Pheromone-Based Monitoring and Management Tools for the Brown Marmorated Stink Bug in Apple Orchards

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

My Introduction to BMSB on October 8, 2003

Shell Service Station and Snax Store, Hagerstown, MD

2010 BMSB Outbreak in Mid-Atlantic

History of BMSB

in the United States

First suspected specimens collected in Allentown, PA

First properly identified specimen in the USA. Collected in Allentown, PA

First confirmed MD specimen

Continued spread and localized reports of injury in Allentown, PA area

First widespread reports of late season injury in tree fruit in Mid-Atlantic

Serious late season injury in tree fruit in Mid-Atlantic

Severe crop injury and serious nuisance problems throughout the mid-Atlantic.

Aggressive chemically-based management. Late-season populations down in most locations, higher than others.

Secondary pest problems become common in east and increasing populations in west and southeast

Rebuilding IPM and mitigating risk

1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013 - Present


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

Widespread Severe Damage

In Fruit, Vegetables, and Row Crops


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

Widespread Nuisance Problems For Homeowners and Businesses

HOME PAGE | TODAY'S PAPER | VIDEO | MOST POPULAR | TIMES TOPICS

Subscribe to The Times | Help | TimesPeople

The New York Times

U.S.

Search All NYTimes.com

Go

ING DIRECT

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION | ARTS | STYLE | TRAVEL | JOBS | REAL ESTATE

POLITICS | EDUCATION | BAY AREA | CHICAGO

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.

Building A Collaborative Team and Identifying Priorities

Northeastern IPM Center

Search

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

Got Pests? Need Funding?

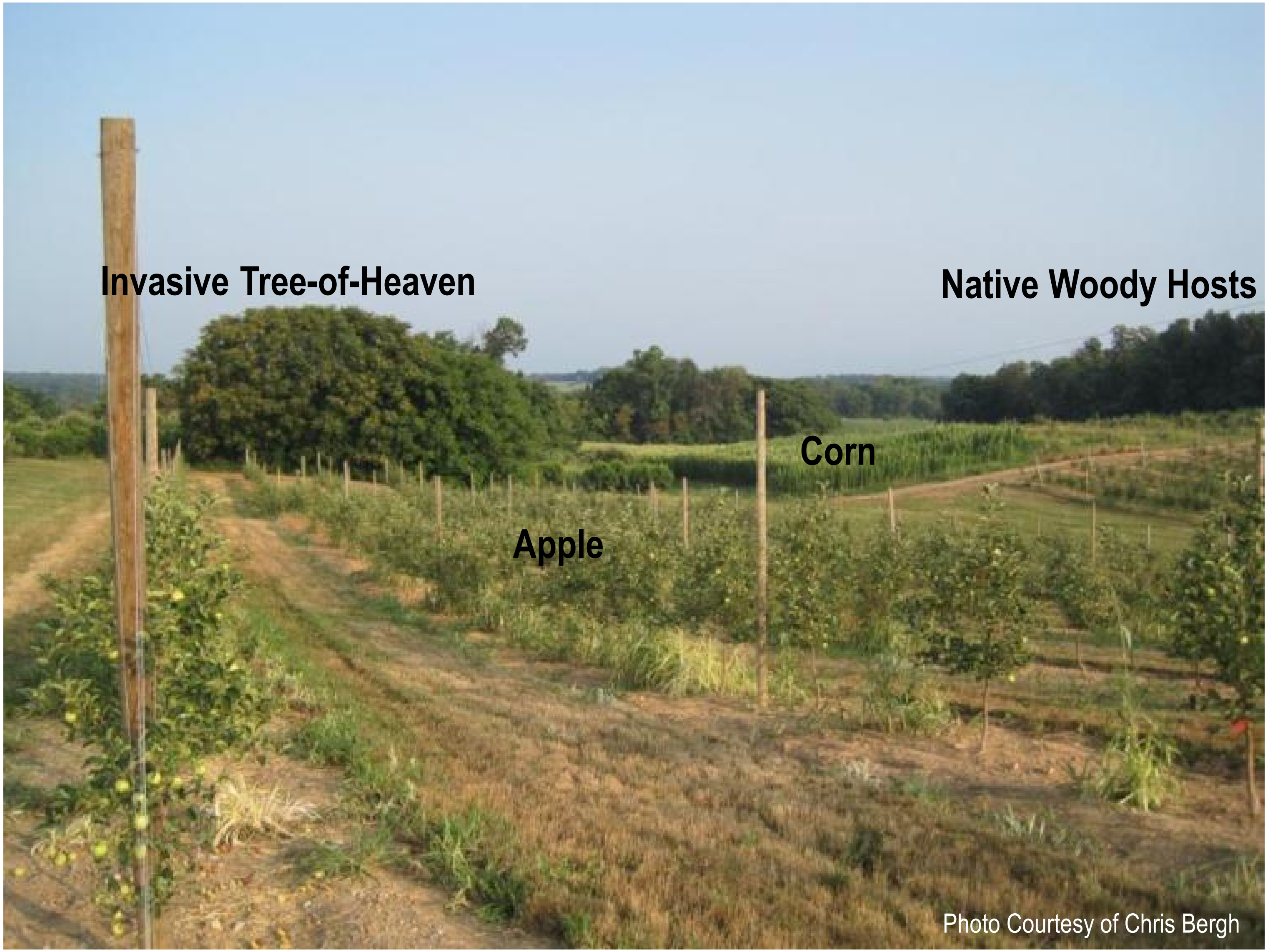
- HOME
- ABOUT US
- IPM IN ACTION
- GRANT PROGRAMS
- WORKING GROUPS
  - Marmorated Stink Bug
  - Pollinator

HOME » WORKING GROUPS » Marmorated Stink Bug

Brown Marmorated Stink Bug IPM Working Group

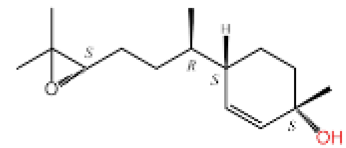
Funded in 2010 and 2011, this working group has established itself as the primary platform for facilitating and coordinating research and outreach efforts for Brown Marmorated Stink Bug (BMSB) across the United States. The group hosts formal meetings on BMSB at which members share the latest research results and field observations and established research and extension priorities. Participants include researchers, extension personnel, growers, pest control operators, and a hotel manager. Learn about this working group's plans for 2011-12.

Landscape-Level Threat To Crops



Research Priorities

Studies of BMSB Biology, Behavior and Ecology



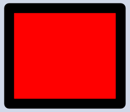
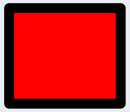
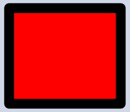
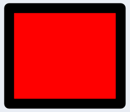
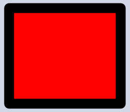
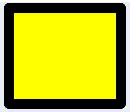
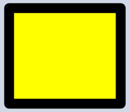
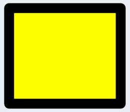
Identification of Aggregation Pheromone

Identification of Effective Biological Control Agents

Identification of Effective Insecticides

Standardized Sampling/Monitoring Techniques

Insecticides Used Against BMSB in Tree Fruit

Insecticide	Lethality	Residual Activity (3d)	Beneficials
Methomyl (Lannate)	HIGH	LOW - MODERATE	
Endosulfan (Thionex)	HIGH	LOW	
Bifenthrin (Brigade)	HIGH	LOW	
Fenpropathrin (Danitol)	HIGH	LOW	
Lambda-Cyhalothrin (Warrior)	MODERATE	LOW	
Clothianidin (Belay)	MODERATE	MODERATE	
Dinotefuran (Scorpion, Venom)	HIGH	LOW	
Thiamethoxam (Actara)	MODERATE	LOW - MODERATE	

JUNE 2011

	SPRAY SCHEDULE – BMSB * every other row lg. apples, peaches * every 4th row trellis apples 1			– ARMS in stone fruit, pome fruit + brambles 2	apples – peaches – 3	McHenry Highland Festival* Blueberries Brambles Cherries (4th)
5	apples peaches, plums strawberries (OUTSIDE) 6	cherries 1/2 potatoes tomatoes vegetables 7	cherries 1/2 1/2 brambles 1/2 blueberry blackberry 8	apples, peaches, plums (INSIDE) 9	blueberries 39/40 44 brambles 13, 15, 16, 44, 41 10	Early Summer Season rates begin this weekend Crack spray cherries 11
Apples Peaches (OUTSIDE) 12	vegs, tomatoes cherries grapes, goose(b) plums, apricot 13	Blueberries Brambles 14	Apples peaches (INSIDE) Blueb. (admire) 15	Crack spray cherries Cherries tomatoes, flowers 16	Blueberries brambles → vegetables cherries crack spray 17	Peach Apple (OUTSIDE) 18
Father's Day 19	Brambles, Blueberries, grapes, gooseberries (OUTSIDE) 20	Peaches apples (INSIDE) 21	cherries/plums (inside) 22	Bramble (outside) Blueberry (inside) 23	peach apple (outside) 24	Summer Season rates begin this weekend 25
Brambles Blueberries (outside) (#50/48) 26	apple peach inside cherry 27	tomatoes vegs. flowers potatoes 28	Brambles Blueberries (inside) 29	Apples Peaches (OUTSIDE) 30	tomatoes, vegs potatoes, flowers 7/1	wood's edge orleans 7/2

Key Components of Trap-Based Monitoring

- Visual Stimulus
- Olfactory Stimulus
- Capture Mechanism
- Deployment Strategy

One Attractant Available Prior to 2012

- Methyl (2E, 4E, 6Z)-decatrieonate is an attractant produced by the Asian stink bug, *Plautia stali.*

- Cross attractive to BMSB and other pentatomids.

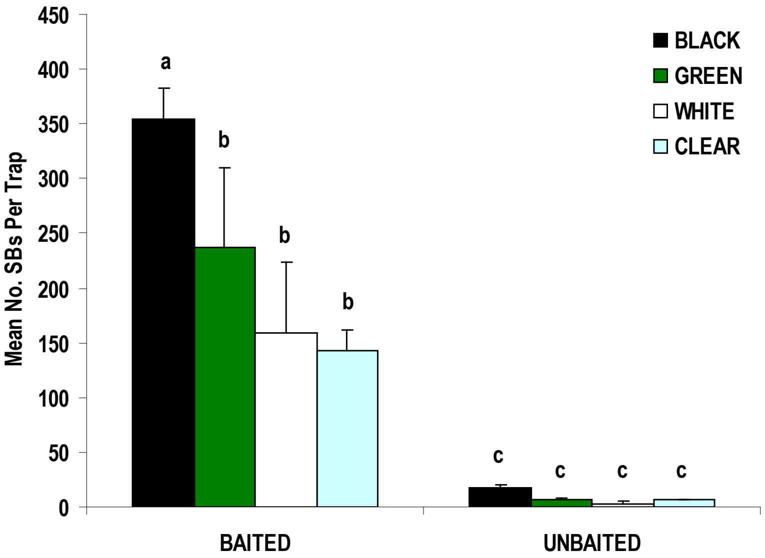
20009-2010 BMSB Response to Visual Stimuli

Black | Green | Yellow | White | Clear

Trunk Mimic | Foliar Stimulus | Foliar Stimulus | Unapparent Stimulus | Unapparent Stimulus

- **Responses to visual stimuli associated with trap bases.**
- **Baited and unbaited traps at the periphery of orchards. Four replicates. Sampled twice weekly.**
- **Captures from October 7-November 17, 2009 and July 23-October 14, 2010.**

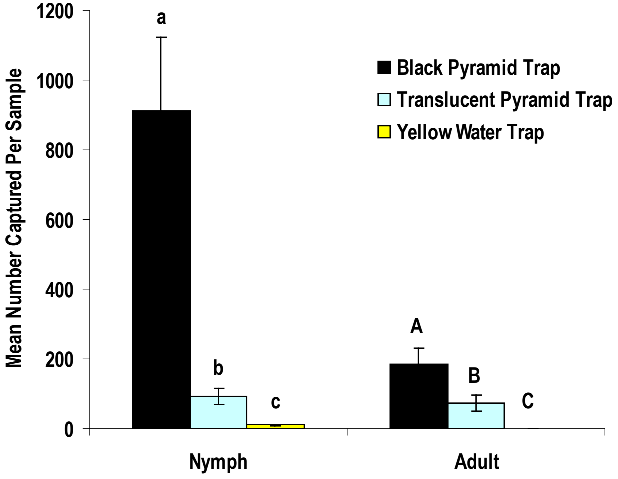
Baseline Trapping Studies



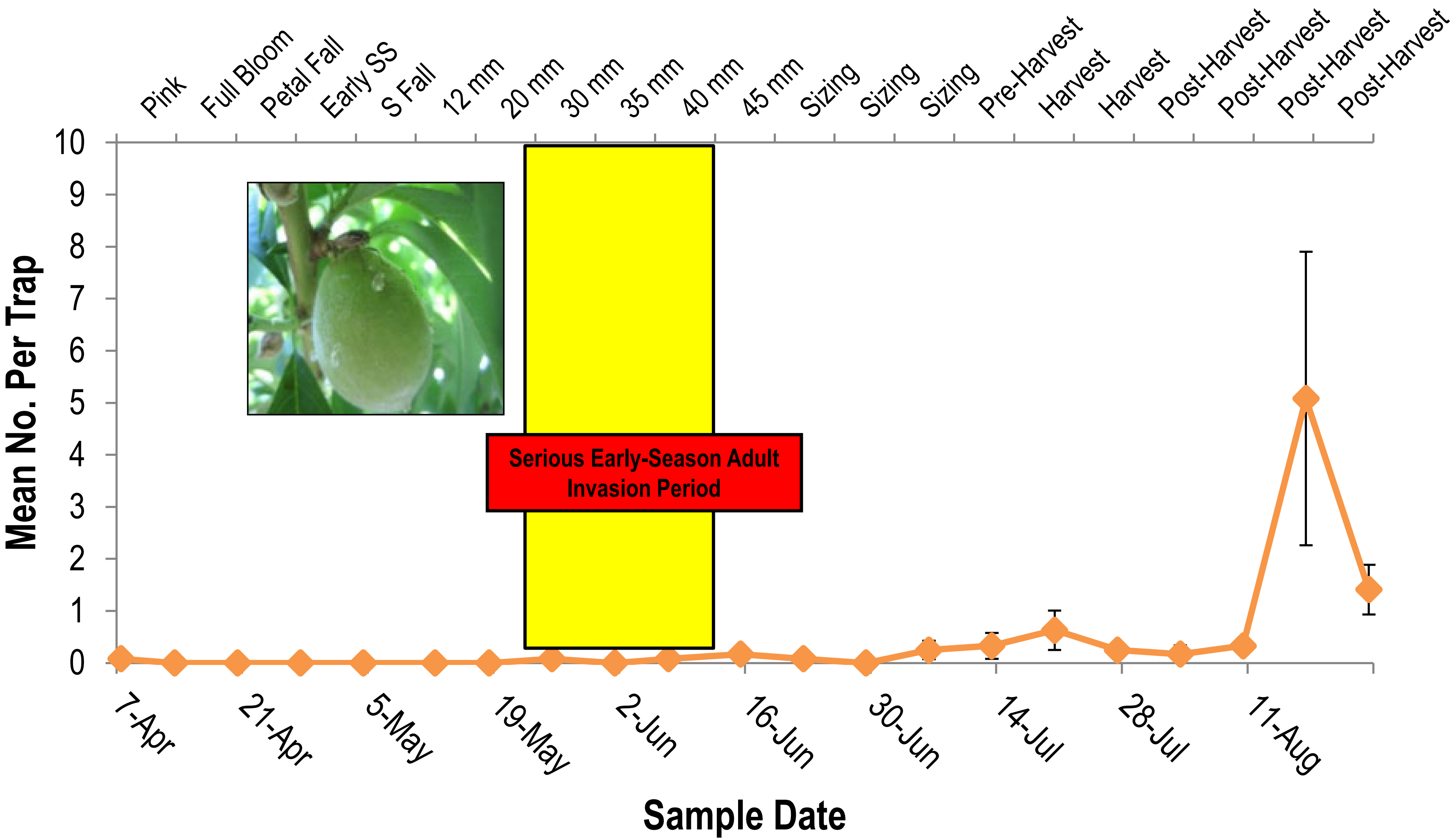
CBC America, Japan

Sankei Chemicals Co., Ltd., Kagoshima, Japan

AFRS

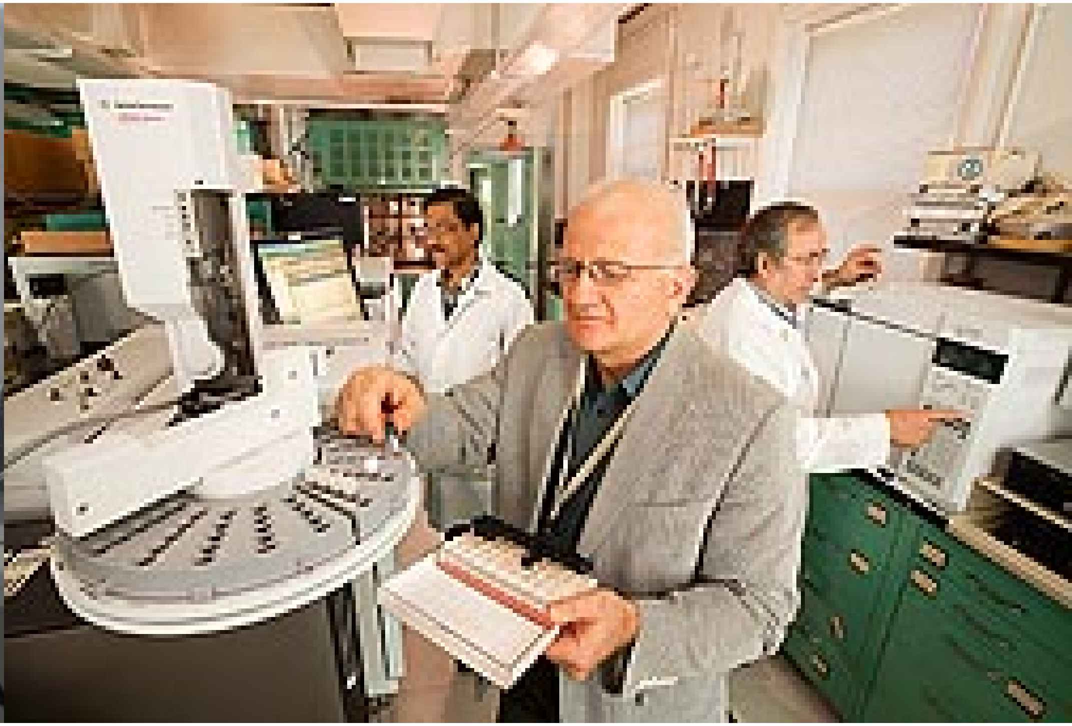


Serious Limitations For Season-Long Monitoring

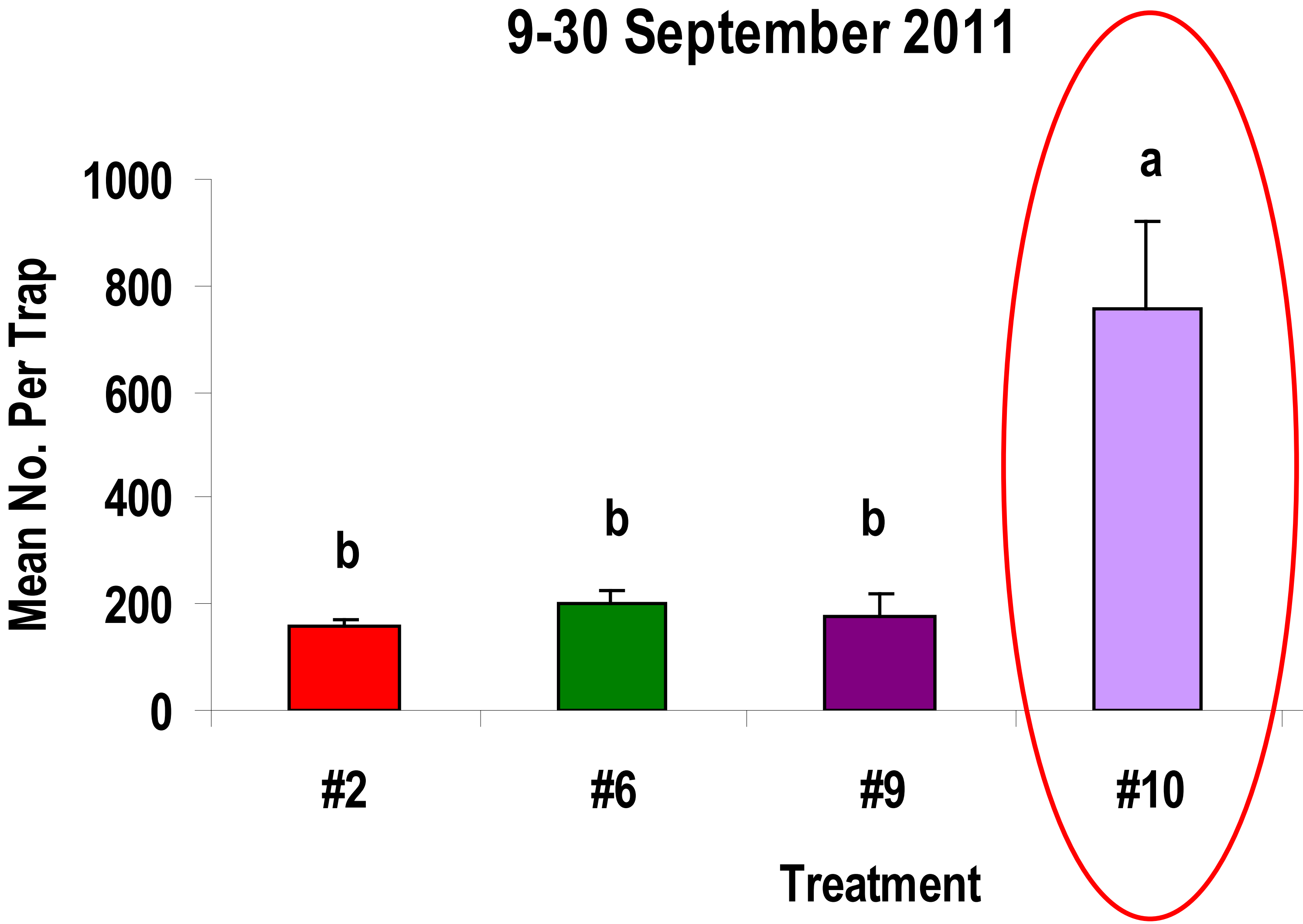


Leskey et al. 2012d

Identification and Commercialization of BMSB Aggregation Pheromone

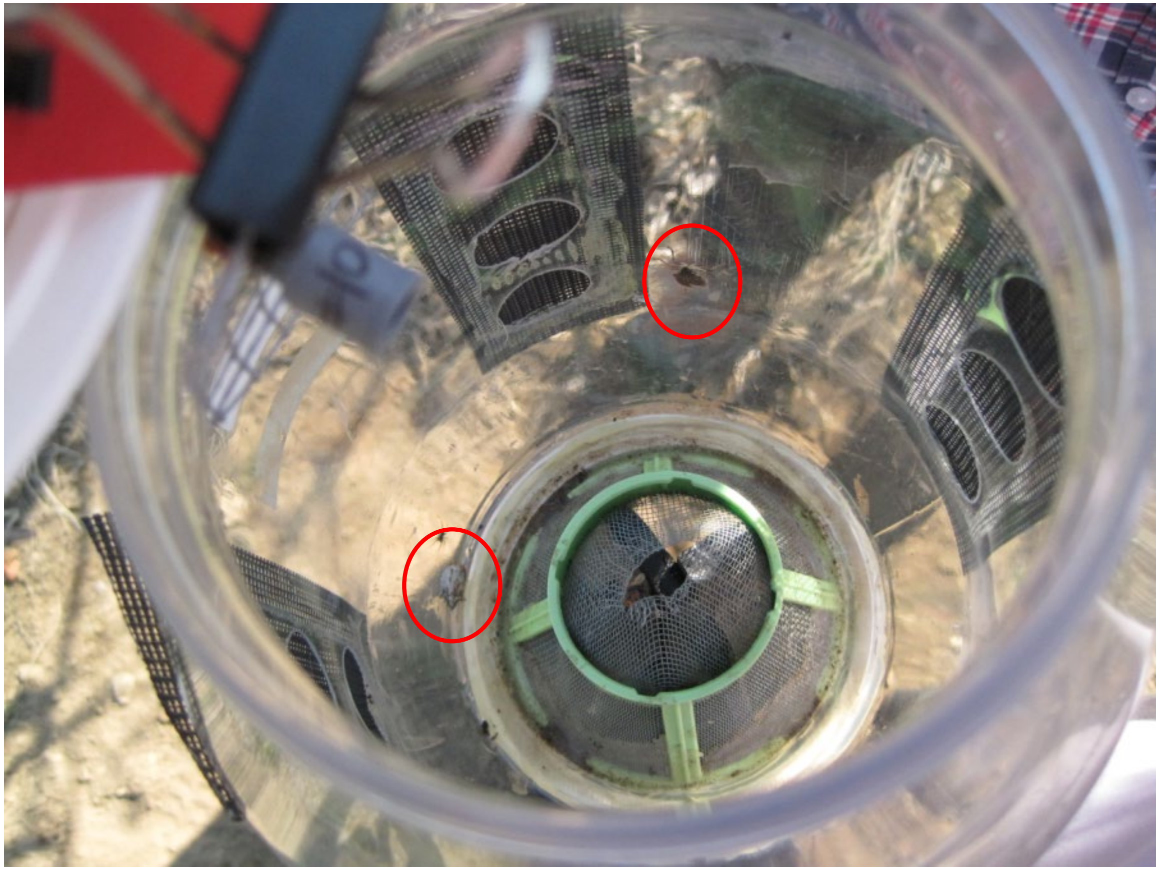


BMSB Aggregation Pheromone Breakthrough

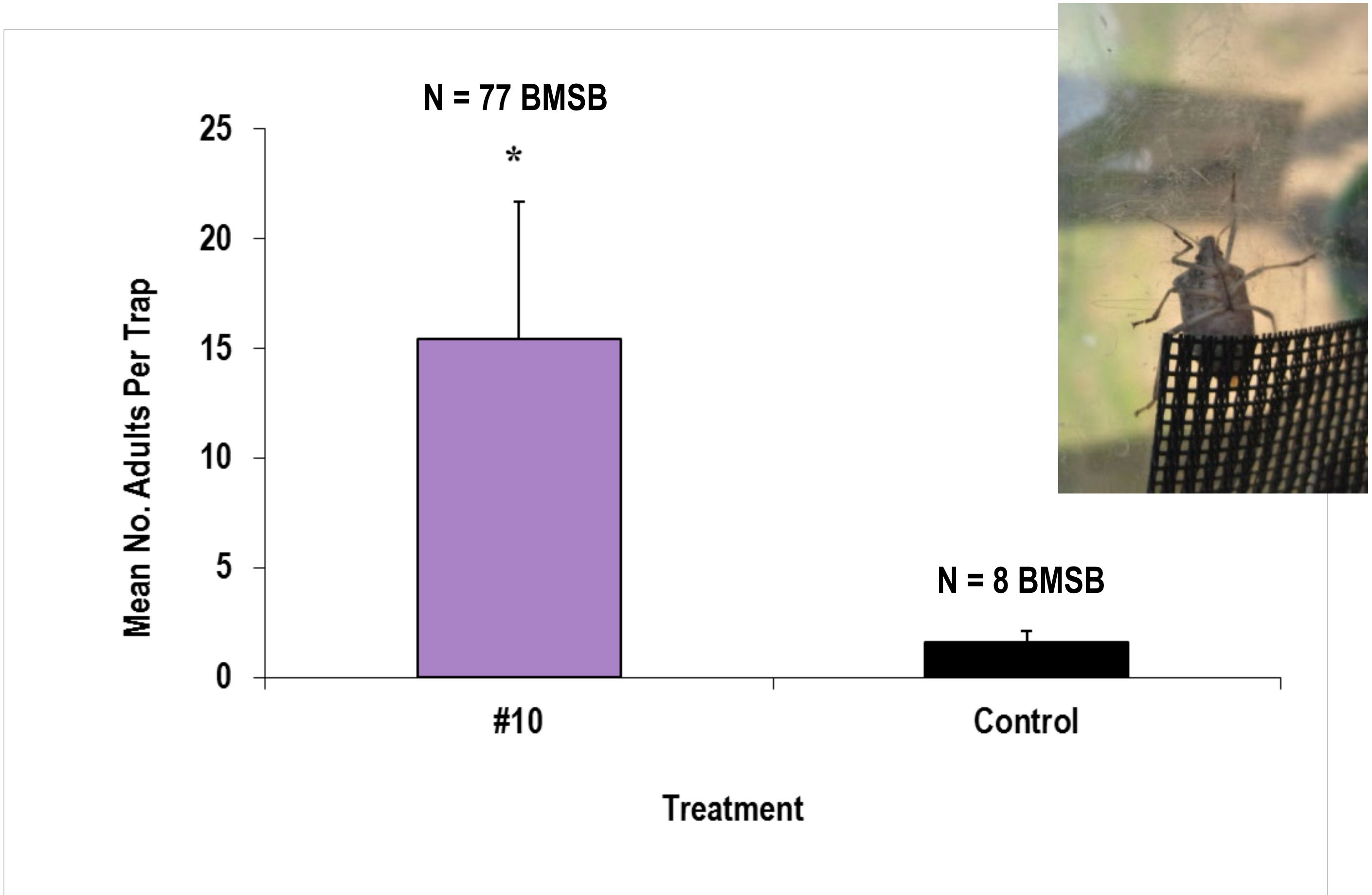


Is #10 Attractive in the Early Season?

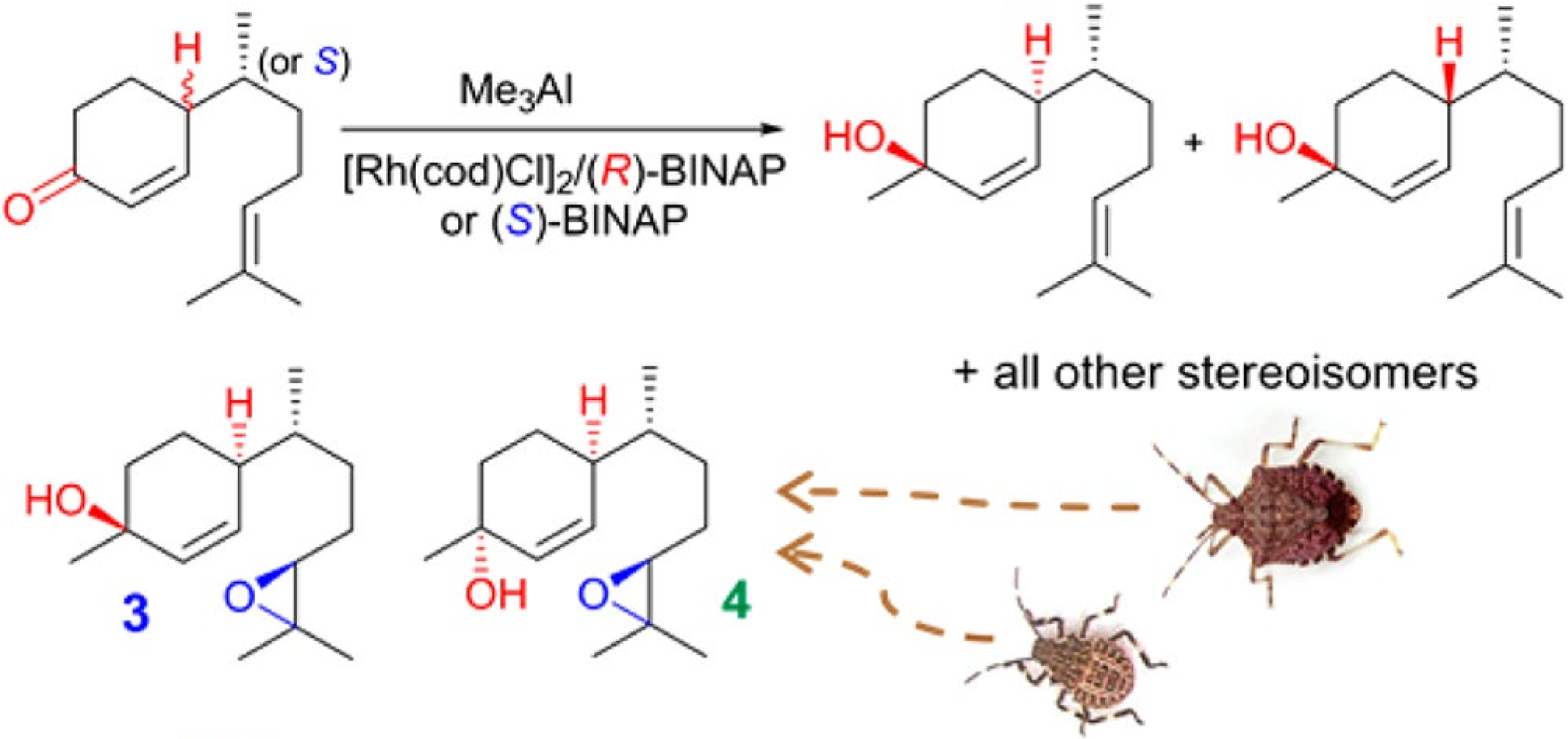
Pre-Trial (March 20-April 17, 2012)



Early Season Attraction Documented for BMSB March 20-April 17, 2012



Two-Component BMSB Aggregation Pheromone Identified



3+4: aggregation pheromone of brown marmorated stink bug, *Halyomorpha halys*

Khrimian et al. 2014

Broad Validation Across The Country

- Is BMSB attracted to the pheromone in the early season?

- Is BMSB attracted to the pheromone season-long?

- How attractive is this stimulus relative to MDT and unbaited traps?

- Traps evaluated in over 12 states across the country.

General Protocol

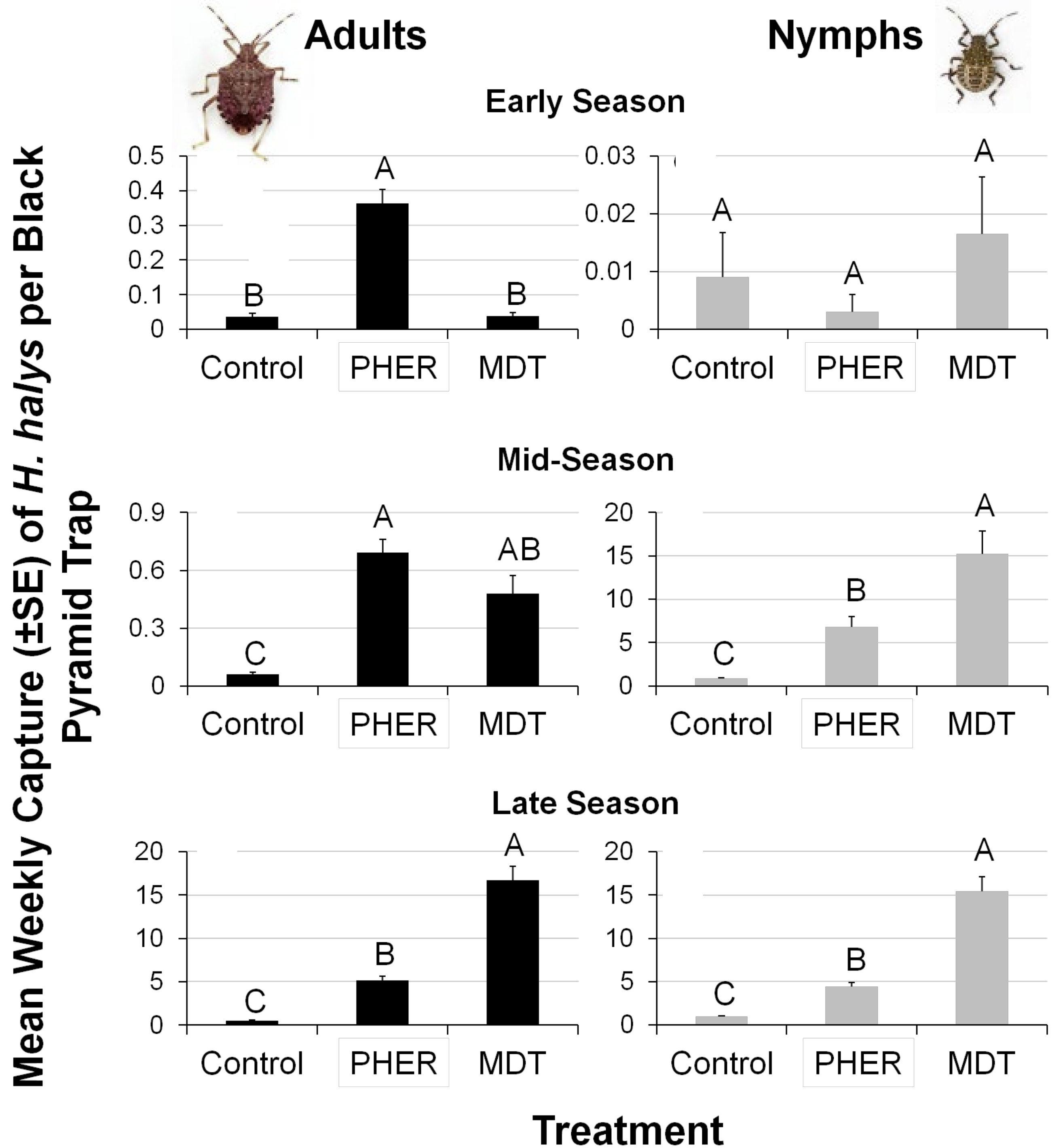
- Black pyramid traps

- Three odor treatments
  - 1) BMSB Pheromone (10 mg)
  - 2) MDT (119 mg) 10X greater
  - 3) unbaited control

- Traps are deployed between wild host habitat and agricultural production areas.

- Traps were deployed in mid-April and left in place season-long.

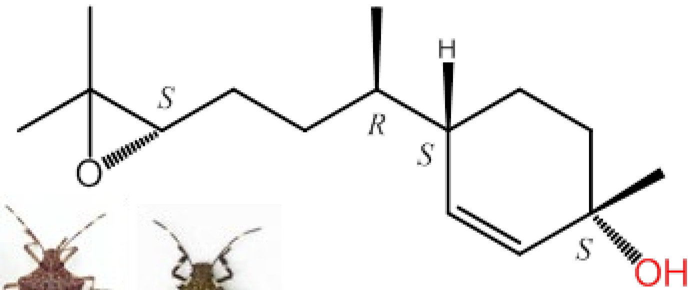
2012 Summary Results



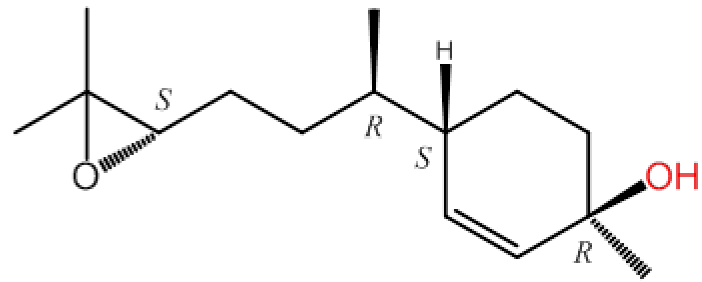
Leskey et al. 2015a

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

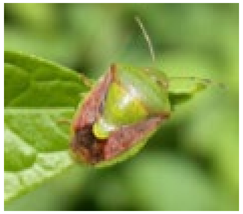


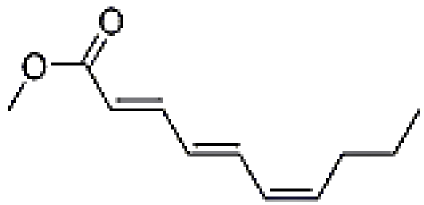
Minor component of BMSB aggregation pheromone
(3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol



+

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





=

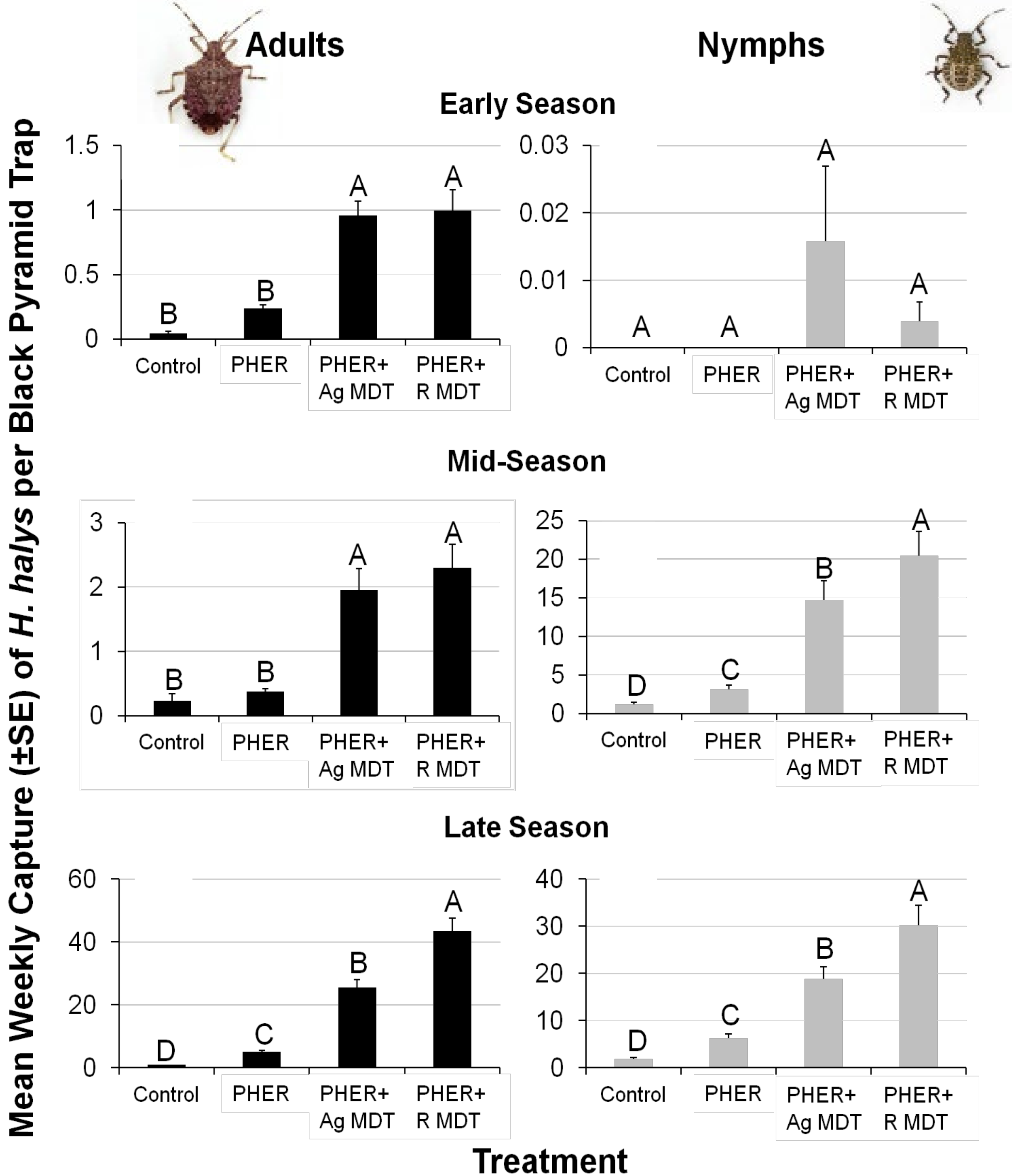
Synergism

Weber et al. 2014

General Protocol

- Black pyramid traps
- Three odor treatments
  - 1) #10 (10 mg)
  - 2) #10 (10 mg) + Rescue MDT (119 mg)
  - 3) #10 (10 mg) + AgBio MDT (66 mg)
  - 4) Unbaited control
- Traps are deployed between wild host habitat and agricultural production areas.
- Traps were deployed in mid-April and left in place season-long.

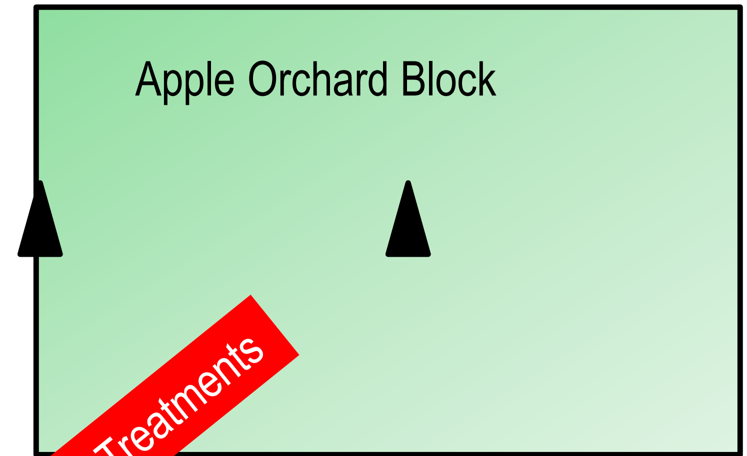
2013 Summary Results



Leskey et al. 2015a

Can we use biological information provided by trap captures to guide management decisions?

- Apple blocks. monitored with two baited traps. Traps checked weekly.
- When adult captures in either trap reached a set threshold, the block was treated with BMSB material (ARM).
- Block treated again 7-d later. Threshold was then reset.



Experimental Treatments

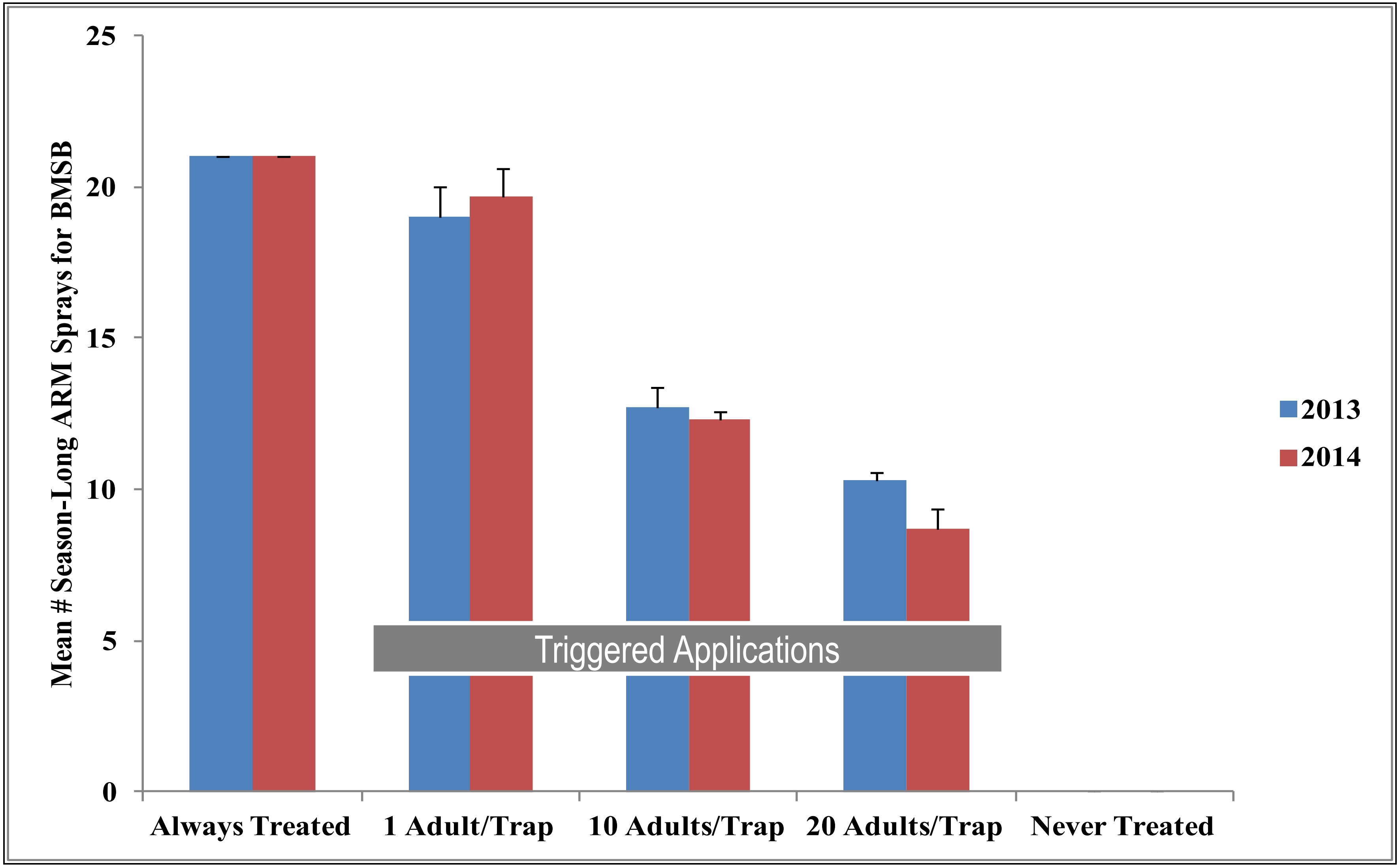
Sprays Triggered at:

1) 1 Adult / Trap
2) 10 Adults / Trap
3) 20 Adults / Trap

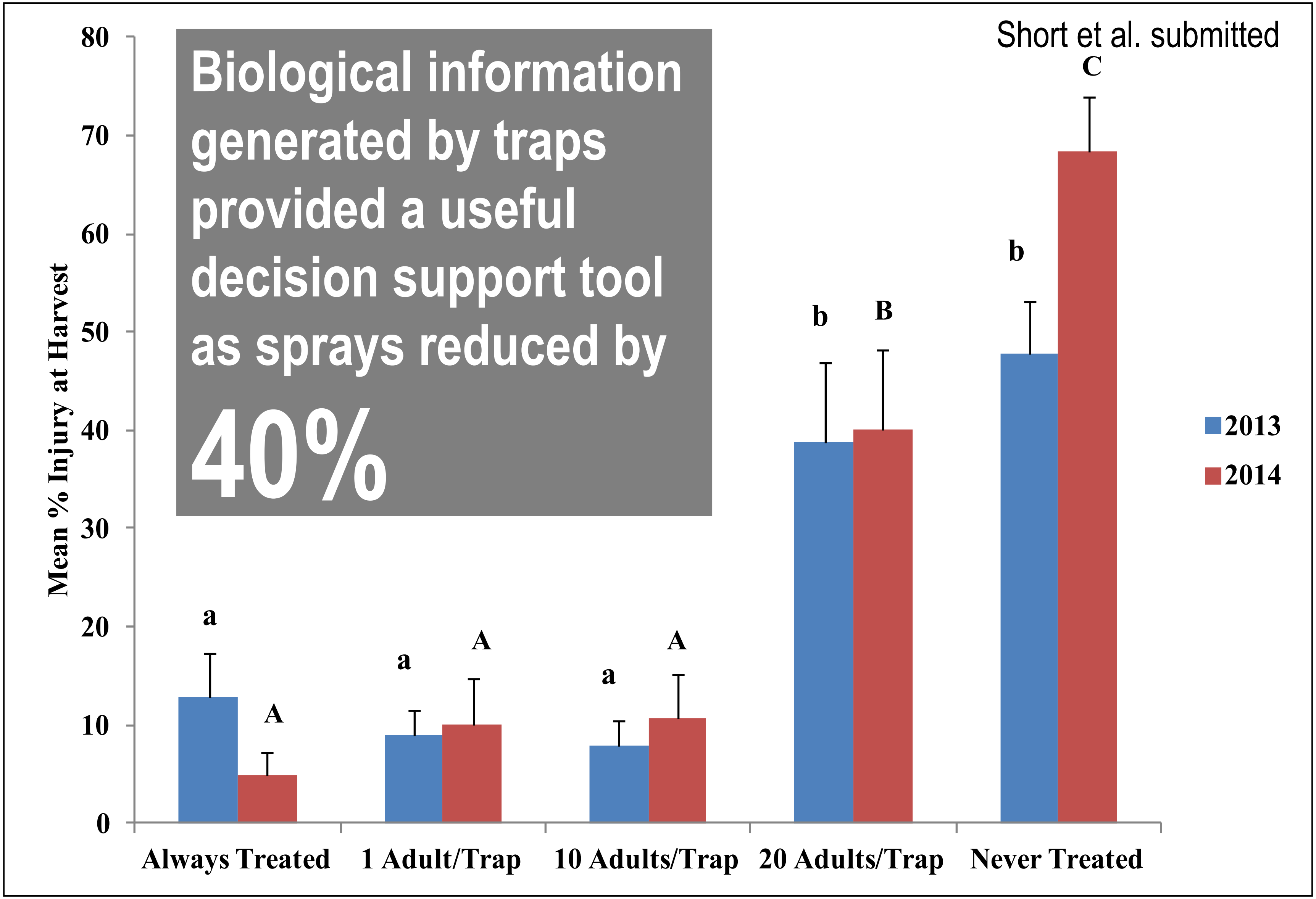
4) Treated Every 7 d

5) No Spray (Control)

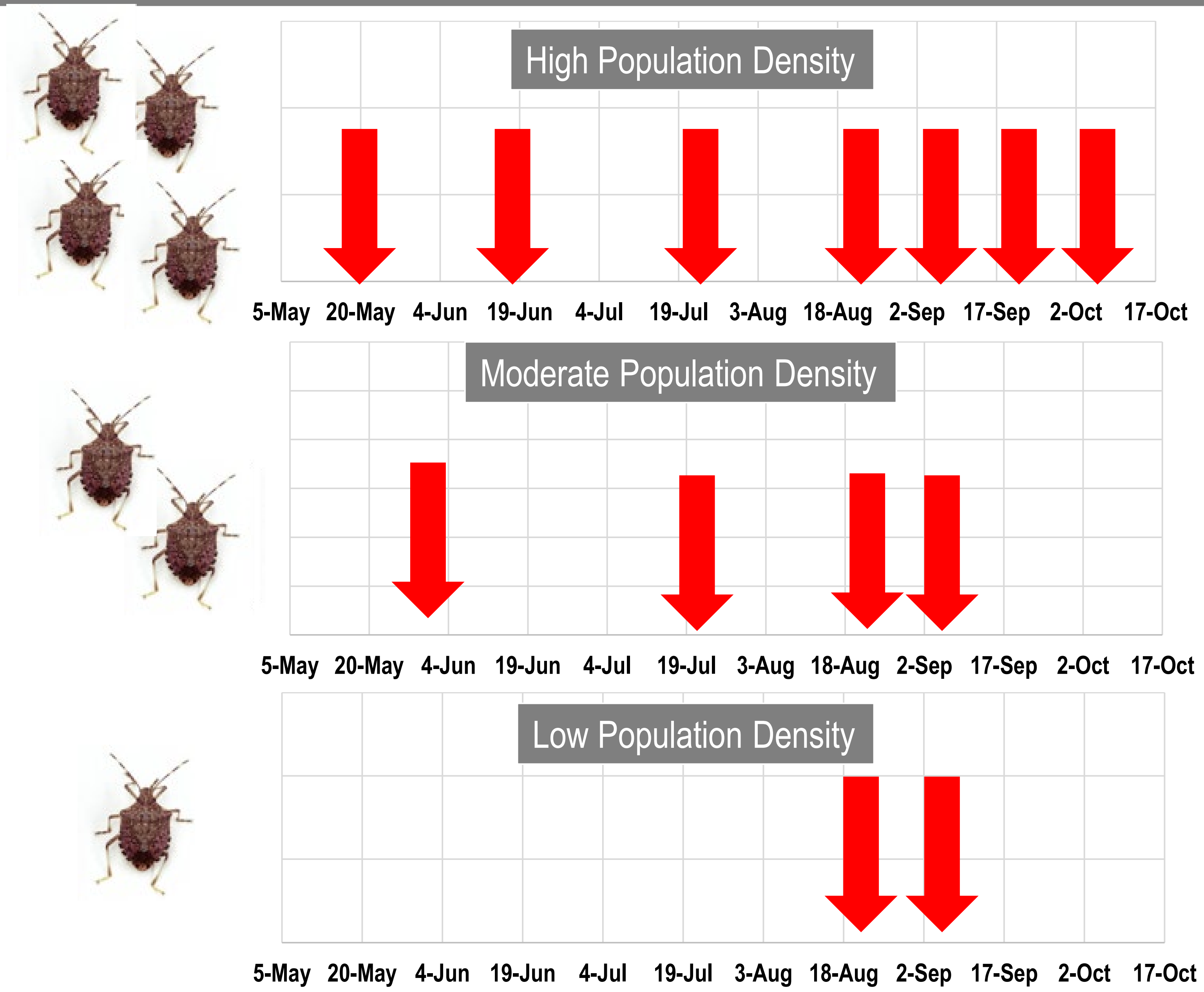
Season-Long Insecticide Applications Made Against BMSB



BMSB Injury at Harvest



Timing of Insecticide Applications



Can we make trapping simpler for growers?

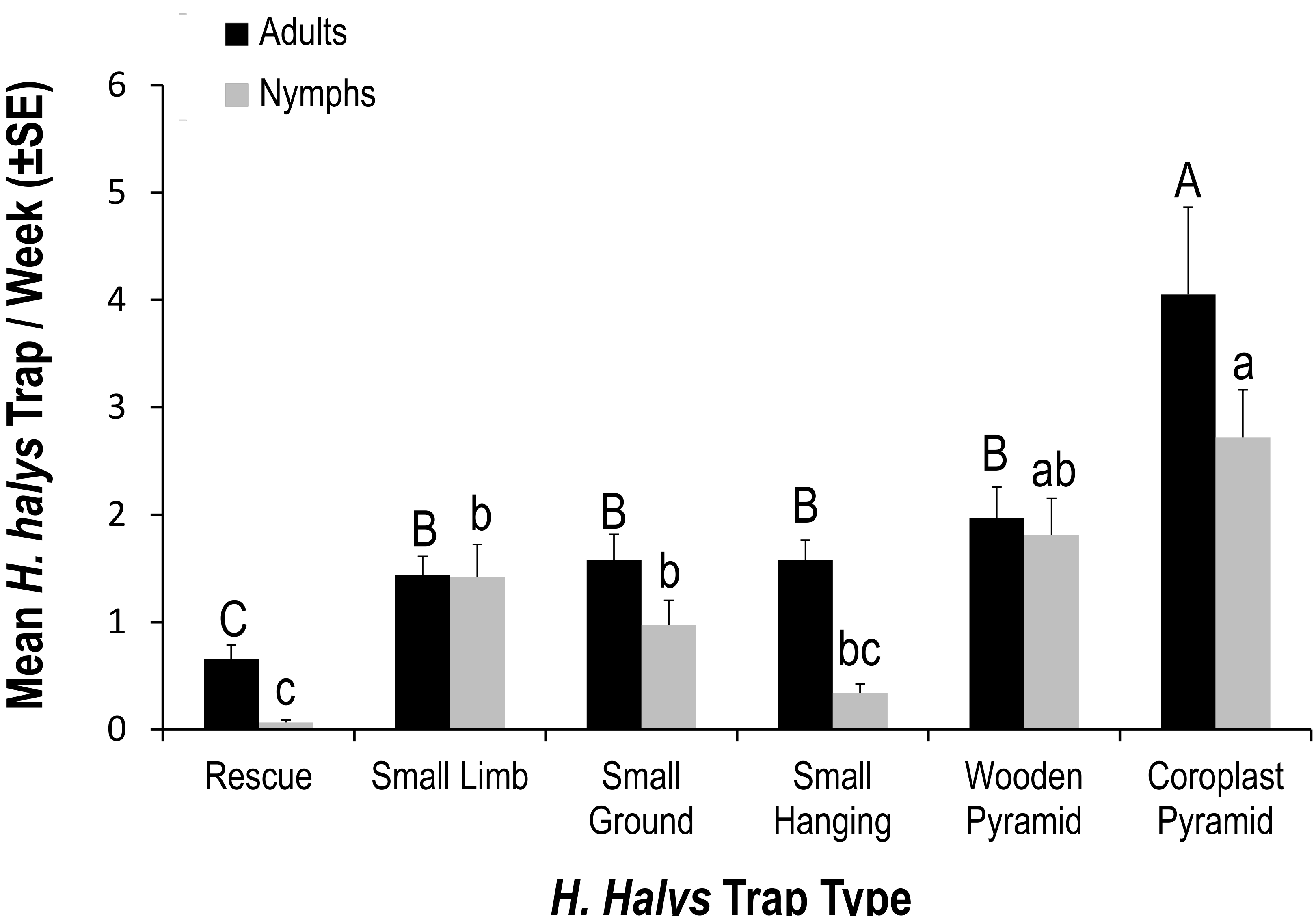
- **Visual Stimulus**
  - **Large black pyramid (trunk-mimicking stimulus)**
- **Olfactory Stimulus**
  - **PHER + MDT**
- **Capture Mechanism**
  - **Tapered pyramid attached to inverted funnel jar with DDVP strip**
- **Deployment Strategy**
  - **Traps placed in peripheral row or border area**

Can we utilize other trap styles?

Experimental Standard Wooden Pyramid	Coroplast Pyramid	Small Pyramid (Ground)	Small Pyramid (Limb)	Small Pyramid (Hanging)	Rescue (Hanging/ Foilage)
					

- Are captures similar among other trap types and deployment strategies compared with our experimental standard?
- Baited with BMSB Pheromone + MDT synergist. Two years of data from commercial orchards.

Season-Long Trap Captures / Sensitivity



(Morrison et al. 2015)

Coroplast vs. All Others

Coroplast Pyramid	Experimental Standard Wooden Pyramid	Small Pyramid (Ground)	Small Pyramid (Hanging)	Small Pyramid (Limb)	Rescue (Hanging/ Foilage)

(Morrison et al. 2015)

New Trap Comparisons

Delta Trap

Yellow Sticky Card

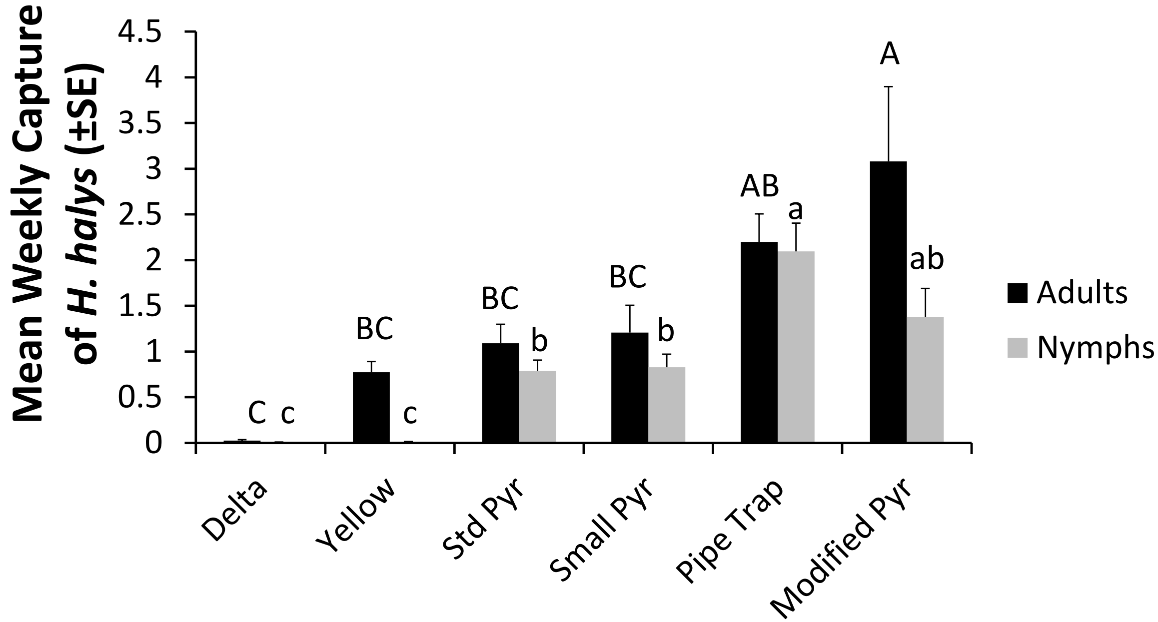
Standard Coroplast Pyramid

Small Black Pyramid

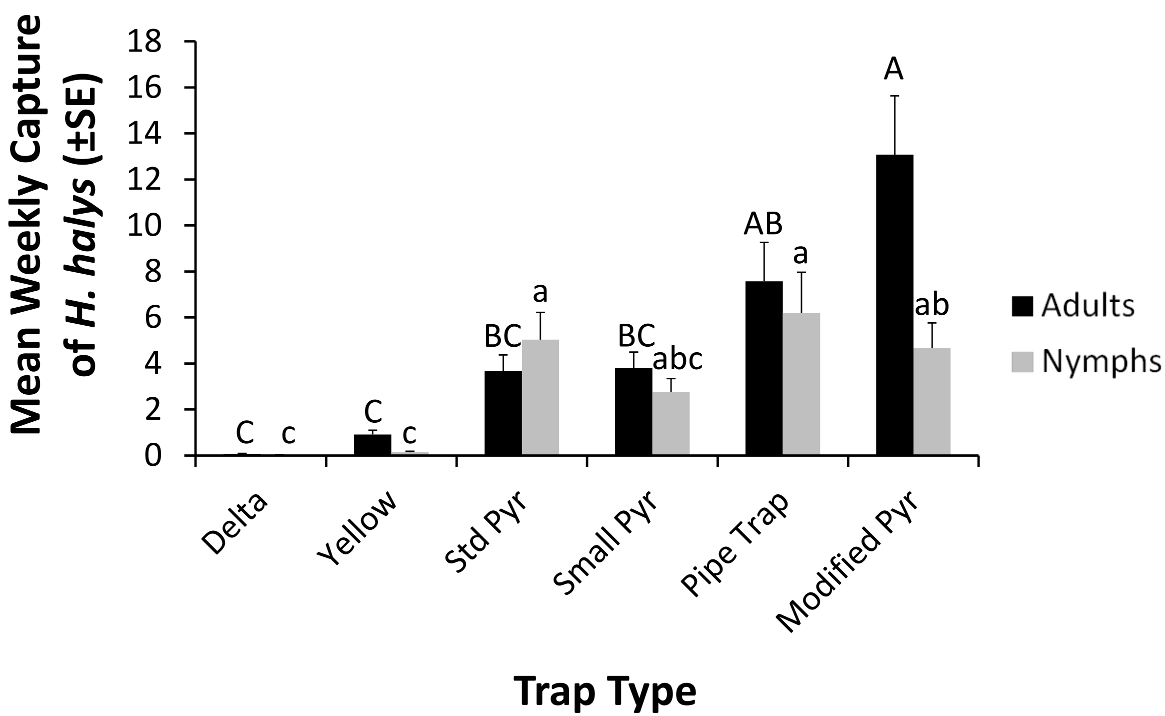
Pipe Trap

Modified Jar Top Pyramid

2015 Results



2016 Results



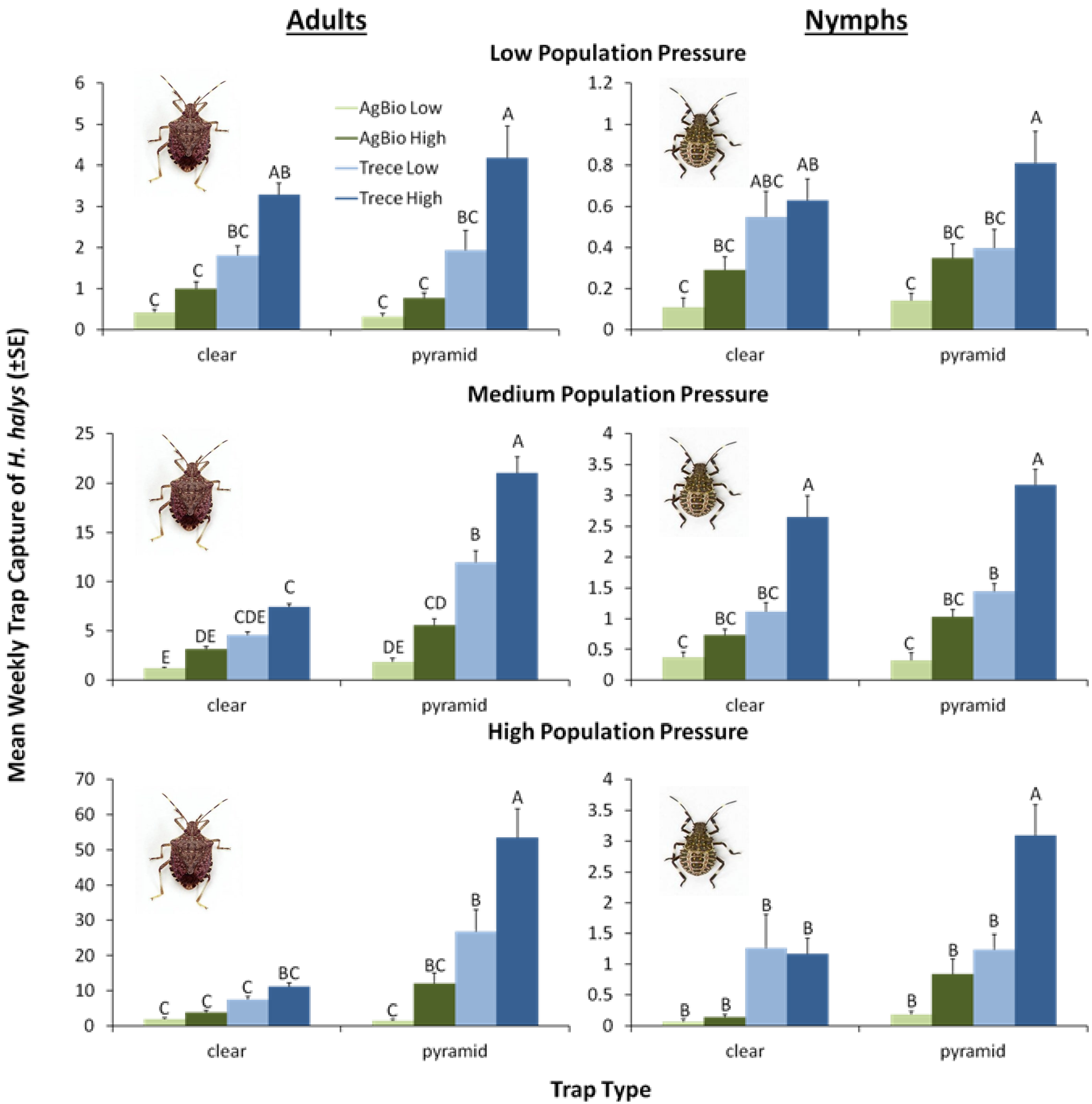
Standard Pyramid vs. All Others

Delta Trap | Yellow Sticky Card | Standard Coroplast Pyramid | Small Black Pyramid | Pipe Trap | Modified Jar Top Pyramid

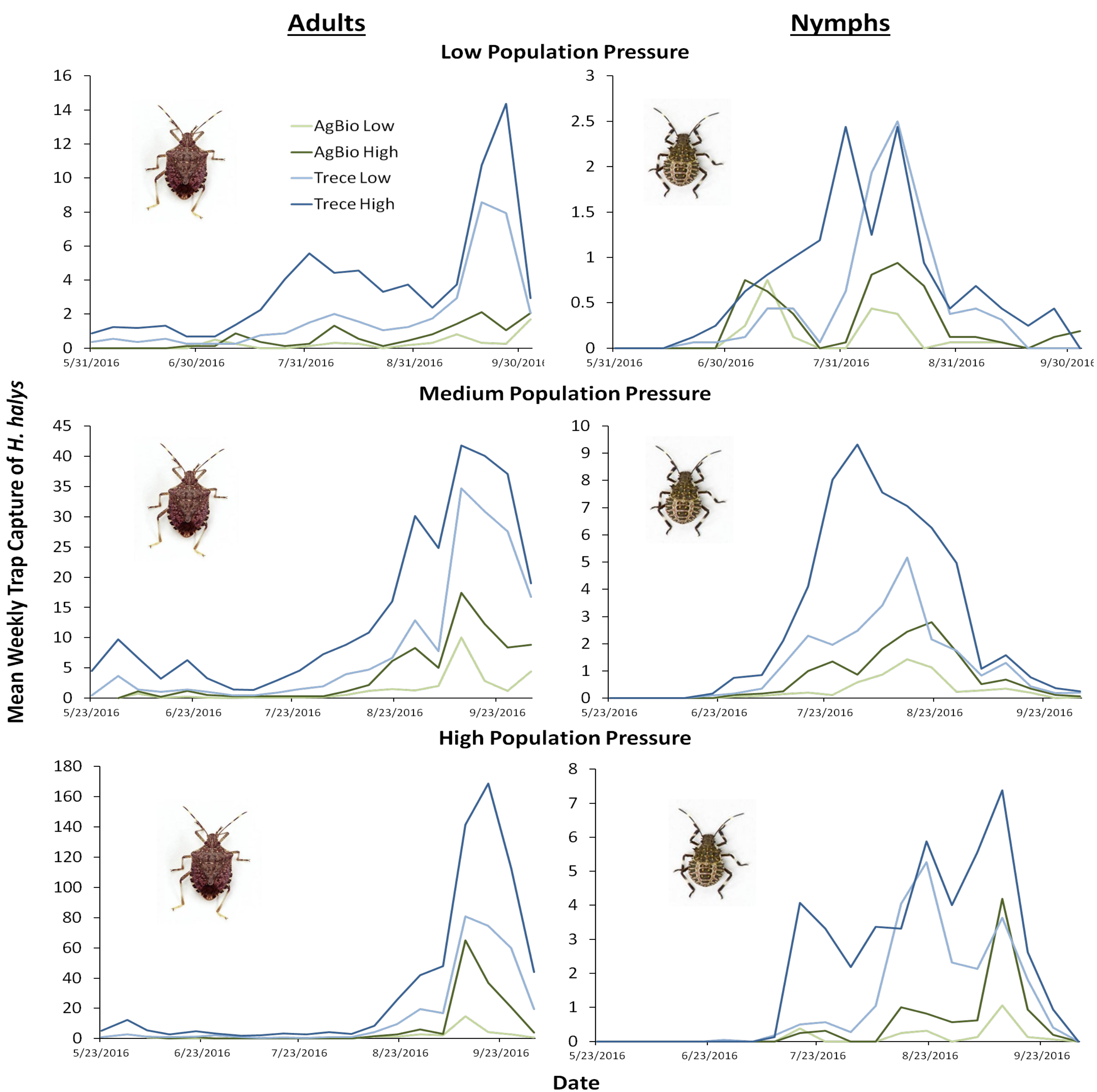
Standard Traps vs. Clear Sticky Cards

- Monitoring Loading (1x, 5/50) and Surveillance Loading (4x, 20/200) loading.
- Twelve sites in WV, MD and VA.
- Season-long trap captures.

Ministry for Primary Industries
Manatū Ahu Matua

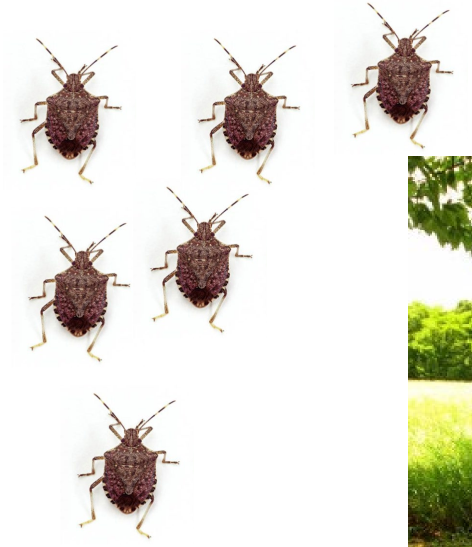


Adults
Nymphs
Low Population Pressure
AgBio Low
AgBio High
Trece Low
Trece High
Medium Population Pressure
High Population Pressure
clear
pyramid
Mean Weekly Trap Capture of H. halys (±SE)
Trap Type



Adults
Nymphs
Low Population Pressure
Medium Population Pressure
High Population Pressure
AgBio Low
AgBio High
Trece Low
Trece High
Mean Weekly Trap Capture of H. halys
Date
5/31/2016
6/30/2016
7/31/2016
8/31/2016
9/30/2016
5/23/2016
6/23/2016
7/23/2016
8/23/2016
9/23/2016

Strong Correlations Between Pyramid Traps and Sticky Cards For Adults and Nymphs Under High, Moderate and Low Pressure



Strong Correlations Between Sticky Cards Baited With Trece High and Low

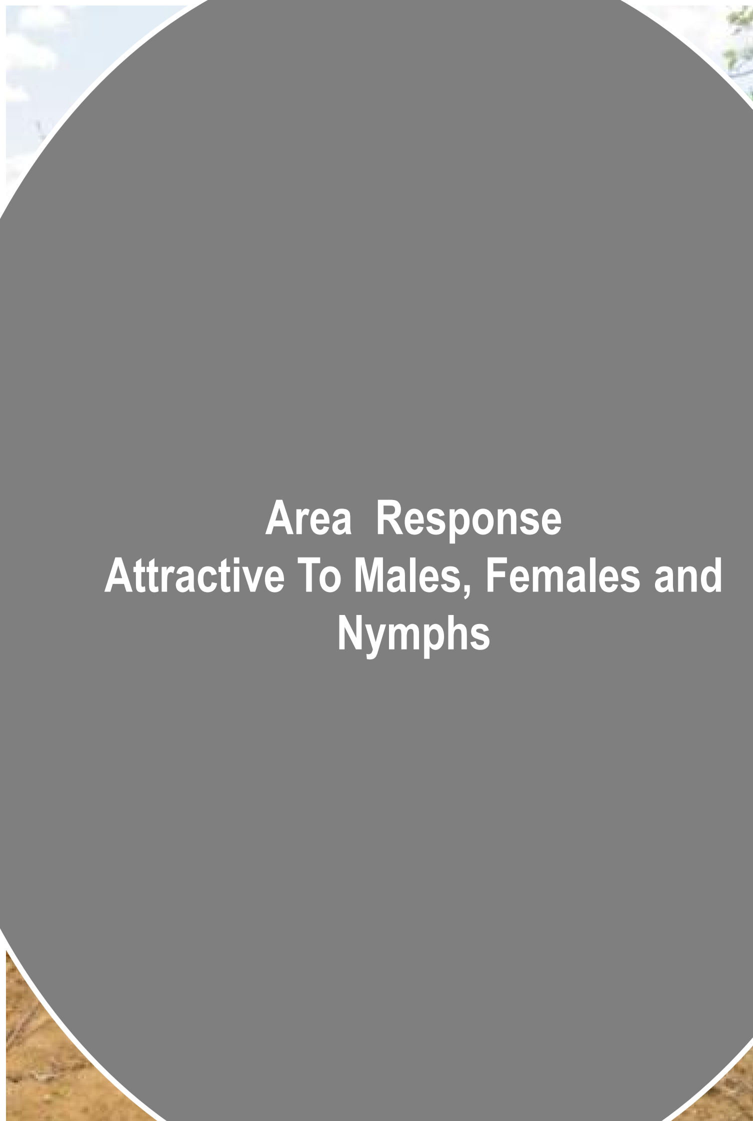
Key Components of Trap-Based Monitoring

- <u>Visual Stimulus</u>
  - Upright wooden post
- <u>Olfactory Stimulus</u>
  - Trece 1x Lure
- <u>Capture Mechanism</u>
  - Double sided sticky card attached to top of post
- <u>Deployment Strategy</u>
  - In border regions between wild host habitat and agricultural production or other habitat.

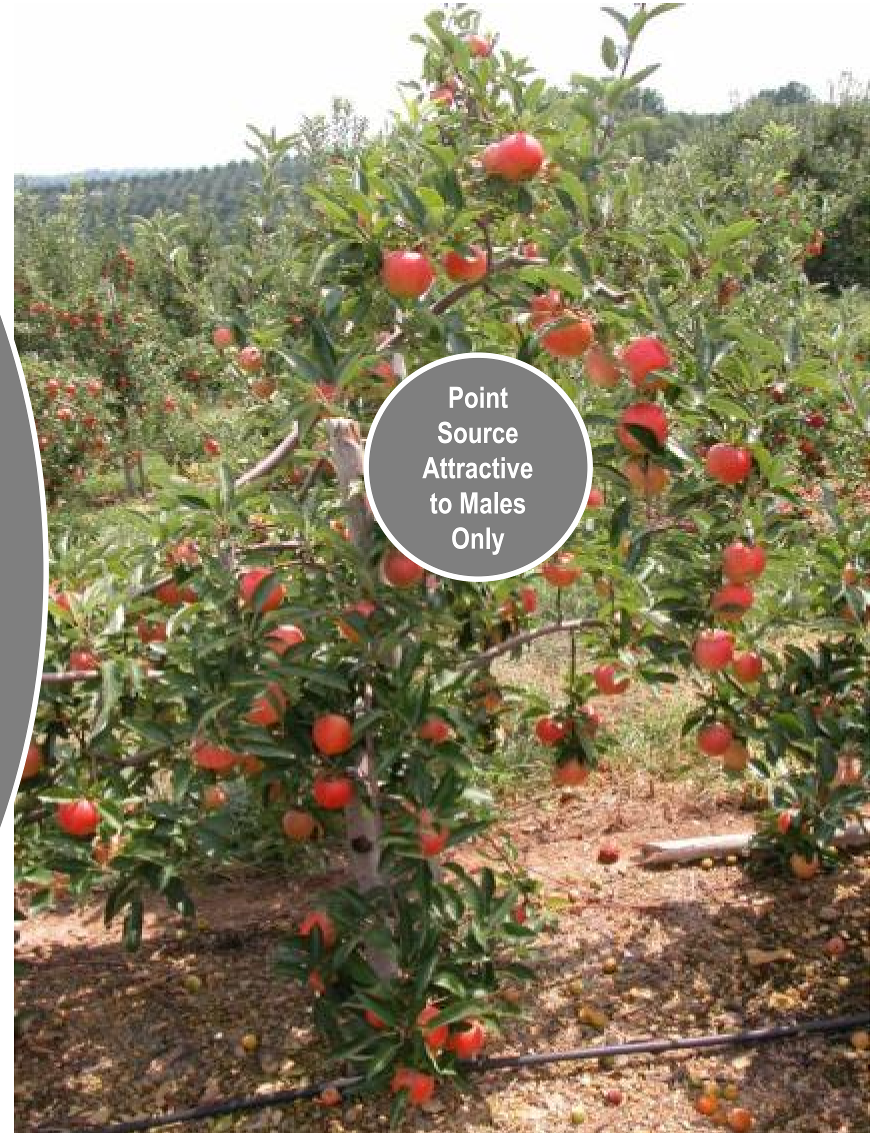
What Are Our Next Steps For Monitoring?

- **Trap Style.** Can we develop a more user-friendly trap design?
- **Lure Efficiency.** What is the distance of response? How many traps do we need?
- **Trap Location.** Where should traps be deployed? What is the impact of surrounding vegetation?
- **Decision support tools**. Can we develop thresholds with these modified designs and for other crops?

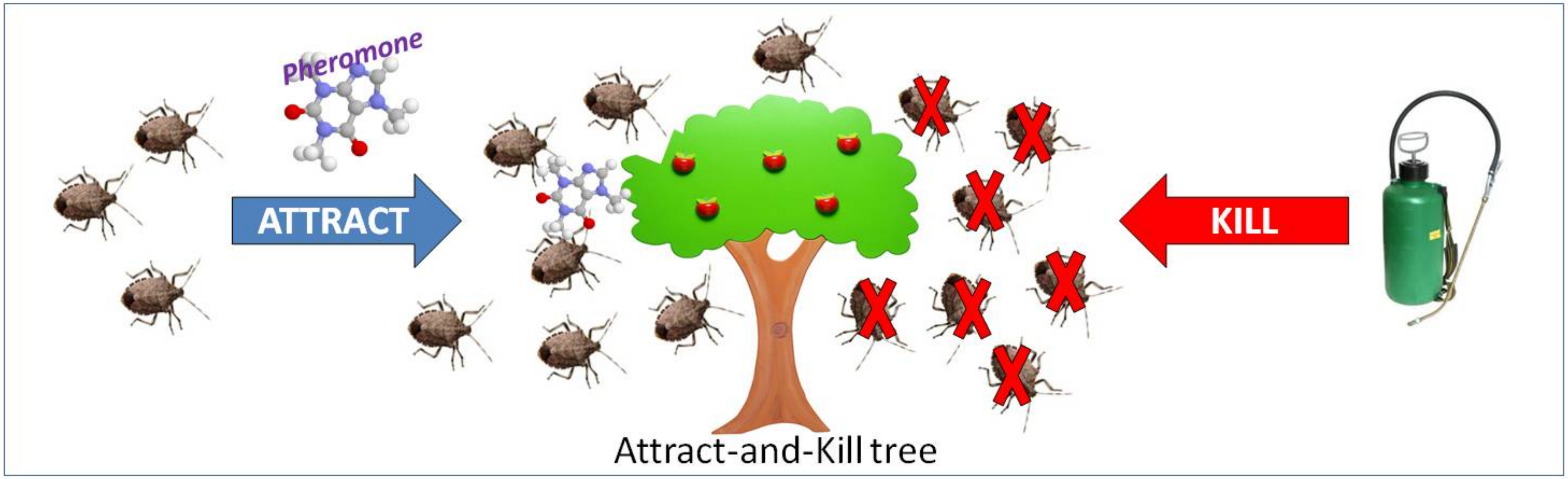
Aggregation Vs. Sex Pheromone



Area Response
Attractive To Males, Females and Nymphs



Can We Reduce Insecticide Inputs Further?



Do BMSB show a dose-response when pheromone deployed in association with apples trees?

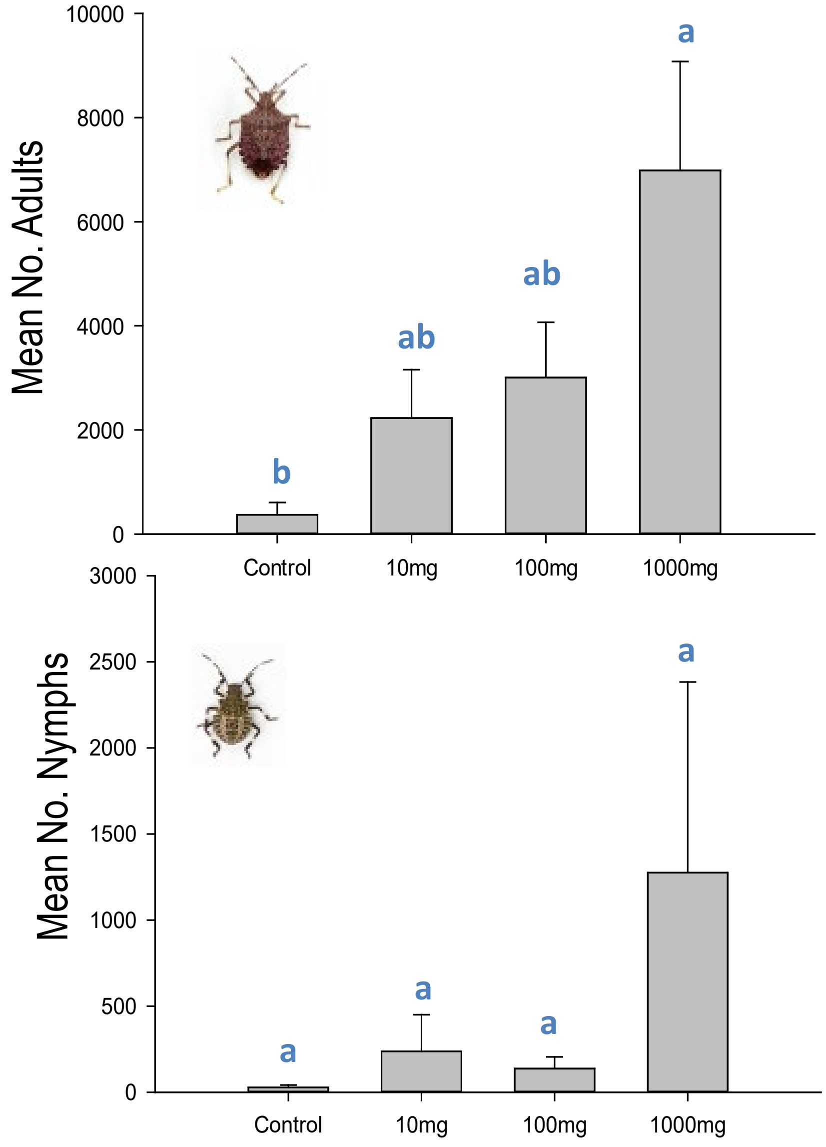
- Baited apples trees with 10, 100 or 1000 mg pheromone + synergist along with unbaited control.

- Treated trees with bifenthrin 48h later.

- Counted number of bugs 6h and 6d after treatment.

Tentative Conclusions

- BMSB do show a strong dose-dependent response to the pheromone + synergist.
- Continuous killing over the course of a week.
- Attract-and-kill hold promise based on preliminary results.



Morrison et al. 2015

Behavioral Basis for Attract and Kill in Apple

- Attraction To A Spatially Precise Location

< 2 m from bait source

- Long Retention Time

Remain on baited host plant for > 24h

- Effective Killing Mechanism

Season-long program

Date of Application	BMSB Trade Name	A.I.	Recommended Rate/A	Gal/A Restrictions	Season Max	Max applications	Min spray interval	PHI
15-May	Lannate SP	methomyl	1 lb	50 gal/A	5 lb/A	5	7 d	14 d
22-May	Mustang Maxx	zeta-cypermethrin	4 oz	20 gal/A	24 oz/A	none	7 d	14 d
29-May	Lannate SP	methomyl	1 lb	50 gal/A	5 lb/A	5	7 d	14 d
5-Jun	Mustang Maxx	zeta-cypermethrin	4 oz	20 gal/A	24 oz/A	none	7 d	14 d
12-Jun	Lannate SP	methomyl	1 lb	50 gal/A	5 lb/A	5	7 d	14 d
19-Jun	Bifenture EC	bifenthrin	6.4 oz	50 gal/A	32 oz/A	none	30 d	14 d
6-Jun	Lannate SP	methomyl	1 lb	50 gal/A	5 lb/A	5	7 d	14 d
ul	Endigo ZCX	thiamethoxam + lan	6 oz	20 gal/A	28 oz/A	none	10 d	35 d
	Danitol	fenpropathrin	21 oz	none	42.666 oz/A	none	10 d	14 d
	igo ZCX	thiamethoxam + lan	6 oz	20 gal/A	28 oz/A	none	10 d	35 d
	re EC	bifenthrin	6.4 oz	50 gal/A	32 oz/A	none	30 d	14 d
	CX	thiamethoxam + lan	6 oz	20 gal/A	28 oz/A	none	10 d	35 d
	ol	fenpropathrin	21 oz	none	42.666 oz/A	none	10 d	14 d
	lay	clothianidin	6 oz	100?	12 oz/A	none	10 d	7 d
	Endigo ZCX	thiamethoxam + lan	6 oz	20 gal/A	28 oz/A	none	10 d	35 d
Aug	Belay	clothianidin	6 oz	100?	12 oz/A	none	10 d	7 d
4-Sep	Bifenture EC	bifenthrin	6.4 oz	50 gal/A	32 oz/A	none	30 d	14 d
11-Sep	Venom	dinotefuran	6.75 oz	50 gal/A	13.5 oz/A	2	7 d	3 d
18-Sep	Leverage 2.7	imidacloprid + cyflu	5.1 oz	100 gal/A	5.1 oz	none	14 d	7 d
25-Sep	Venom	dinotefuran	6.75 oz	50 gal/A	13.5 oz/A	2	7 d	3 d

Morrison et al. 2015

Commercial Attract-and-Kill Set-Up

- 10 Orchard Blocks in MD, WV, VA, PA and NJ
- Two treatments: ‘Attract and Kill’ and Grower Standard
- Monitored with baited pyramid traps

Damage Assessments To Fruit

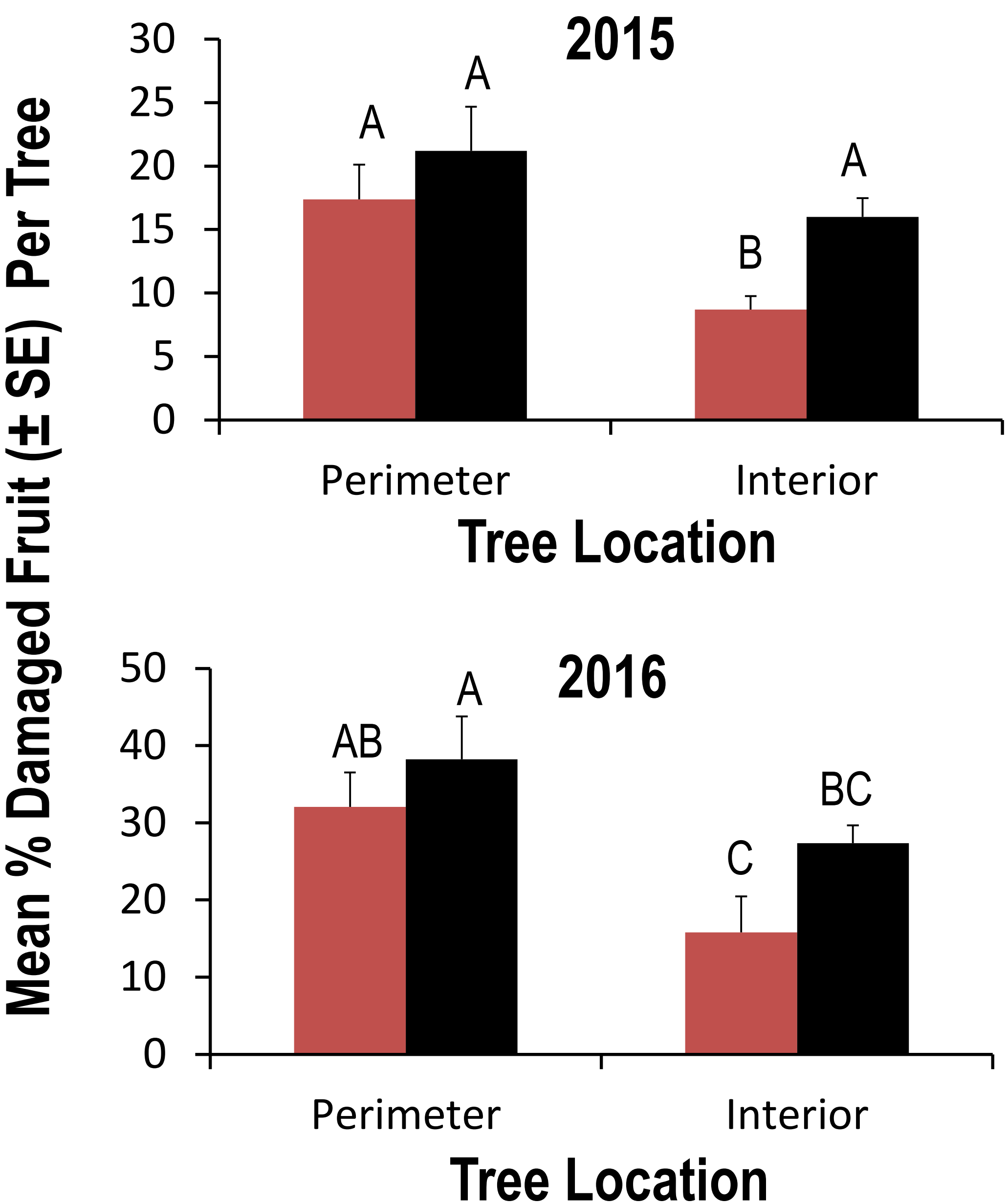
•Damage samples taken early-season, mid-season and at harvest.

•Destructively sampled 10 fruit/tree from 16 interior trees, 4 exterior and baited ‘attract and kill’ trees.

•Counted the number of internal damage sites.

•Identical numbers of fruit sampled in grower standard blocks.

Commerical SARE Attract-and-Kill Summary



Low Population Density

Higher Population Density

Additional Comparisons

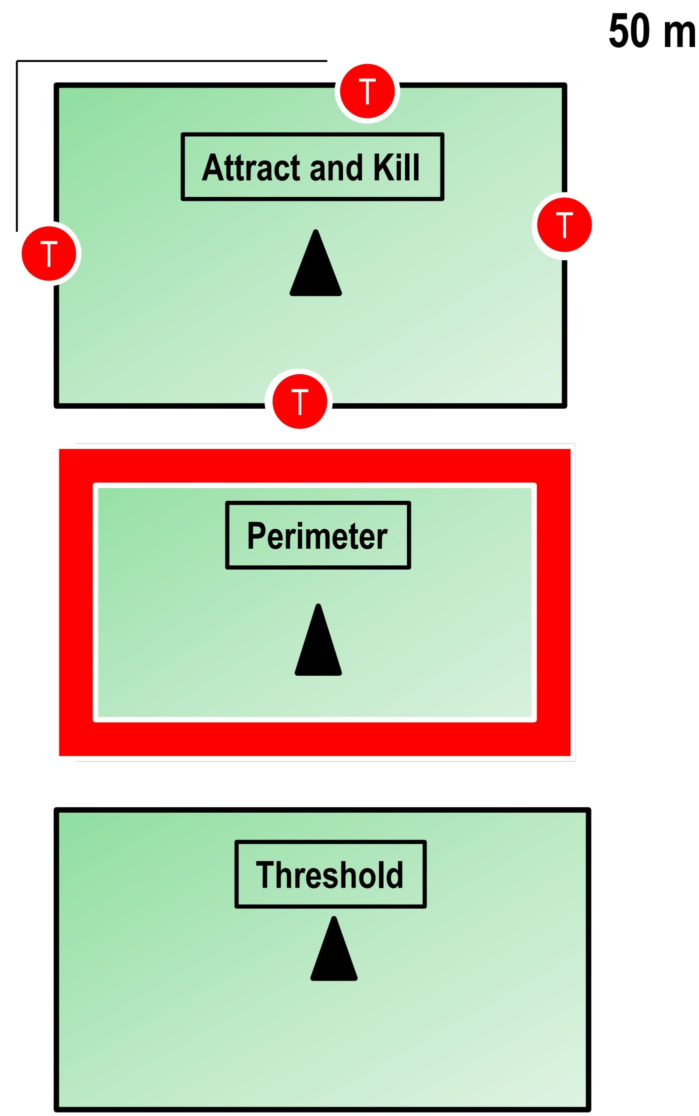
	Attract and Kill	Grower Standard
Percentage of Orchard Treated (Spray Events)	3-4% (15)	100% (3)
Additional Sprays Triggered By Traps	0.7 – 1.6	1.6 – 1.8
Cost of Pheromone Per Acre / Season	~$1536	~$36
Cost of Insecticide Per Acre / Season	~$6-20	~$30-100

Other factors: fuel use, extra trips to field, secondary pest management

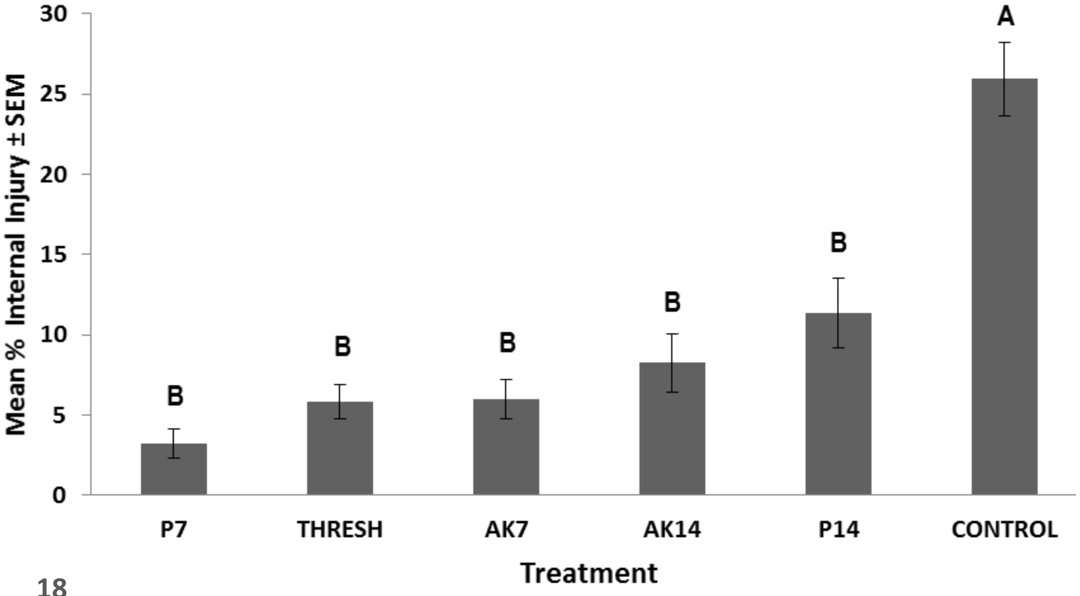
2015-2016 Perimeter-Based Management Trials

- Can we reduce spray intervals for perimeter-based management?
- Apple blocks managed by the following perimeter-based management strategies and compared with treatment threshold and an unsprayed control.

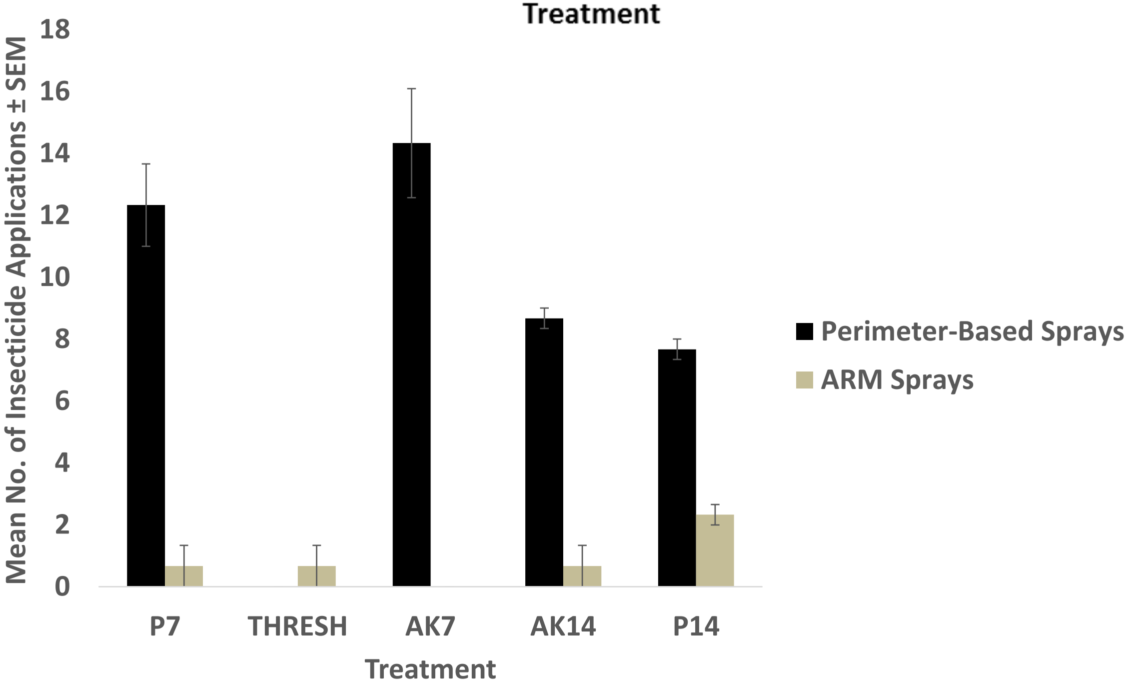
1) Standard AK – 7-d intervals
2) Modified AK – 14-d intervals
3) Standard Full Perimeter – 7-d intervals
4) Modified Full Perimeter – 14-d intervals
5) Treatment Threshold (10 BMSB/Trap)
6) Control (No Insecticide Applications)



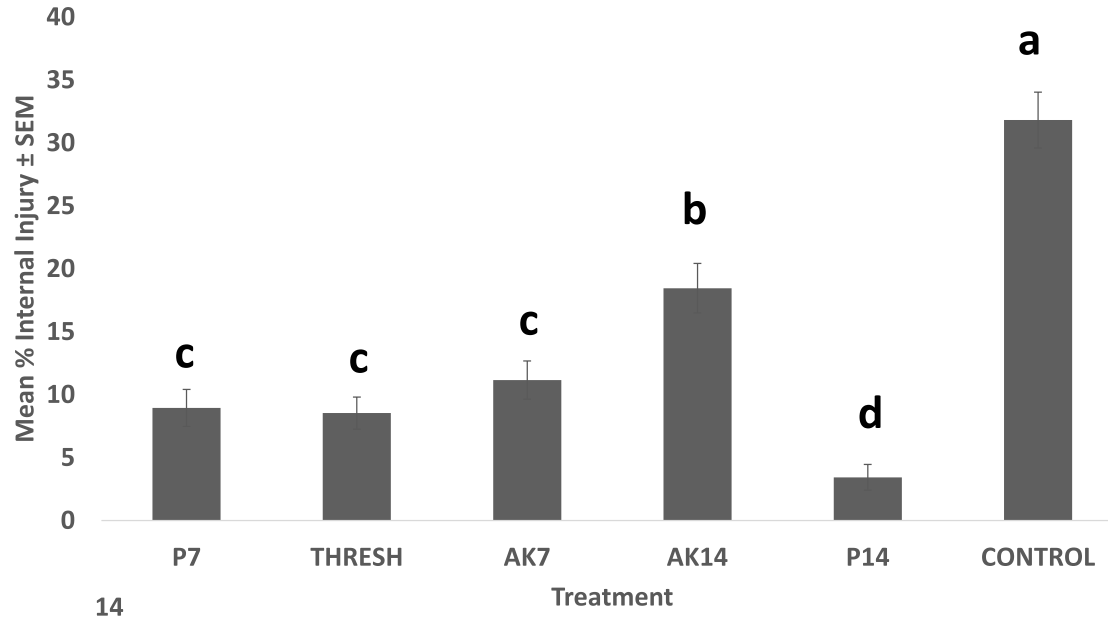
2015 Harvest Results



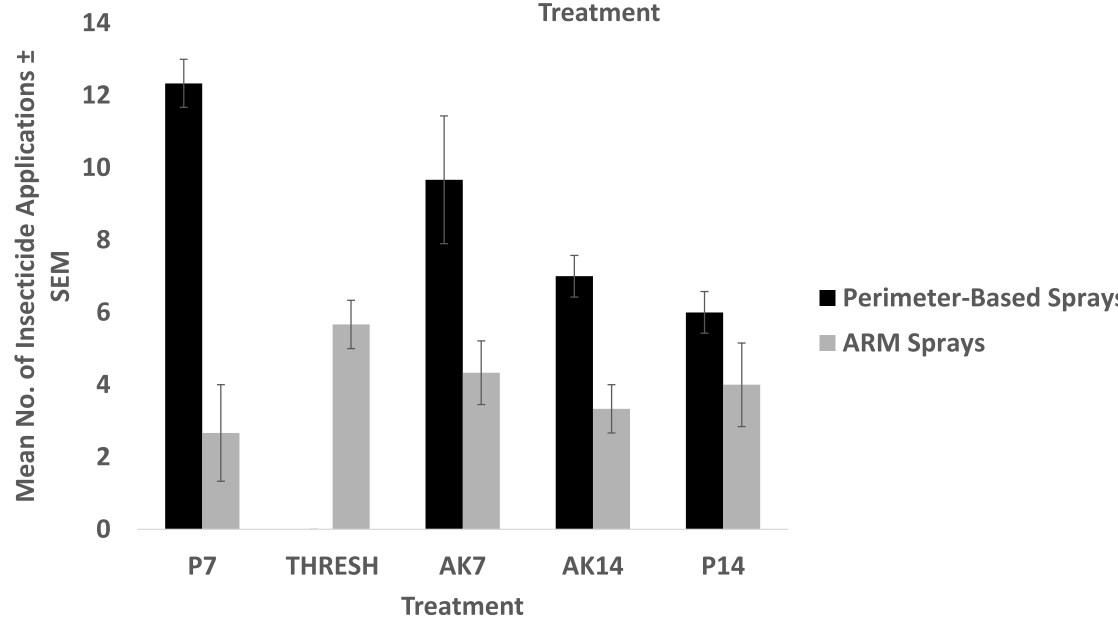
Low Population Density



2016 Harvest Results



Higher Population Density



Cost/Benefit by Program

- **Percentage of Orchard Treated**
  - AK = **~3%**
  - Perimeter = ~20%
  - Threshold = ~100%
- **Number of Standard Spray Events**
  - Standard 7d interval = ~12 / season
  - Modified 14d interval = ~7 / season
  - Threshold = ~3 / season
- **Additional Arm Sprays Triggered by Monitoring Traps**
  - AK 7d = 2 , AK 14d = 2
  - P 7d = 2, P 14d = 3
- **Cost of Pheromone**
  - Monitoring = $4.35 per lure changed at 8-week intervals
  - AK = $830/acre
- **Other Considerations**
  - Labor and fuel
  - Secondary pests
  - Longer term benefits

Tentative Conclusions

- Pheromone-based tools hold promise for BMSB management in apple orchards. Traps can be used as decision-support tools and simpler trap designs likely will increase adoptability.

- Perimeter Spray and Attract and kill can work to reduce insecticide inputs in commercial orchards. Some growers are not willing to commit to a 7d regime. Cost of pheromone for attract and kill is high. Need to reduce cost via commercial competition, other refinements such as inclusion of host plant volatiles or fewer baited trees.

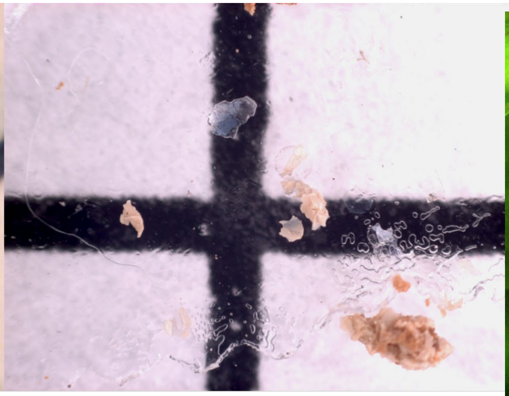
- NEXT STEP – Perimeter sprays triggered by threshold.

Future Project Directions

- Continued cooperative, collaborative and integrated approach to research and Extension on a national level.

- Developing IPM-based strategies including trap-based treatment thresholds, border sprays, cultural control, behavioral control, etc.

- Strong emphasis on long-term, landscape-level solutions including conservation biological control as well as classical biological control.

Acknowledgements

- BMSB SCRI CAP Team and Leskey Lab
- USDA NIFA SCRI # 2011-51181-30937, USDA NIFA OREI #2012-51300-20097
- NE SARE # LNE14-334

Acknowledgements

- BMSB SCRI CAP Team and Leskey Lab
- USDA NIFA SCRI # 2011-51181-30937, USDA NIFA OREI #2012-51300-20097
- NE SARE # LNE14-334

Stop BMSB