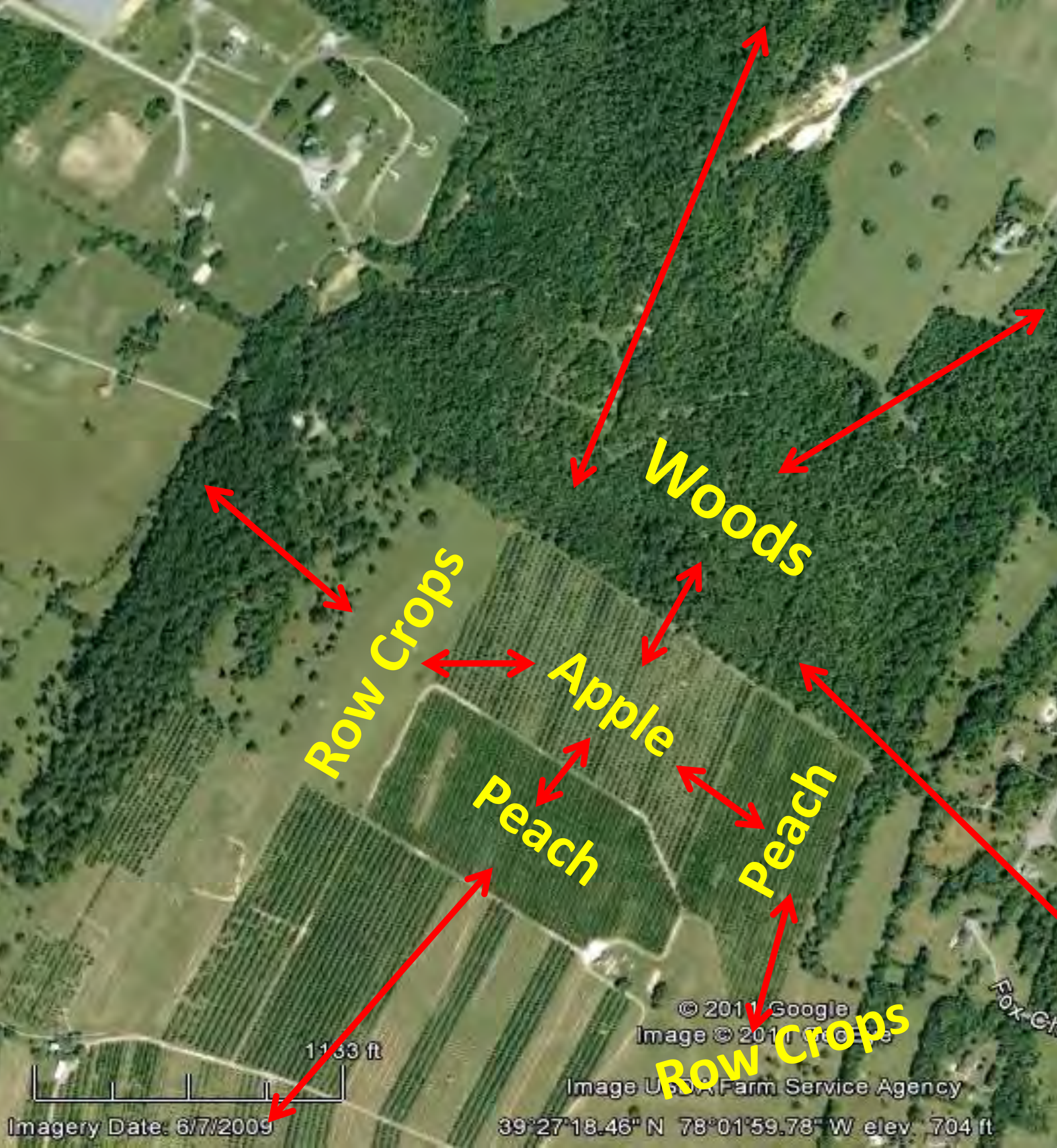
Exploring the Spread of Brown Marmorated Stink Bug in New Jersey Through the Use of Crowdsourced Reports

NOEL G. HAHN, ALEX J. KAUFMAN, CESAR RODRIGUEZ-SAONA, ANNE L. NIELSEN, JOSEPH LAFOREST, AND GEORGE C. HAMILTON

The brown marmorated stink bug (BMSB), *Halyomorpha halys* Stål (Hemiptera: Pentatomidae), is an insect native to China, Japan, and Korea that is an invasive pest of agricultural crops in the mid-Atlantic United States (Hoebeke and Carter 2003, Gonzales 2012). It was introduced around 1996 into Allentown, Pennsylvania, and since then has caused significant crop losses in multiple states and has expanded its range to 42 states (StopBMSB 2014, Leskey and Hamilton 2014). High populations in 2010 resulted in more than $37 million in losses to apples and vegetables in the mid-Atlantic region (USApple 2011, Rice et al. 2014). As a highly polyphagous pest, it is able to feed on a variety of non-agricultural plants in addition to numerous agricultural crops. This has given *Halyomorpha halys* an advantage by using the diverse landscape of the mid-Atlantic to its benefit.

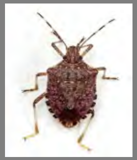
Attics and garages provide a suitable location for several overwintering insects. The multicolored Asian lady beetle, *Harmonia axyridis* Pallas, and boxelder bugs, *Boisea trivittata* Say, are known to overwinter in homes (Crenshaw 2011). *Harmonia axyridis* was introduced into the United States as a biocontrol agent and has since become a homeowner pest. Large aggregations overwinter in houses starting in the fall, and annoy and sometimes cause allergic reactions in homeowners (Huelsman et al. 2002, Koch and Gavan 2008). *H. halys* does not bite or harm humans or pets and is not known to transmit disease to humans, so it does not pose a public health threat; however, it is a nuisance pest to homeowners because it can use houses and man-made structures as overwintering sites. When the photoperiod and temperature decrease in the fall, *H. halys* adults begin moving into overwintering sites, where they remain until late spring (Nielsen 2009). Periodically, *H. halys* will emerge in a homeowner's dwelling throughout the winter season. It can enter through any small openings, such as gaps in the outer frame of windows or doors. In some cases, *H. halys* can be found in extremely high numbers. One homeowner was able to document 26,205 individuals in his house over half a year (Inkley 2012). Large aggregations of *H. halys* such as this can pose problems for homeowners, as they can continuously emerge by the dozens or hundreds every day throughout the winter and early spring. It also overwinters in dead trees in forested areas (Lee et al. 2014), which can be a refuge for populations that can subsequently invade other nearby suitable locations.

Monitoring of *H. halys* has been conducted mostly in agricultural settings using baited pyramid traps, visual sampling, and blacklight traps (Leskey et al. 2012b). These traps are mainly in or close to soybean, vegetable, and fruit-producing farms. Currently, *H. halys* control involves frequent insecticide application, which has disrupted established IPM programs (Leskey et al. 2012a). New Jersey has been recording *H. halys* catches from blacklight traps throughout the state since 1999. All blacklight trap locations in New Jersey have been georeferenced and insect



Adults can fly

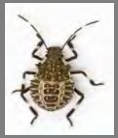
>2 km



and

Nymphs

can walk



>25 m in a single day

Wiman et al. 2015, Lee and Leskey 2015, and Lee et al. 2014

Gut Symbionts, Transcriptome, and Salivary Proteins

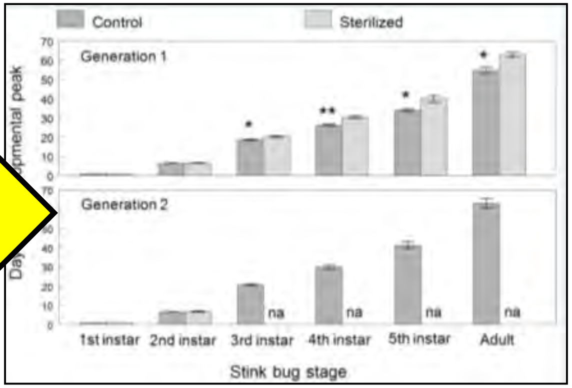
OPEN ACCESS Freely available online

PLOS | ONE

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



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*]

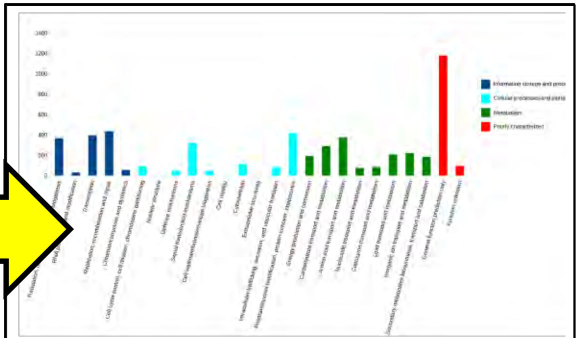


Figure 3. Transcript functional categories. The NCBI Cluster of Orthologous Groups (COG) database was used to classify the predicted proteins in the 13,211 representative transcripts. Assignment of COG categories showed that a large number of ORFs belonged to categories of proteins whose functions are poorly characterized, namely those that have general function prediction only and those with unknown function.

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PLOS | ONE

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

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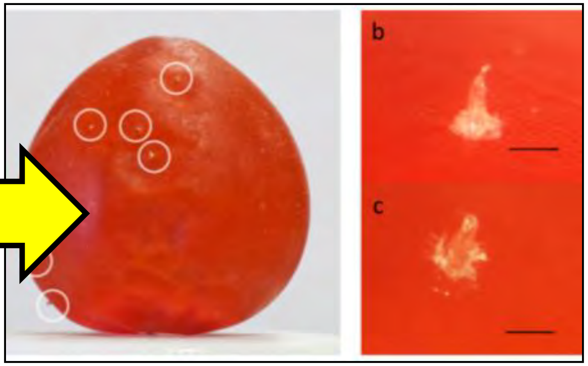

Host Plants of BMSB Includes >170 Records

made by collaborating researchers

Stop BMSB

Biology, ecology, and management of brown marmorated stink bug in specialty crops

Search

Host Plants of the Brown Marmorated Stink Bug in the U.S.

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A publication of the Brown Marmorated Stink Bug IPM Working Group in conjunction with the Northeastern IPM Center

Contributing authors (in alphabetical order):
Erik Bergmann, Karen M. Bernhard, Gary Bernon, Matthew Bickerton, Stanton Gill, Chris Gonzales, George C. Hamilton, Chris Hedstrom, Katherine Kamminga, Carrie Koplinka-Loehr, Greg Krawczyk, Thomas P. Kuhar, Brian Kunkel, Jana Lee, Tracy C. Leskey, Holly Martinson, Anne L. Nielsen, Michael Raupp, Peter Shearer, Paula Shrewsbury, Jim Walgenbach, Joanne Whalen, and Nik Wiman

Brown marmorated stink bug adults feeding through the bark of an elm tree (Ulmus sp.) (photo: M. Raupp)

Since its initial discovery in eastern Pennsylvania in the mid-1990s, the invasive brown marmorated stink bug (BMSB, *Halyomorpha halys* [Heteroptera: Pentatomidae]) has become a conspicuous insect in residential areas and farms in the mid-Atlantic U.S. As part of several ongoing research projects, entomologists have been observing which plants this insect typically uses for food and reproduction in its new environment. BMSB is a tree-loving bug but has a very broad host plant range. We have observed it on hundreds of plant species in Delaware, Maryland, New Jersey, North Carolina, Oregon, Pennsylvania, Virginia, and West Virginia.

In the spring, BMSB adults emerge from overwintering sites and become active during warm sunny days. During this time, adult bugs can be found on virtually any plant that exposes them to the sun. Trees, shrubs, and ornamental plants that are near BMSB overwintering shelters often serve as the best places to observe early bug activity. Tall plants and trees tend to have more bugs on them than plants lower to the ground. As adult bug activity increases throughout the month of May and as mating, egg laying, and nymphal development occurs throughout the summer, BMSB can be found on a wide range of plant species (Table 1). Plants bearing reproductive structures, such as fruiting bodies, buds, and pods, tend to have more bugs than plants without these parts. Furthermore, BMSB prefers certain species of plants more than others, often at particular times during the growing season. These plants, listed in boldface in Table 1, may provide the most suitable habitat and/or nutrition for BMSB. The list of host plants for this bug will undoubtedly grow as the pest spreads to new regions.

Table 1. Plants hosting BMSB adults and immature stages in the United States. Plant species in bold represent those with the highest densities of bugs in a given habitat.

Habitat*	Genus	Species	Common Name	Image
Orn.	*Abelia*	*× grandiflora*	glossy abelia	
Agric.	*Abelmoschus*	*esculentus*	okra	
Orn.	*Acer*	*buergerianum*	trident maple	
Orn.	*Acer*	*circinatum*	vine maple	
Orn.	*Acer*	*japonicum*	Amur (Japanese Downy) maple	

Importance of Fruiting Structures

Journal of Pest Science
September 2015, Volume 88, Issue 3, pp 461–468

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

Authors | Authors and affiliations

Holly M. Martinson, P. Dilip Venugopal, Erik J. Bergmann, Paula M. Shrewsbury, Michael J. Raupp

Environmental Entomology, 45(3), 2016, 663–670
doi: 10.1093/ee/nvw018
Advance Access Publication Date: 24 March 2016
Research article

OXFORD

Plant–Insect Interactions

Host Plant Effects on *Halyomorpha halys* (Hemiptera: Pentatomidae) Nymphal Development and Survivorship

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Landscape and Edge Effects

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

P. Dilip Venugopal, Holly M. Martinson, Erik J. Bergmann, Paula M. Shrewsbury, Michael J. Raupp

DOI: http://dx.doi.org/10.1093/ee/nvv061 474-479 First published online: 1 May 2015

Community and Ecosystem Ecology

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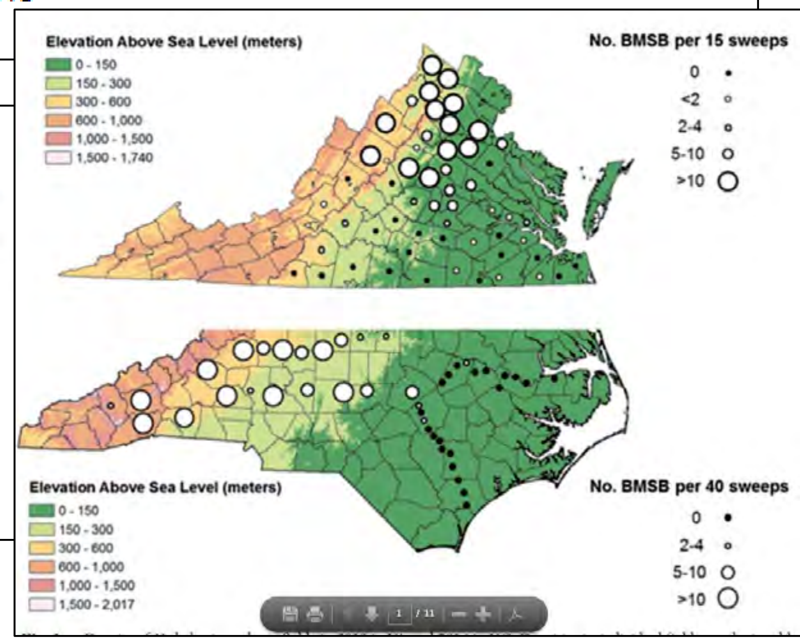
Environ. Entomol. 1–11 (2015); DOI: 10.1093/ee/nvv092



Established BMSB Risk, Phenology, and Damage Symptoms in Specialty Crops

Accepted for publication 20 April 2012. Published 23 May 2012.

The Pest Potential of Brown Marmorated Stink Bug on Vegetable Crops

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Horticultural Entomology

Research article

Seasonal Abundance, Host Suitability, and Feeding Injury of the Brown Marmorated Stink Bug, *Halyomorpha halys* (Heteroptera: Penatomidae), in Selected Vegetables

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Re

Injury to apples and peaches at harvest from feeding by *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) nymphs early and late in the season

Angelita L. Acebes-Doria [a,*], Tracy C. Leskey [b], J. Christopher Bergh [a]

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[b] USDA-ARS, Appalachian Fruit Research Station, 2217 Wiltshire Rd, Kearneysville, WV, 25430, USA

Field and Forage Crops

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

WILLIAM J. CISSEL,[1,2] CHARLES E. MASON,[1] JOANNE WHALEN,[1] JUDITH HOUGH-GOLDSTEIN,[1] AND CERRUTI R. R. HOOKS[3]

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]

Horticultural Entomology

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

C. S. HEDSTROM,[1,2] P. W. SHEARER,[3] J. C. MILLER,[1] AND V. M. WALTON[1]

Horticultural Entomology

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

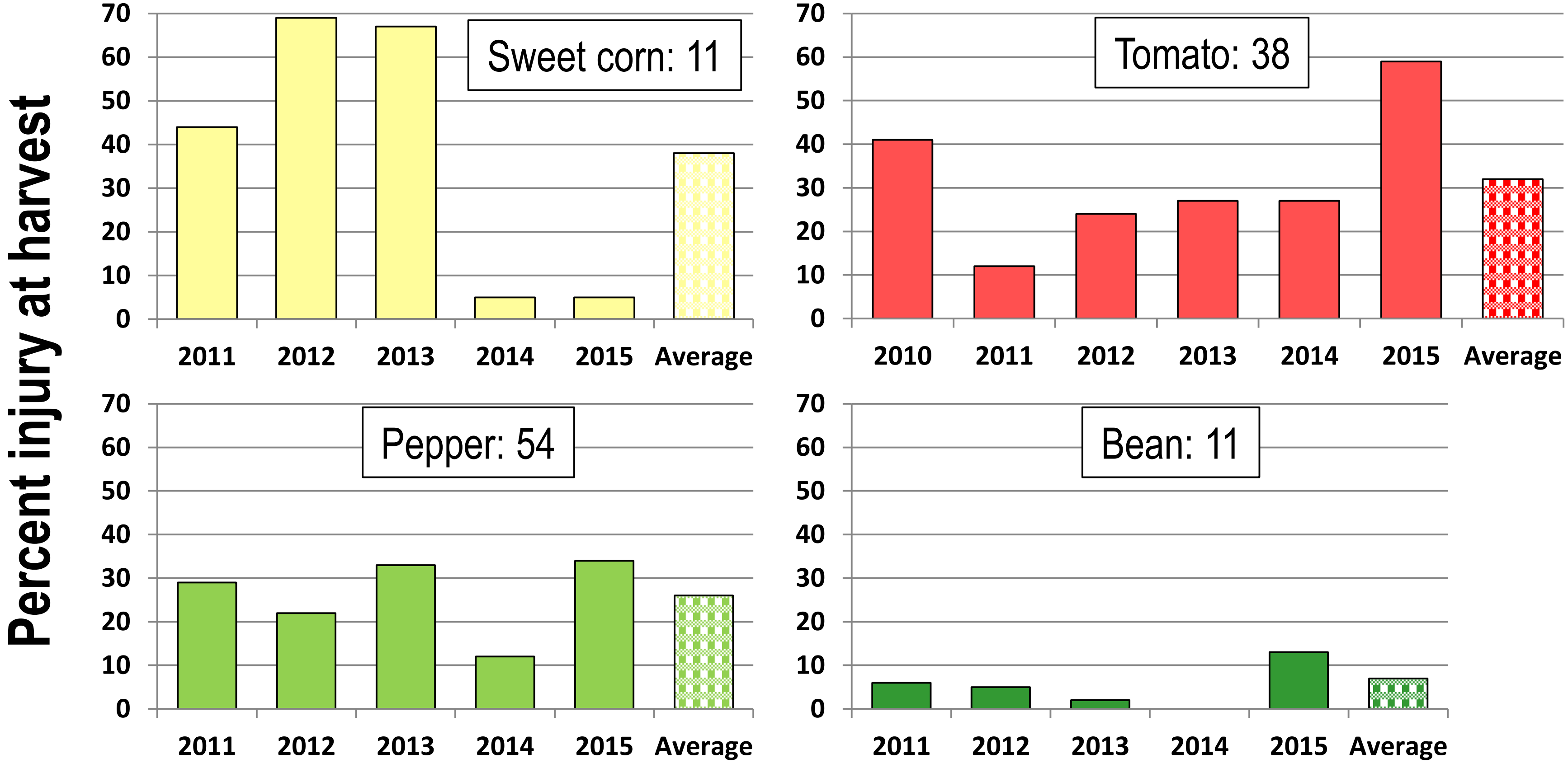
G. WIMAN,[1,2] JOYCE E. PARKER,[3,4] CESAR RODRIGUEZ-SAONA,[3] AND VAUGHN M. WALTON[1]

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

Sanjay Basnet[2], Laura M. Maxey[3], Curtis A. Laub[2], Thomas P. Kuhar[2] and Douglas G. Pfeiffer[2]

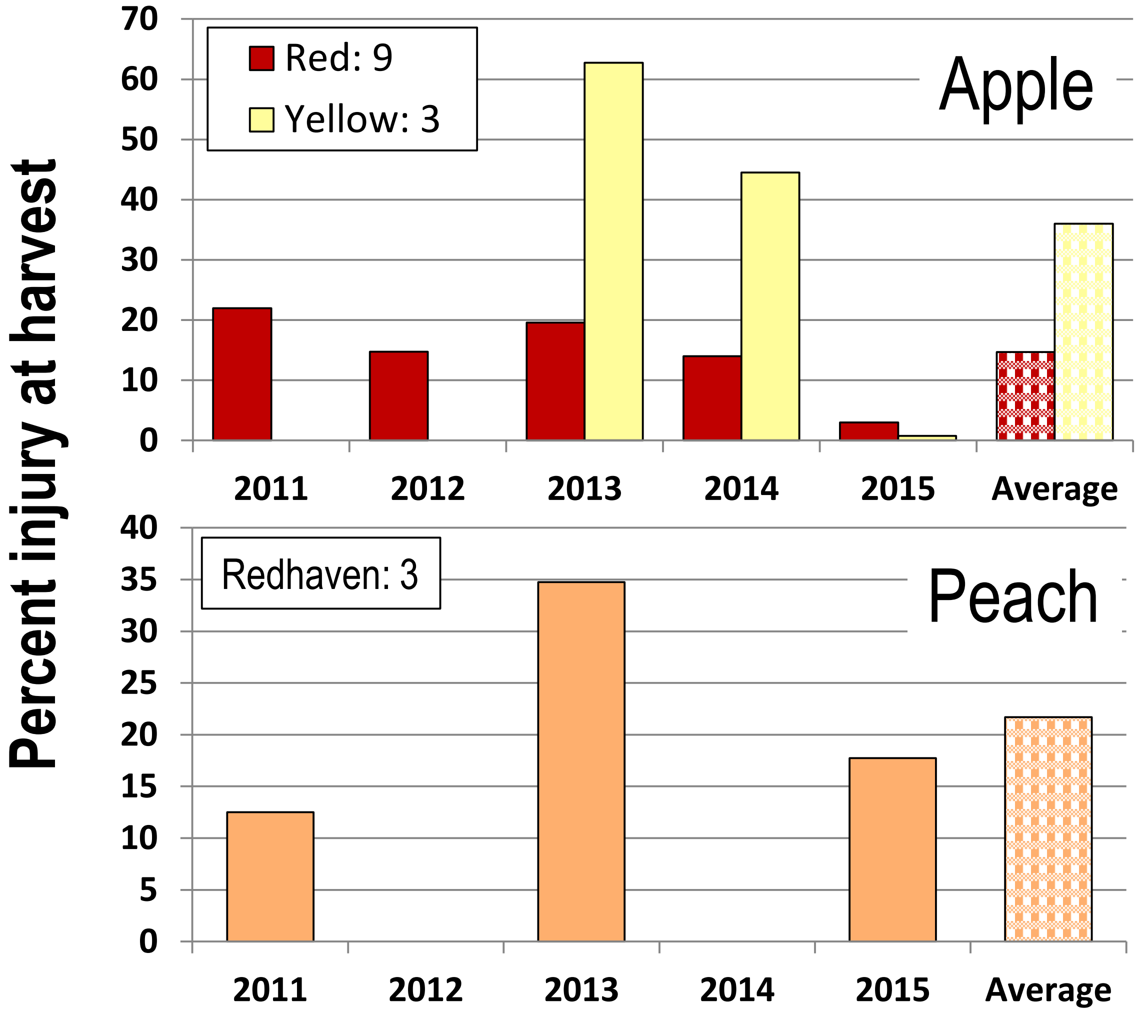
Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061 USA

BMSB injury at harvest in unsprayed control plots: **Vegetables**



Trials conducted in DE, MD, NJ, NC and VA

BMSB injury at harvest in unsprayed control plots: **Tree fruit**



Relative BMSB importance or risk from a management or injury perspective

(researcher perceptions of BMSB based on top 5 pests by crop)

Vegetables[1]

Crop	Rank
Pepper	1
Tomato	2
Sweet corn	3
Bean	4
Okra	4

Eastern orchards

Crop	Rank
Peach	1-3
Pear	2-3
Apple	1-4
Cherry	<5

Western orchards[2]

Crop	Rank
Hazelnut	3
Peach	<5
Pear	<5
Apple	<5
Cherry	<5

Small fruit and grape[3]

Crop	Rank
Caneberry	<5
Blueberry	<5
Strawberry	<5
Grape	≤5

Ornamentals: All <5

[1] In production areas with BMSB pressure. Most production in areas with low pressure.

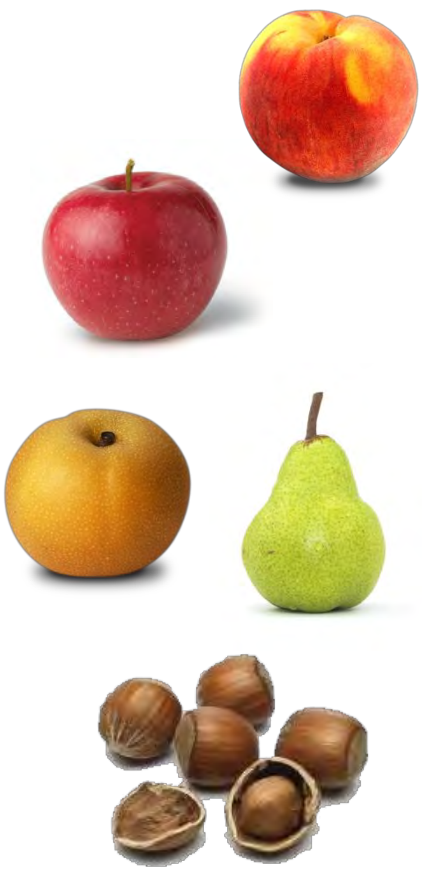
[2] Pressure still relatively low in production regions. Growers consider BMSB a significant threat due to potential for spray program effects on 2º pests.

[3] Producers most concerned about taint from crushed bugs. Nuisance issue in tasting rooms.

Relative susceptibility to injury from BMSB: **Vegetables**

High	Moderate	Low

Relative susceptibility to injury from BMSB:
Orchard crops

High	Moderate	Low
		

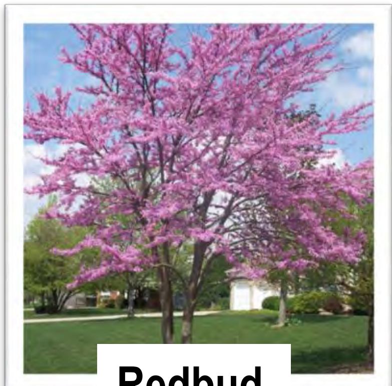
Relative susceptibility to injury from BMSB:

Small fruit and grape

High	Moderate	Low
		    

Relative abundance of BMSB:
Ornamentals

High


Redbud


Red maple


Elm


Peking lilac

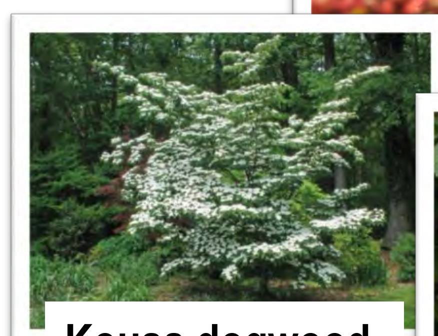

Japanese Pagoda tree

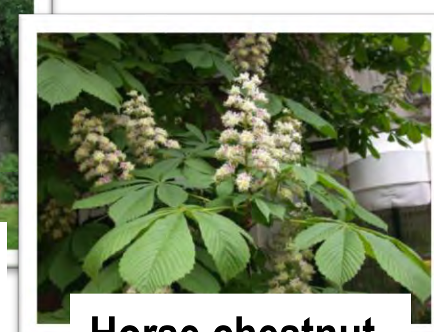
Low


Katsura


Needled evergreens


Japanese maple


Kousa dogwood


Horse chestnut

Specialty Crops at Risk to BMSB Damage

Risk	Crops
HIGH RISK	apple, Asian pear, beans (green, pole, snap), bee-bee tree, edamame, eggplant, European pear, grape[1], hazelnut, Japanese pagoda tree, nectarine, okra, peach[2], Peking tree lilac, pepper, redbud, sweet corn, Swiss chard, tomato
MODERATE RISK	apricot, asparagus, blueberries[1,3], broccoli, cauliflower, cherry[2], collard, cucumber, flowering dogwood, horseradish, lima bean, littleleaf linden, serviceberry, tomatillo
LOW RISK	blackgum, carrot, cranberries, garlic, ginkgo, greens, Japanese maple, kohlrabi, kousa dogwood, leeks, lettuce, many gymnosperms, onion, potato, spinach, sweet potato, turnip
UNKNOWN	almond, citrus, hops, kiwi, olive, pistachio, plum, strawberries, walnut
HOSTS — Non-Specialty Crop BMSB Hosts Contributing to Specialty Crops Risk	field corn, soybean

1—Potential risk of taint/contamination. 2—Additional risk potential due to bark feeding. 3—Considered moderate-high risk.

About BMSB

The brown marmorated stink bug, *Halyomorpha halys* (Stål), is a voracious eater that damages fruit, vegetable, and ornamental crops in North America. With funding from USDA's Specialty Crop Research Initiative, our team of more than 50 researchers is uncovering the pest's secrets to find management solutions that will protect our food, our environment, and our farms.

Learn more at **StopBMSB.org**.

USDA

Funded by USDA-NIFA SCRI Coordinated Agricultural Project, grant #2011-51181-30937. Image credits—sweet corn: Joe Zlomek; eggplant: Howard F. Schwartz, Colorado State University, Bugwood.org; apple, carrots: morguefile.com/creative/bekahboo42; flowering dogwood: Richard Floyd, Creative Ideas LLC, Bugwood.org; blueberries, cauliflower: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org; ginkgo: Jan Samanek, State Phytosanitary Administration, Bugwood.org; cranberries: Cjboffoli (CC-BY-3.0). Printed May 2015.

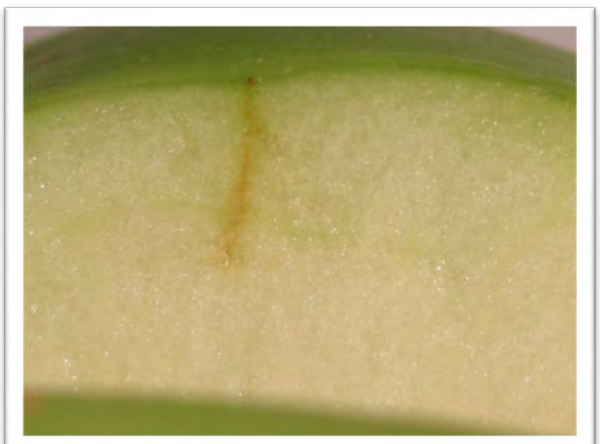
Stop BMSB

Injury diagnostics: **Vegetables**

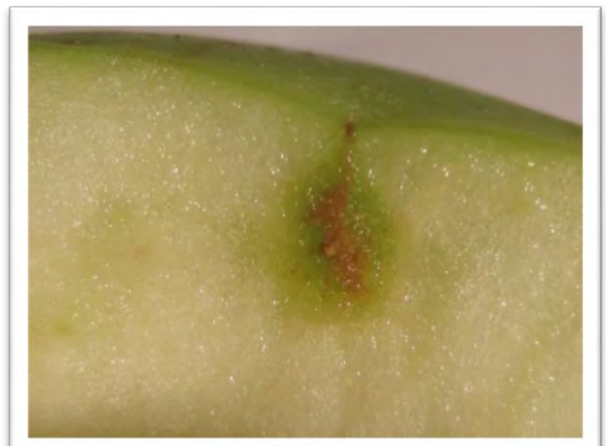
Necrotic or clorotic areas, distortion, or kernel loss/injury

Injury diagnostics: **Apple**

Stylet insertion point



Stylet sheath (early season)



Stylet sheath (mid-season)

Injury diagnostics: **Apple**

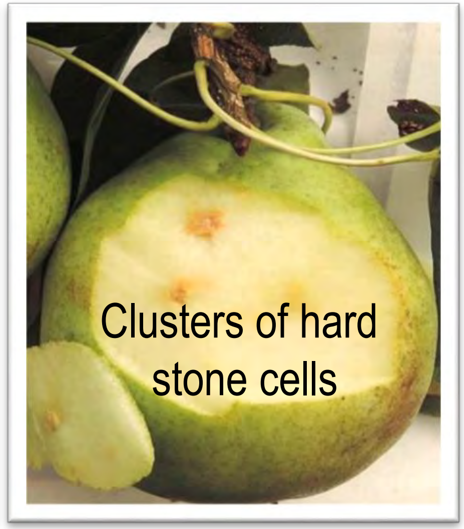
Discolored depressions

Internal necrosis

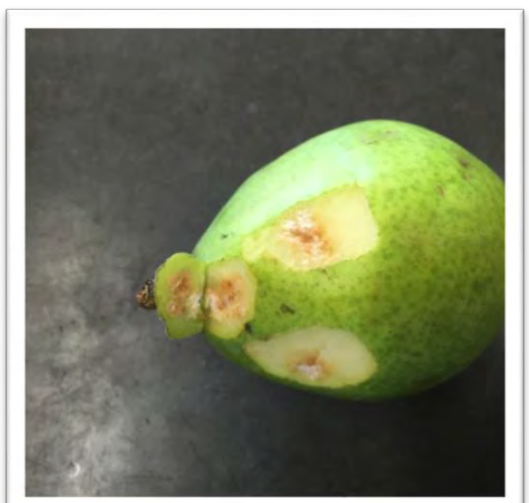
BMSB versus bitter pit and cork spot?

- Tends to be about 1:1 relationship between external & internal injuries at harvest
- Additional injury can be expressed during post-harvest cold storage
- Apples not a particularly suitable host for BMSB nymphal development

Injury diagnostics: **Pear**



Caged BMSB at "turn-down" stage (4 June) …………………and at ~ 3 wk before harvest



BMSB feeding close to harvest not expressed as external injury at harvest, but caused internal necrosis

Injury diagnostics: **Peach**

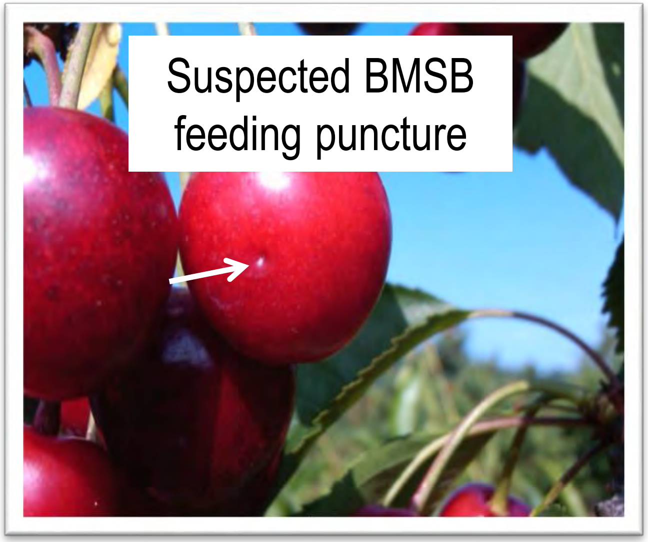
Gummosis on young peaches

Internal necrosis in young peaches

Deformation & internal necrosis

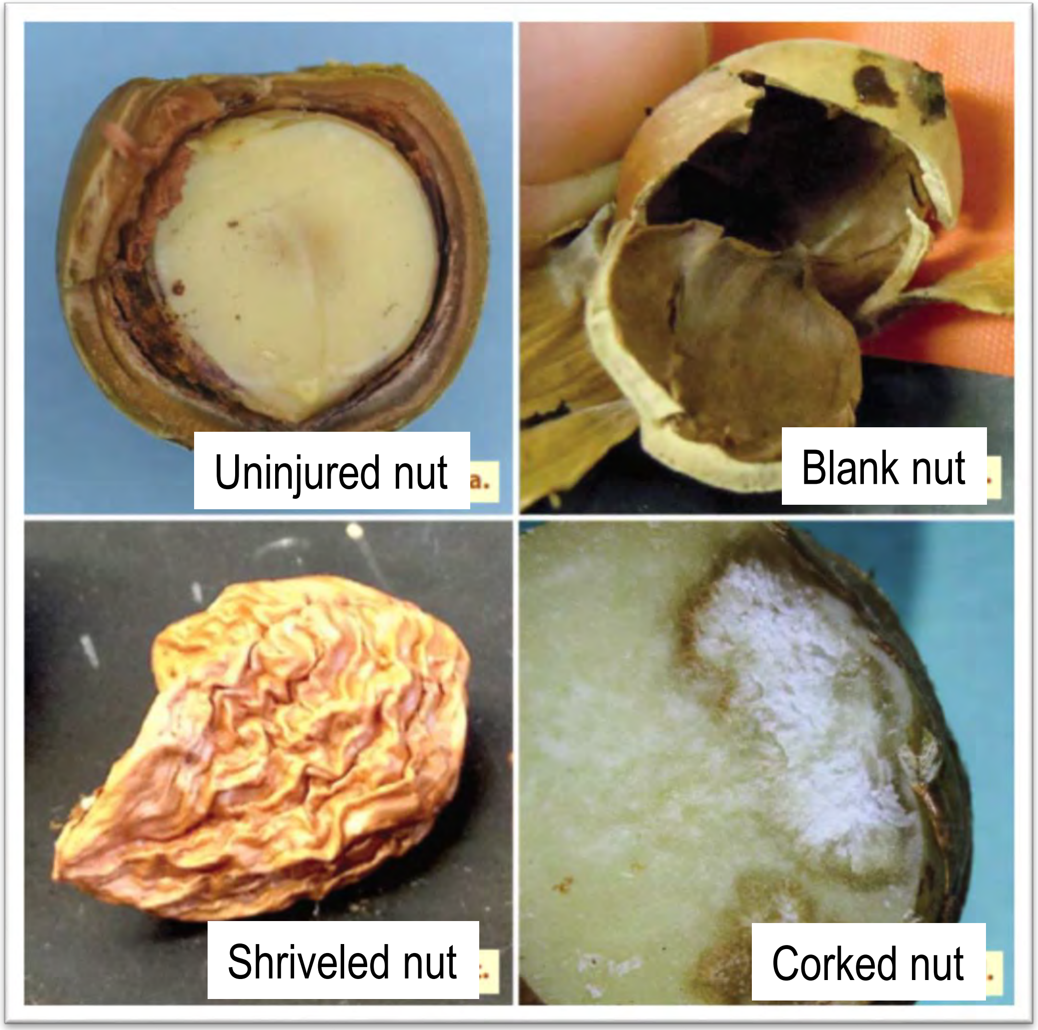
- Peaches with no external injury at harvest can show internal injury
- Need to cut fruit to evaluate injury
- Peaches highly suitable for BMSB nymphal development

Injury diagnostics: **Cherry**



Cherries exposed to BMSB on 4 June

Injury diagnostics: **Hazelnut**



Injury diagnostics: **Small fruit & grape**

- Injury not characterized on some small fruits & grape as well as on some other crops
- Likely affects development of caneberry druplets

Injury Diagnostics: **Ornamentals**

Inclusion cage

Stippling on crabapple foliage

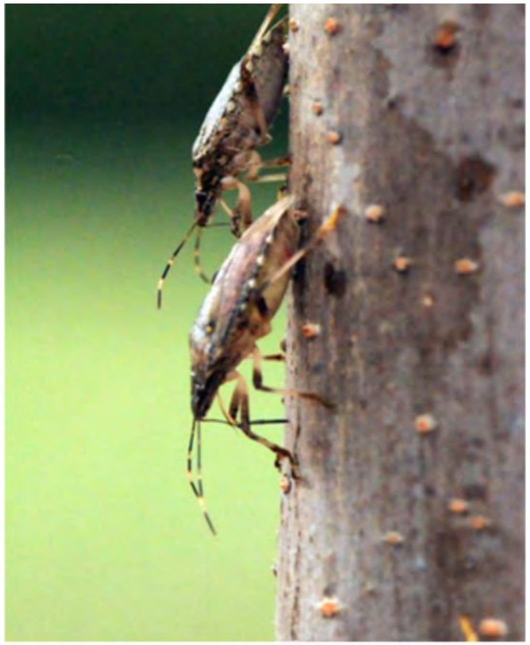
Stippling on serviceberry fruit

<u>Preliminary Results</u>:

- Minor damage apparent on leaves & fruits
- May be negligible compared to other pests (*e.g.*, Japanese beetles)

Injury Diagnostics: **Ornamentals**

BMSB known to feed through the bark of some hosts



Does this cause economic injury or promote fungal growth?

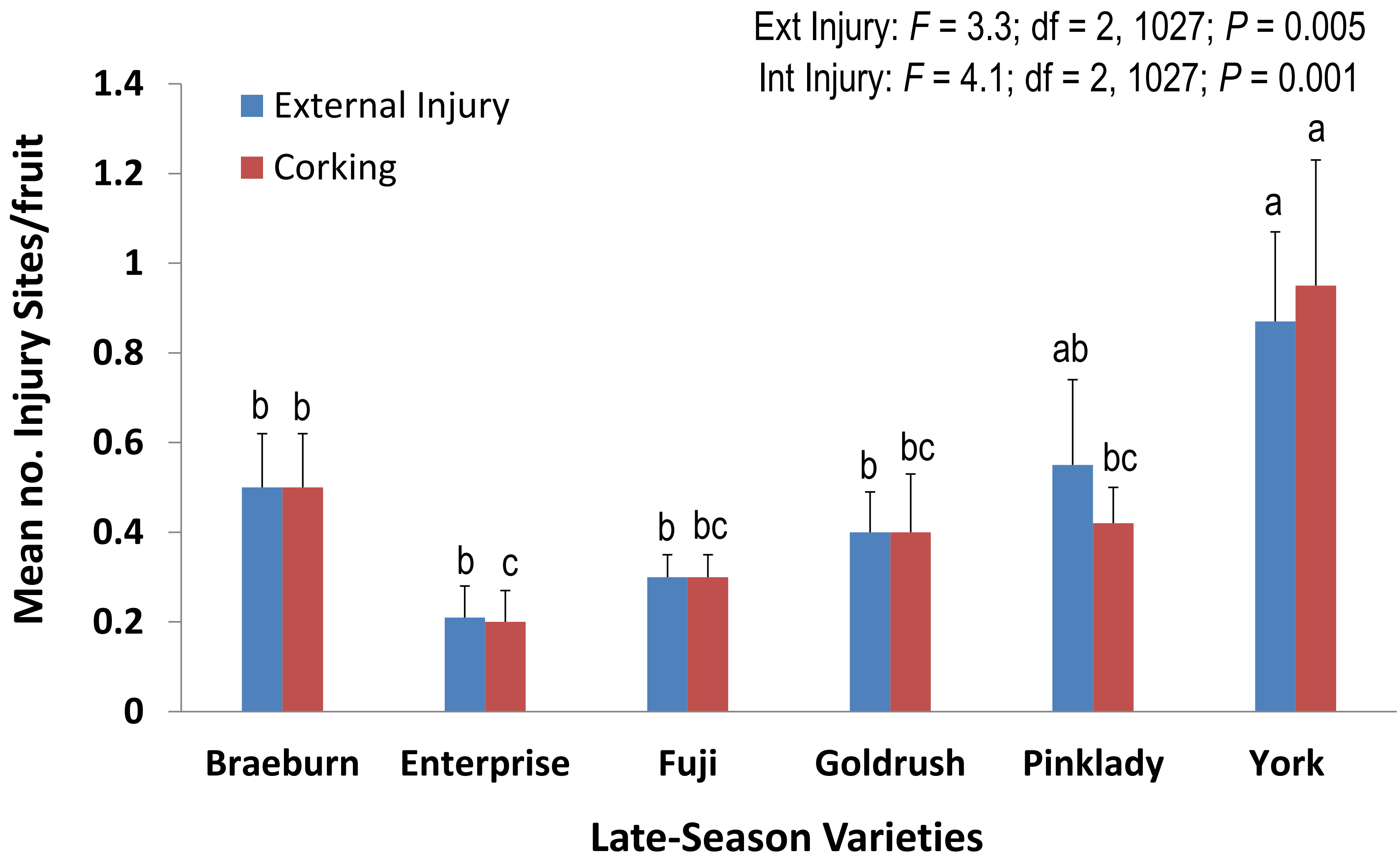
<u>Results forthcoming</u>:

- Fungal growth from exposure to different numbers of BMSB
- Incremental growth, DBH, visual feeding damage
- Minimal visual damage by bark-feeding

Varietal Differences in Susceptibility

Crop group	Crop	Comments
Vegetables	all crops	• None detected • VERY hot peppers not susceptible
Orchard crops	apple	• Not well understood • Anecdotal reports of some differences
	peach	• Not well understood
	pear	• Bosc more than d'Anjou • Asian pears possibly more than European
	hazelnut	• Thick- and thinner-shelled varieties equal
Small fruit	all crops	• None detected
Grape		• White varietals (*e.g.* Chardonnay, Traminette) more susceptible than reds • Harvest date effects? • Taint more evident in delicate wines (flavor profile, fermentation process)
Ornamentals		• Major differences in abundance among families, genera, species and cultivars • Seasonal differences in abundance

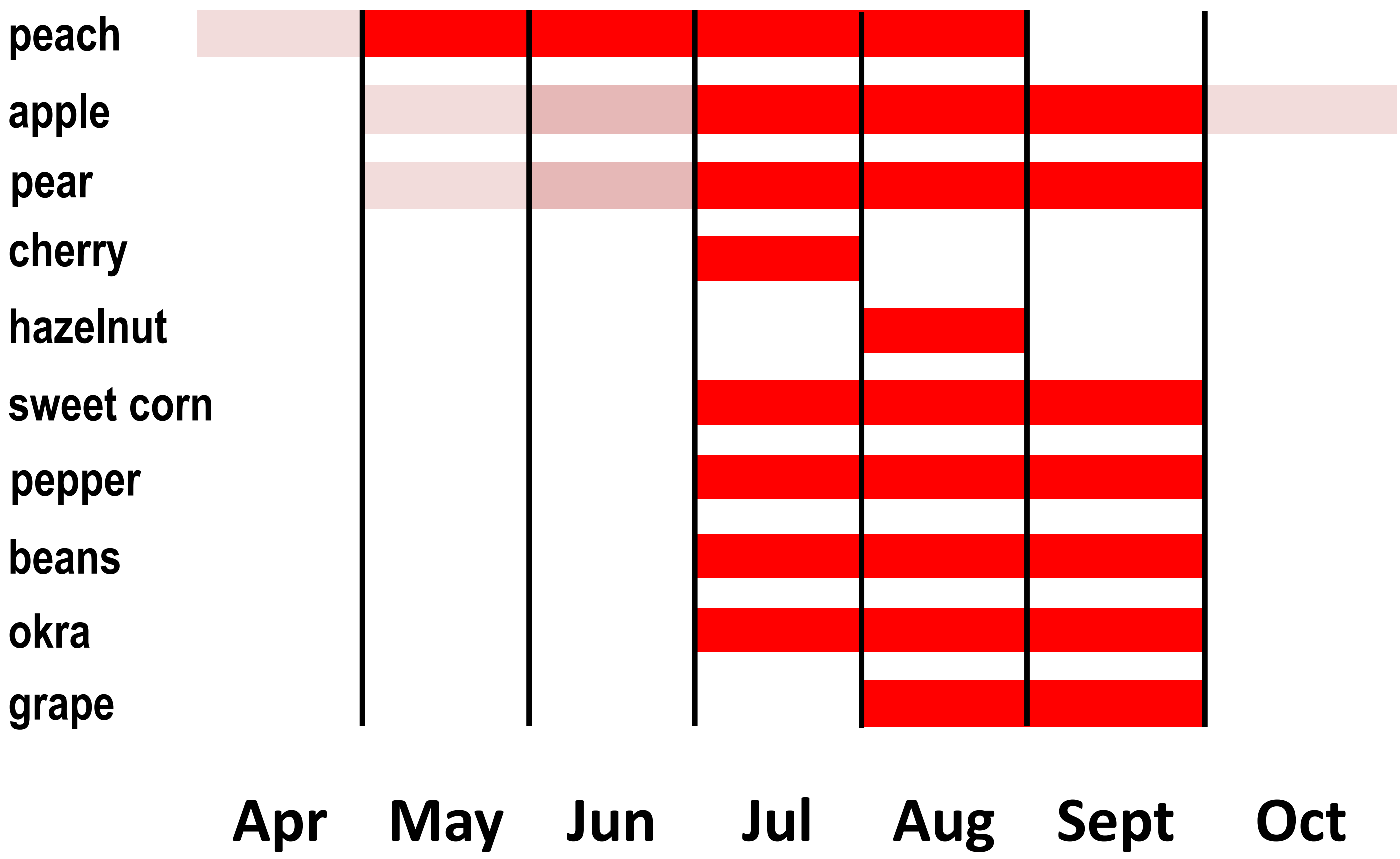
Apple variety screening 2011



Impact on Management Programs

Crop Group	Significant to moderate	Minimal	None
Vegetables	pepper beans okra	sweet corn tomato	
Orchard crops	peach apple pear hazelnut	cherry	
Small fruit, grape		caneberry grape	blueberry strawberry
Ornamentals			all hosts

Seasonal timing of injury/intervention



Original Grant Objectives

2. Develop monitoring and management tools for BMSB.

Insecticide Efficacy and Management Programs

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

ERIK J. BERGMANN AND MICHAEL J. RAUPP*
University of Maryland, Department of Entomology, College Park, MD 20742, USA

Arthropod Management Tests, 2015, 1–2
doi: 10.1093/amt/tsv072
(E19)

BELL PEPPER: *Capsicum annuum* "Aristotle"

Efficacy of organic Insecticides for Control of BMSB on Pepper in Virginia, 2014*

J. Adam Morehead,[1] John D. Aigner, Jr., James M. Wilson, Louis B. Nottingham, Anthony DiMeglio, and Thomas P. Kuhar

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Research Article

Received: 1 February 2016 Revised: 6 May 2016 Accepted article published: 23 May 2016 Published online in Wiley On
(wileyonlinelibrary.com) DOI 10.1002/ps.4322

The consequences of sublethal exposure to insecticide on the survivorship and mobility of Halyomorpha halys (Hemiptera: Pentatomidae)

William R Morrison, III [a*] Brittany Poling [b] and Tracy C Leskey [a]

Toxicities of Neonicotinoid Insecticides for Systemic Control of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) in Fruiting Vegetables[1]

J. D. Aigner,[2] J. F. Walgenbach,[3] and T. P. Kuhar[2,4]

Pest Management Science

Research Article

Received: 23 May 2013 Revised: 6 September 2013 Accepted article published: 12 September 2013 Published online in Wiley Online L
(wileyonlinelibrary.com) DOI 10.1002/ps.3653

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

Tracy C. Leskey, *Brent D. Short and Doo-Hyung Lee

Most Commonly Used Insecticides for BMSB

Crop group	Crop(s)	Insecticide	Chemical class
Vegetables	sweet corn, pepper, etc.	1) bifenthrin 2) λ-cyhalothrin 3) beta-cyfluthrin	all pyrethroids
Orchard crops	apple and pear	1) Endigo 2) Lannate 3) bifenthrin	pyrethroid + neonic carbamate pyrethroid
	peach	1) permethrin 2) bifenthrin 3) Endigo	pyrethroid pyrethroid pyrethroid + neonic
	hazelnut	1) esfenvalerate 2) Doubletake	pyrethroid diflubenzuron + pyrethroid

- BMSB rarely targeted specifically in small fruit, grape & ornamentals
- In tree fruits, insecticide use/selection depends to some degree on annual BMSB pressure (personal observations, researchers/extension)
- ARM sprays quite widely adopted by tree fruit growers
- Pyrethroid use has created 2^{o} pest issues in fruit orchards & vegetables

Chemical Ecology

JOURNAL OF NATURAL PRODUCTS
Article
pubs.acs.org/jnp

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[∇]

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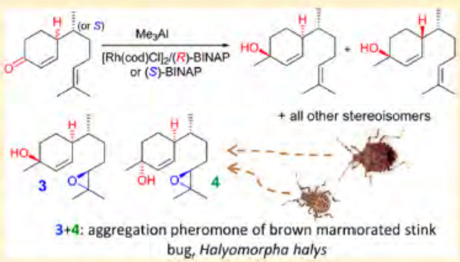
Supporting Information

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.

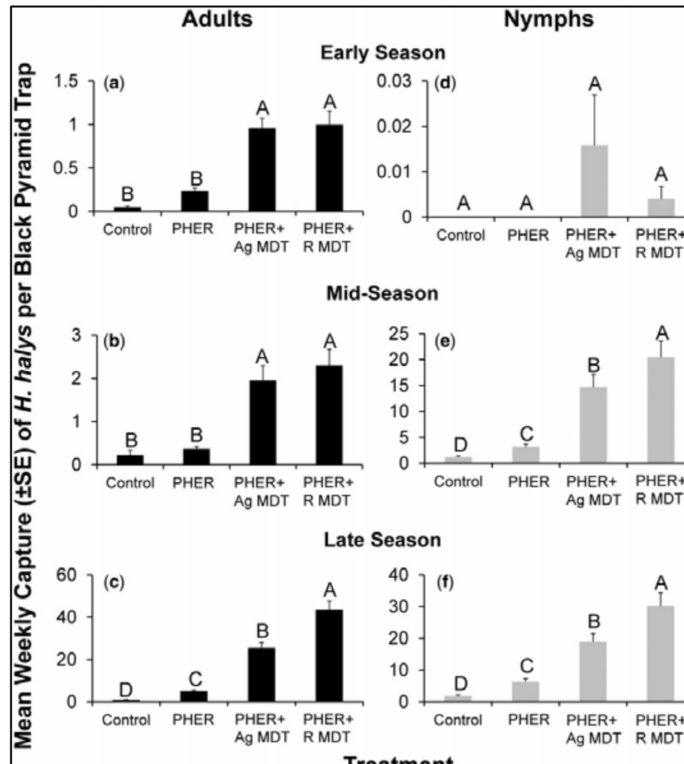


CHEMICAL ECOLOGY

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



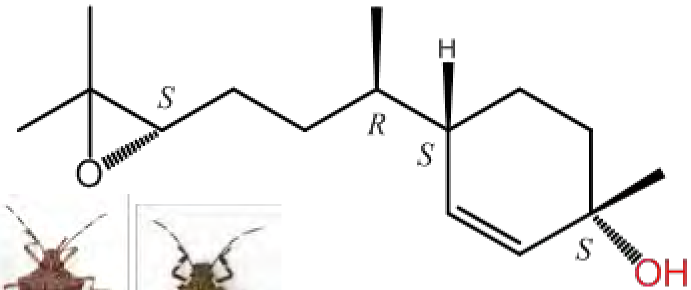
ECOLOGY AND BEHAVIOR

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

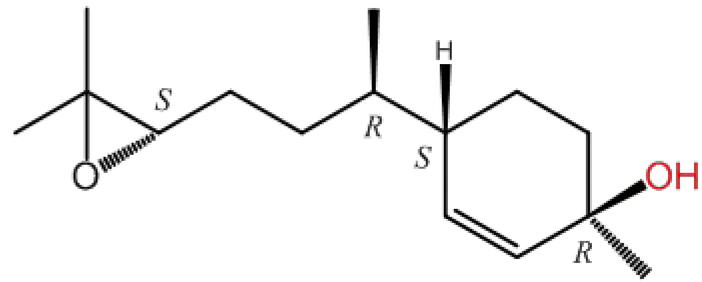
DONALD C. WEBER,[1,2] TRACY C. LESKEY,[3] GUILLERMO CABRERA WALSH,[4] AND ASHOT KHRIMIAN[1]

Two-Component BMSB Aggregation Pheromone and Synergist

Main component of BMSB aggregation pheromone
(3*S*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol



Minor component of BMSB aggregation pheromone
(3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol



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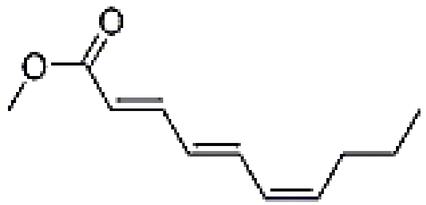
Methyl (*E*,*E*,*Z*)-2,4,6-decatrienoate (MDT) acts as a synergist for BMSB pheromone



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Synergism

Weber et al. 2014

Biological Control

Natural enemy impact on eggs of the invasive brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), in organic agroecosystems: A regional assessment

Emily C. Ogburn[a], Ricardo Bessin[b], Christine Dieckhoff[c], Rachelyn Dobson[b], Matthew Grieshop[d], Kim A. Hoelmer[e], Clarissa Mathews[f], Jennifer Moore[g], Anne L. Nielsen[h], Kristin Poley[d], John M. Pote[h], Mary Rogers[g,1], Celeste Welty[i], James F. Walgenbach[a,*]

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[b] Department of Entomology, University of Kentucky, S-225 Agricultural Science Center N, Lexington, KY, USA
[c] Entomology & Wildlife Ecology, University of Delaware, Newark, DE, USA
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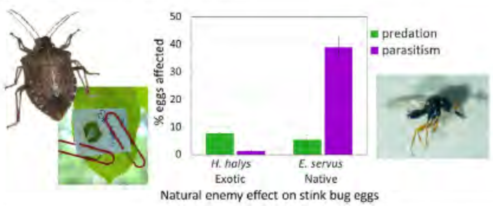
[f] Institute of Environmental and Physical Sciences, Shepherds University, Shepherdstown, WV, USA
[g] Department of Plant Sciences, University of Tennessee, Knoxville, TN, USA
[h] Department of Entomology, Rutgers University, Bridgeton, NJ, USA
[i] Department of Entomology, Ohio State University, Columbus, OH, USA

H I G H L I G H T S

- Broad-scale assessment of natural enemies' effect on invasive *H. halys* eggs in eastern US crops.
- Predation, mainly by chewing predators, accounted for the majority of control of *H. halys* eggs.
- Parasitism of *H. halys* eggs by native parasitoids was very low.
- Baseline data to evaluate potential future biocontrol programs and native parasitoid adaptation.

G R A P H I C A L   A B S T R A C T



Frequency, efficiency, and physical characteristics of predation by generalist predators of brown marmorated stink bug (Hemiptera: Pentatomidae) eggs

William R. Morrison III[a,*,1], Clarissa R. Mathews[b,1], Tracy C. Leskey[a]

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[b] Institute of Environmental and Physical Sciences, Shepherd University, Shepherdstown, WV 25443, USA

H I G H L I G H T S

- The native natural enemy community of *Halyomorpha halys* in the US is not well-documented.
- We systematically categorized damage to and main predators of *H. halys* egg masses.
- Egg damage consisted of complete or incomplete chewing, and stylet or punctured sucking.
- The main predators were Tettigoniidae, Carabidae, Gryllidae, and to a lesser extent, Salticidae.

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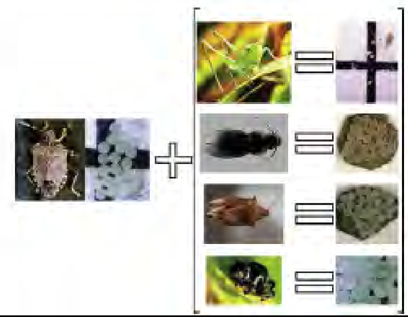


Trissolcus japonicus (Ashmead) (Hymenoptera, Scelionidae) emerges in North America

Elijah J. Talamas[1], Megan V. Herlihy[2], Christine Dieckhoff[3,4], Kim A. Hoelmer[4], Matthew L. Buffington[1], Marie-Claude Bon[5], Donald C. Weber[2]

1 Systematic Entomology Laboratory, USDA/ARS c/o NMNH, Smithsonian Institution, Washington DC, USA 2 Invasive Insect Biocontrol and Behavior Laboratory, USDA/ARS, BARC-West Beltsville MD, USA 3 Department of Entomology and Wildlife Ecology, University of Delaware, Newark, DE, USA 4 Beneficial Insects Introduction Research Unit, USDA/ARS, Newark, DE, USA 5 European Biological Control Laboratory, USDA/ARS, Montpellier, France

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

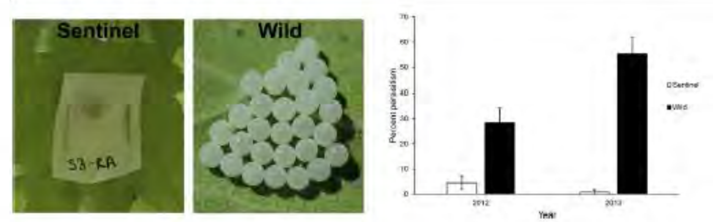
Ashley L. Jones, David E. Jennings, Cerruti R.R. Hooks, Paula M. Shrewsbury *

Department of Entomology, University of Maryland, 4112 Plant Sciences Building, College Park, MD 20742, USA

H I G H L I G H T S

- 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.

G R A P H I C A L   A B S T R A C T



Original Grant Objectives

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

Objective 3 - Progress

CURRENT STATE We are on the cusp of integrating tactics.

Original Grant Objectives

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

Stop BMSB

Biology, ecology, and management of brown marmorated stink bug in specialty crops

Search

- HOME
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- MANAGING BMSB
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Video Series

TRACKING THE BROWN MARMORATED STINK BUG

"Tracking the Brown Marmorated Stink Bug" shows growers and others how to identify BMSB, why this pest is important in agriculture, and what's at stake if we don't stop it. A team of 50 scientists is working toward sustainable solutions, and our outreach team is producing this video series to showcase the group's work.

Part 1: History and Identification
Duration: 4:34

Part 2: Overwintering and Spread
Duration: 5:38

Part 3: Monitoring and Mapping
Duration: 6:32

Part 4: Host Plants and Damage in Orchard Crops
Duration: 6:24

Part 5: Host Plants and Damage in Small Fruit
Duration: 3:05

Part 6: Host Plants and Damage in Vegetables
Duration: 4:52

Part 7: Host Plants and Damage in Ornamentals
Duration: 4:17

Part 8: Host Plants and Damage in the Pacific Northwest
Duration: 3:35

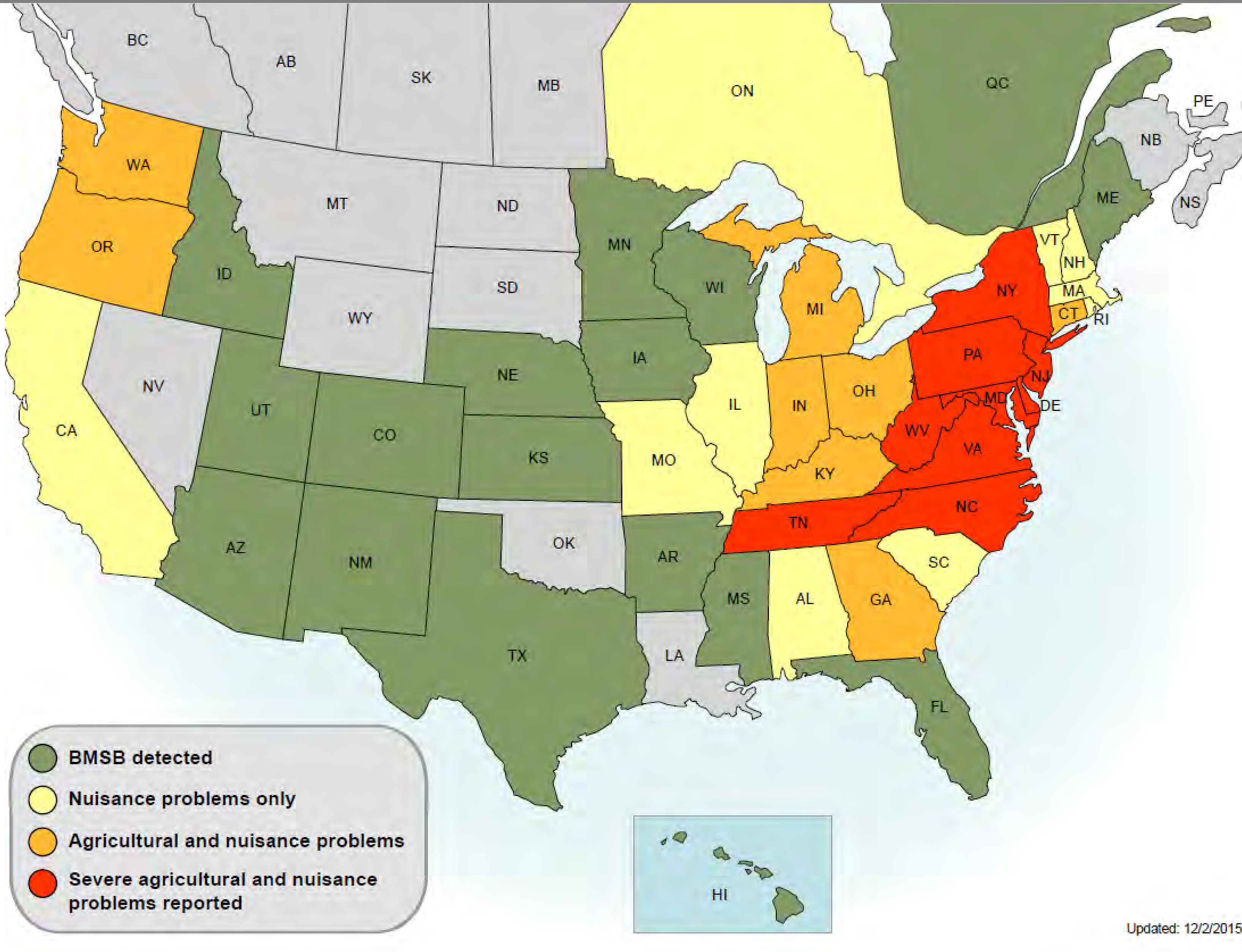
To Fight Stink Bugs, Take a Closer Look at Their Spit Scientists have developed a way to extract saliva from stink bugs and identify the proteins in it, paving the way

RELATED VIDEOS

Brown marmorated stink bug control: Keeping stink bugs out of your house
Source: Mike Raupp, Univ. of Maryland Extension

https://www.youtube.com/watch?v=BzM7IkdtOLs

Current Distribution of BMSB in North America



Specialty Crops at Risk to BMSB Damage

HIGH RISK	apple, Asian pear, beans (green, pole, snap), bee-bee tree, edamame, eggplant, European pear, grape[1], hazelnut, Japanese pagoda tree, nectarine, okra, peach[2], Peking tree lilac, pepper, redbud, sweet corn, Swiss chard, tomato	
MODERATE RISK	apricot, asparagus, blueberries[1,3], broccoli, cauliflower, cherry[2], collard, cucumber, flowering dogwood, horseradish, lima bean, littleleaf linden, serviceberry, tomatillo	
LOW RISK	blackgum, carrot, cranberries, garlic, ginkgo, greens, Japanese maple, kohlrabi, kousa dogwood, leeks, lettuce, many gymnosperms, onion, potato, spinach, sweet potato, turnip	
UNKNOWN ?	almond, citrus, hops, kiwi, olive, pistachio, plum, strawberries, walnut	
HOSTS — Non-Specialty Crop BMSB Hosts Contributing to Specialty Crops Risk	field corn, soybean	

1—Potential risk of taint/contamination. 2—Additional risk potential due to bark feeding. 3—Considered moderate-high risk.

About BMSB

The brown marmorated stink bug, *Halyomorpha halys* (Stål), is a voracious eater that damages fruit, vegetable, and ornamental crops in North America. With funding from USDA's Specialty Crop Research Initiative, our team of more than 50 researchers is uncovering the pest's secrets to find management solutions that will protect our food, our environment, and our farms.

Learn more at **StopBMSB.org**.

Stop BMSB

USDA

Funded by USDA-NIFA SCRI Coordinated Agricultural Project, grant #2011-51181-30937. Image credits—sweet corn: Joe Zlomek; eggplant: Howard F. Schwartz, Colorado State University, Bugwood.org; apple, carrots: morguefile.com/creative/bekahboo42; flowering dogwood: Richard Floyd, Creative Ideas LLC, Bugwood.org; blueberries, cauliflower: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org; ginkgo: Jan Samanek, State Phytosanitary Administration, Bugwood.org; cranberries: Cjboffoli (CC-BY-3.0). Printed May 2015.

Identification Kits

Integrated Pest Management for Brown Marmorated Stink Bug in Orchard Crops

A synopsis of what researchers have learned so far and management recommendations using an integrated approach

Authored by the BMSB SCRI CAP Orchard Crop Commodity Team:
Chris Bergh and Angel Acebes-Doria (Virginia Tech), Tracy Leskey, Rob Morrison and Brent Short (USDA ARS Kearneysville, WV), Greg Krawczyk (Pennsylvania State University), Jim Walgenbach (North Carolina State University), Arthur Agnello and Peter Jentsch (Cornell University), George Hamilton, Anne Nielsen and Brett Blaauw (Rutgers University), Vaughn Walton, Nik Wiman, Chris Hedstrom and Peter Shearer (Oregon State University), and Betsy Beers (Washington State University)

Basic Biology and Life Cycle of BMSB

- References herein to specific points in the growing season are based on information from the mid-Atlantic region, where the seasonal biology of BMSB is currently understood best, and may vary in other regions.
- BMSB is a serious agricultural pest of numerous crops during the late spring and summer.
- After emerging from overwintering sites in May and June, BMSB adults begin mating and laying eggs on various host plants (Fig. 1).
- In most of its range in North America, BMSB completes one to two generations per year, progressing from the egg stage through five nymphal stages (instars) before molting into a winged adult (Fig. 2).

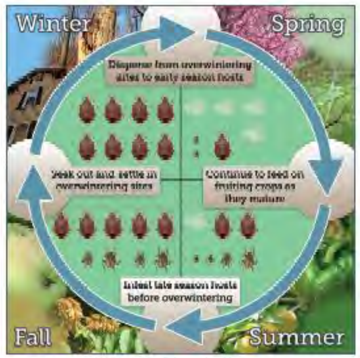


Fig. 1. Typical seasonal biology of brown marmorated stink bug.

Orchard Crops at Risk / Crops Not at Risk

- BMSB may move frequently among different wild and cultivated host plant species, feeding alternately among them.
- BMSB nymphs and adults feed by inserting their piercing-sucking mouthparts into fruit, nuts, seed pods, buds, leaves, and stems and appear to prefer plants bearing reproductive structures. Their mouthparts can penetrate very hard and thick tissue, such as the hazelnut hull.
- Older nymphs and adults cause more injury to apples and peaches than young nymphs.
- Peach is considered a preferred and highly vulnerable host. The survival of BMSB nymphs has been studied on only a few hosts, but peach was the only host on which they completed development without feeding on another plant.
- Nectarines show BMSB injury and may be as vulnerable as peach, but the relative susceptibility of apricots is less well known.
- Apples and European and Asian pears are also very susceptible to BMSB feeding injury.
- Economic injury from BMSB to hazelnuts has been documented in Oregon, but other nut crops have been less well studied at present.
- Cherries can sustain BMSB feeding injury, but the effects at harvest are usually small.
- Plums and plum hybrids are not considered as vulnerable to BMSB as some other tree fruits.

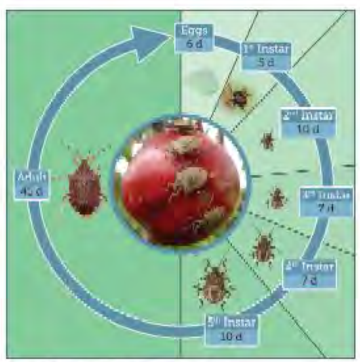


Fig. 2. Life cycle of brown marmorated stink bug.

Orchard Crop Injury Diagnostics

- BMSB feeding through the skin of tree fruits can cause injury to the fruit surface and flesh. These injuries are not immediately apparent, but develop gradually after feeding has occurred.
- Feeding on young peaches, nectarines, and apricots causes gummosis at the feeding site (Fig. 3), deformations on the fruit surface (Fig. 4), and brownish-red internal necrosis (Fig. 5).
- Feeding on more mature peaches and nectarines may or may not result in apparent surface injury at harvest but can cause areas of whitish necrosis in the flesh (Fig. 6), which has been an important marketing issue.
- The mouthpart insertion point on apples and pears leaves a tiny hole in the skin (Fig. 7) and a "stylet sheath" that runs into the flesh (Fig. 8), both of which are best detected under magnification. Apples and pears also exhibit surface deformations and shallow discolored depressions from BMSB feeding (Fig. 9).
- In apples and pears, most surface depressions are associated with an area of brown necrosis in the flesh beneath (Fig. 10).
- BMSB injury symptoms on apples may be mistaken for the physiological disorders associated with calcium deficiency, known as bitter pit and cork spot.
- Cherries show small punctures in the surface (Fig. 11) and external discoloration, but internal injury has not been as well characterized as for some other tree fruit crops.
- Hazelnuts show no visible external signs of damage. Injury from feeding on the nut flesh can only be determined by shelling the nut, revealing blank nuts (Fig. 12), shriveling (Fig. 13), or corky tissue (Fig. 14).


Fig. 3. Gummosis from BMSB feeding on peach.


Fig. 4. Surface deformations on peach.

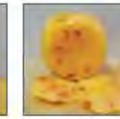


Fig. 5. Reddish-brown internal necrosis on peach.


Fig. 6. Shallow whitish internal necrosis on peach.


Fig. 7. BMSB stylet insertion point on apple.

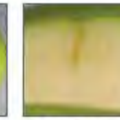


Fig. 8. Stylet sheath on apple.


Fig. 9. Discolored depressions on apple.


Fig. 10. Internal necrosis on apple.


Fig. 11. BMSB injury on cherry.


Fig. 12. Blank hazelnut.


Fig. 13. Shriveled hazelnut.


Fig. 14. Internal necrosis on hazelnut.

Period of Risk/Susceptibility

- BMSB adults and nymphs have a strong dispersal capacity and can fly or walk into crops from surrounding habitat and host plants through most or all of the fruiting period. In general, highest populations in orchards have been recorded in August and September.
- In the mid-Atlantic region, peaches, nectarines, and likely apricots are considered vulnerable to BMSB attack from soon after crop set through harvest.
- Mid-Atlantic apples and pears may exhibit some injury by late May, but this is most common starting about mid-June and increases as the season progresses. The timing of injury expression may vary in other regions.
- Apples harvested in September and later are exposed to the highest annual BMSB populations.
- BMSB feeding on apples during the last 1–2 weeks before harvest may not be expressed as injury at harvest; however, apples showing no surface injury at harvest may develop both surface and internal injuries following a period in post-harvest cold storage.
- At present, the period of risk to cherry varieties with different harvest dates has not been characterized.
- In hazelnut, feeding damage can occur throughout the season. Feeding during nut flesh formation in June and July can cause blank or shriveled nuts. Feeding after nut flesh formation (August–September) can result in corking at harvest (classified as "decay" by processors).

Provisional Monitoring and Scouting Recommendations

- Pyramid traps baited with a commercial lure containing the BMSB aggregation pheromone and the pheromone synergist, methyl decatrienoate, can be an excellent monitoring tool and are effective at capturing BMSB adults and nymphs season-long, even when populations are low (Fig. 15).
- In apples, research in West Virginia and Maryland has demonstrated that captures in these traps can be used to trigger a management action. When cumulative captures of adult BMSB in any trap within the orchard or at the orchard border reached a threshold of 10, an effective insecticide was applied as two alternate-row-middle sprays with 7 days between. This strategy has been demonstrated to reduce the number of BMSB-targeted sprays while maintaining good control of injury.
- Research has demonstrated that BMSB injury to apples at harvest tends to be greatest in fruit from the upper canopy of trees in border rows next to woods, aiding injury scouting efforts during the season. It is recommended that scouting for BMSB injury to peaches and nectarines should include periodically inspecting sampled fruit for internal injury, since it may not be associated with injury on the fruit surface.

Fig. 15. Commercial stink bug pheromone trap.

Provisional Management Strategies

- BMSB is a landscape-level threat that can invade orchards from wooded habitats, other nearby crops, and in the spring, potentially from human-made structures (Fig. 16).
- BMSB does not reside permanently in any crop; pest pressure from it is often

Fig. 16. BMSB is a landscape-level threat that can invade orchards from wooded habitats and other nearby crops.

highest along orchard edges, especially edges bordering woodlands with its wild host plants.

- The intensity of BMSB management required during each growing season can vary according to the size of the adult population that survives the winter and the subsequent rate of population growth. Winter temperatures lower than about 10°F cause increasing rates of mortality, although BMSB numbers tend to increase substantially between spring and late summer.
- BMSB management in peaches and nectarines may be considered from shuck-split onward. Management in apple and pears may begin in early to mid-June, although in years with high BMSB pressure, intervention beginning in the latter part of May could be prudent.
- In hazelnut, intervention against BMSB in August and September may yield the most beneficial economic impacts.
- Use of the pheromone trap-based provisional threshold (see Provisional Monitoring and Scouting Recommendations) in apples may enhance management effectiveness and efficiency.
- The overwintering generation of BMSB tends to be more susceptible to insecticides than the summer generation. Therefore, products with the best effectiveness against this pest should be used later in the season.
- Insecticides should be rotated among products in different classes with different modes of action (see Table).
- Many of the effective insecticides for BMSB have relatively short residual activity against it; thus, alternate-row-middle applications at about 7-day intervals may improve control.
- Virtually all effective insecticides against BMSB (see Table) also kill natural enemies and should be used only when necessary. Reducing pyrethroid applications in crops and/or limiting sprays to border row trees can help protect important natural enemies.
- Weekly border sprays (insecticide treatment to orchard perimeter plus the first full row) in peach have shown to be equally effective as alternate row middle application at protecting fruit.
- Perimeter-based management tactics, such as orchard border row sprays and pheromone-based "attract-and-kill," are being evaluated and show promise for BMSB management in apple.
- ALWAYS read the label before applying any insecticide.

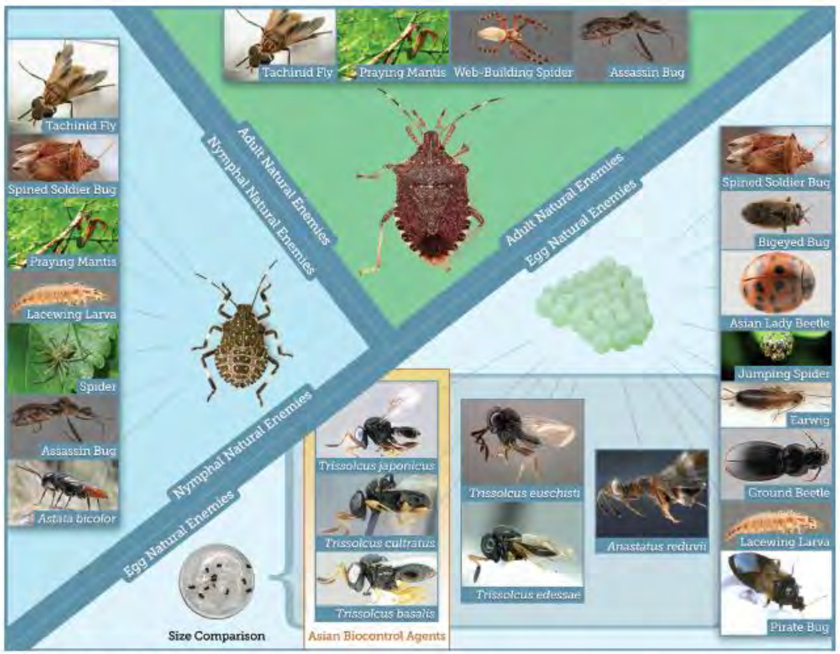


Fig. 17. Arthropod natural enemies of BMSB.

Biological Control

- Various species of tiny wasps that parasitize the eggs of most native stink bug pests are key natural enemies that can reduce populations. However, parasitism levels of BMSB eggs by these North American species have been low and have not significantly impacted BMSB populations. An Asian egg parasitoid of BMSB eggs was recently detected in the eastern and western USA. This species shows high levels of BMSB egg parasitism in Asia and may eventually have significant impacts on BMSB here.
- Various generalist predatory insects will feed on BMSB eggs and nymphs, and also may provide important biological control services against this pest (Fig. 17).

Effective Insecticides for Controlling BMSB in Orchard Crops

The following is a list of insecticides registered for use on orchard crops in the U.S. that have demonstrated efficacy against BMSB in laboratory and/or field trials. This list may not be exhaustive for every active ingredient or labeled product. Before using any pesticide, ensure that the product is registered for use on the target crop in your state. Some materials that have shown effectiveness against BMSB are not labeled for use in certain states. This list is not to be considered a substitute for pesticide labeling. Always read, understand, and follow the label directions before using any pesticide.

		Crops listed on pesticide label with pre-harvest interval (days). "NL" indicates not labeled on that crop.					
Active Ingredient (IRAC class*)	Product Name(s)	Peach	Nectarine	Apricot	Apple	Pear	Hazelnut
beta-cyfluthrin (3A)	Baythroid XL	7	7	7	7	7	14
beta-cyfluthrin (3A) + imidacloprid (4A)	Leverage 360	7	7	7	7	7	14
bifenthrin (3A)	Bifenture, Brigade, Sniper	NL	NL	NL	NL	14	7
clothianidin (4A)	Belay	21	NL	NL	7	7	21
cyfluthrin (3A)	Tombstone	7	7	7	7	7	14
diflubenzuron (15) + lambda-cyhalothrin (3A)	DoubleTake	NL	NL	NL	NL	NL	28
dinotefuran (4A)	Scorpion[1], Venom[1]	3	3	NL	NL	NL	NL
fenpropathrin (3A)	Danitol	3	3	3	14	14	3
gamma-cyhalothrin (3A)	Declare, Proaxis	14	14	14	21	21	14
imidacloprid (4A)	Admire Pro, Alias, Wrangler	0	0	0	7	7	7
lambda-cyhalothrin (3A)	Warrior II, Lambda-Cy, Silencer	14	14	14	21	21	14
lambda-cyhalothrin (3A) + thiamethoxam (4A)	Endigo	14	14	14	35	35	14
methomyl (1A)	Lannate	4	1	NL	14	7[2]	NL
permethrin (3A)	Permethrin 3.2EC, Perm-UP	14	14	NL	—[3]	—[3]	14
thiamethoxam (4A)	Actara	14	14	14	35[4]	35[4]	NL
zeta-cypermethrin (3A)	Mustang Maxx	21	21	21	28	28	7

* – IRAC (Insecticide Resistance Action Committee) class: 1A = carbamates, 3A = pyrethroids, 4A = neonicotinoids.

1 – Scorpion and Venom have a Section 3 label for peaches and nectarines. Since the residue tolerances for these products were established before BMSB became an issue, even the highest rate on these labels may not provide adequate control of BMSB.

2 – Lannate can be used in pears only in CT, DE, MD, ME, NH, NJ, NY, PA, RI, & VT.

3 – Permethrin-based products cannot be applied after petal fall in apples and only during pre-bloom in pears and are therefore not useful for BMSB management in those crops.

4 – Pre-harvest interval of 35 days for apples and pears based on the use of rates that would be considered effective against BMSB (see label).

Product names are mentioned for convenience only. No endorsement of products is intended, nor is criticism of unnamed products implied. Consult your local Extension Service for more information about the relative effectiveness of the various products listed.

Problems That May Arise from Multiple Post-Bloom Applications of Broad-Spectrum Insecticides in Orchard Crops

- Destruction of natural enemies, including arthropod predators and parasitoids that can control other pests
- Outbreaks of secondary pests such as woolly apple aphid, San Jose scale, white peach scale, spider mites, hazelnut and filbert aphid, and filbert big bud mite
- Selection for resistance in pest populations

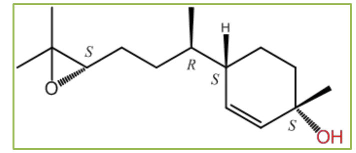
Produced by the Brown Marmorated Stink Bug SCRI CAP Orchard Crop Commodity Team in conjunction with the Northeastern IPM Center.
This work was supported in part by: USDA-NIFA SCRI award #2011-51181-30937.
Published June 2016.

Key Personnel Trained

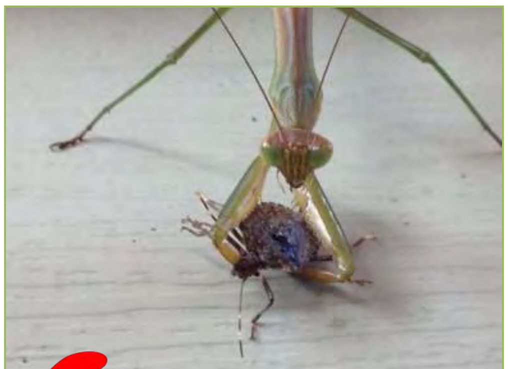
Undergraduates and H.S.	Graduate Students	Post-Docs and Visiting Scholars	Technical Staff
147	39	30	43

Research Priorities

Studies of BMSB Biology, Behavior and Ecology



Identification of Aggregation Pheromone



Identification of Effective Biological Control Agents

Identification of Effective Insecticides

Standardized Sampling/Monitoring Techniques

Pending Questions

- Invasion ecology and pest status? *Establishment in other regions of the country – southeast is rapidly increasing, west coast areas and continued pressure in the mid-Atlantic and conversely, areas where it seems limited – Eastern coastal plains, northern locations. Influence of abiotic factors (high/low temperature, daylength, humidity). Multiple introductions?*
- Phenology and impact on other specialty crops? *Hops, olive, kiwi, citrus, nut crops (almond, pecan, walnut, pistachio), and tomato. (strawberry and plum?). Adult vs nymphal contribution and damage diagnostics for numerous crops*
- Biology and population ecology in various regions? *Diapause, voltinism, reproduction, model validation and refinement? Methods developed, but not well characterized yet.*
- Early spring biology and ecology? *What happens when they leave an overwintering site? Reproduction? Feeding? Dispersal and fate?*
- Mid season biology and ecology? *What triggers movement between hosts? Host quality? Volatiles? Etc.*
- Late season biology and ecology? *What triggers dispersal from hosts to an overwintering site? What behavioral events?*
- Contribution of wild and non-specialty crop hosts on overall populations? *Influence of acceptable hosts and their density on overall populations.*
- Optimized methods for rearing BMSB colonies? *Food, conditions, identifying issues (pathogens).*
- Conventional and organic insecticides for specialty crops? *Identifying insecticides for additional specialty crops (nut crops, citrus, olives). Impacts on beneficials?*
- Non-neonic programs? *If regulatory changes occur, how will we manage in their absence?*
- Optimization of pheromone lures for monitoring and management? *Improved synthetic pathways for main component, optimized ratio of pheromone/synergist, release rates, distance of response, management (attract and kill, baited trap crops)*
- Key native natural enemies and their conservation in different regions and cropping system? *Vary across regions and near crops, how to best promote and conserve them*
- Impact of *T. japonicus*? Did it survive, distribution, biology and ecology, impact on natives?
- Optimized trapping methods for various specialty crops? *Different trap types may be best for different specialty crops*
- Fungal pathogens? *Can we overcome the difficulty for fungi penetrating cuticle and potential for defensive compounds to reduce viability?*
- Cultural Techniques? *Exclusion, host removal?*
- Incorporating and integrating tools into a single crop and across crops? *Some orchard crops (apples, peaches) are working on this, but much more to do.*
- Development and validation of tools in other specialty crops? *Fruiting vegetable crops and many others.*
- Farmscape-level managment? *Based on identified risk factors, can we integrate tools and improve management (host removal and natural enemy promotion/conservation, attract-and-kill, for example).*
- Area-wide management? *Implementing landscape-level management tactics (T. japonicus, for example) to reduce overall populations and decrease grower-level inputs into specialty crop production.*
- Resistance management ? *Establish baseline levels and monitor potential development in different area of US.*
- Economics of BMSB? *Programs with integrated tools? Production of pheromone depending on synthetic pathway, loading, ratios, etc. Cost of and potential ROI for conventional tactics and classical biological control program, Damage estimates over time?*
- Longitudinal grower surveys? *Adoption of new tactics and technology, mitigation of damage due to knowledge (identification of adults and nymphs)?*
- Sustained delivery of information? *As new information is generated, integrate with existing and utilize at a national level.*
- Connection with and feedback from longtime and new stakeholders? *As new information is generated, integrate with existing and utilize at a national level.*

Pending Questions

- **Invasion ecology and pest status?** *Establishment in other regions and continuing pressure in existing range. Influence of abiotic factors (temperature, daylength, humidity). Multiple introductions?*
- **Non-neonic programs?** *If regulatory changes occur, how will we manage in their absence?*
- **IPM Programs?** *Based on identified risk factors, can we integrate tools and improve management (decision support tools, host removal, natural enemy promotion/conservation, attract-and-kill).*
- **Area-wide management?** *Implementing landscape-level management tactics (T. japonicus, for example) to reduce overall populations and decrease grower-level inputs into specialty crop production.*
- **Sustained delivery of information?** *As new information is generated, integrate with existing and utilize at a national level.*

Thank you!