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Brown Marmorated Stink Bug in Fruit Orchards
Past, present and the future



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Halyomorpha halys (Stål) (Hemiptera - Pentatomidae)

in United States - a brief history

1996 (?) – estimated introduction into US

2001 - first proper identification (Allentown, PA)

2004 - confirmed in NJ, MD, WV, VA (Mid-Atlantic)

2008 – first serious damages observed in orchards

2010 – estimated loses in apples over $ 35 mln

2011 - detected in more than 30 States across US

2012 -current … – collaborative search for solution(s)…

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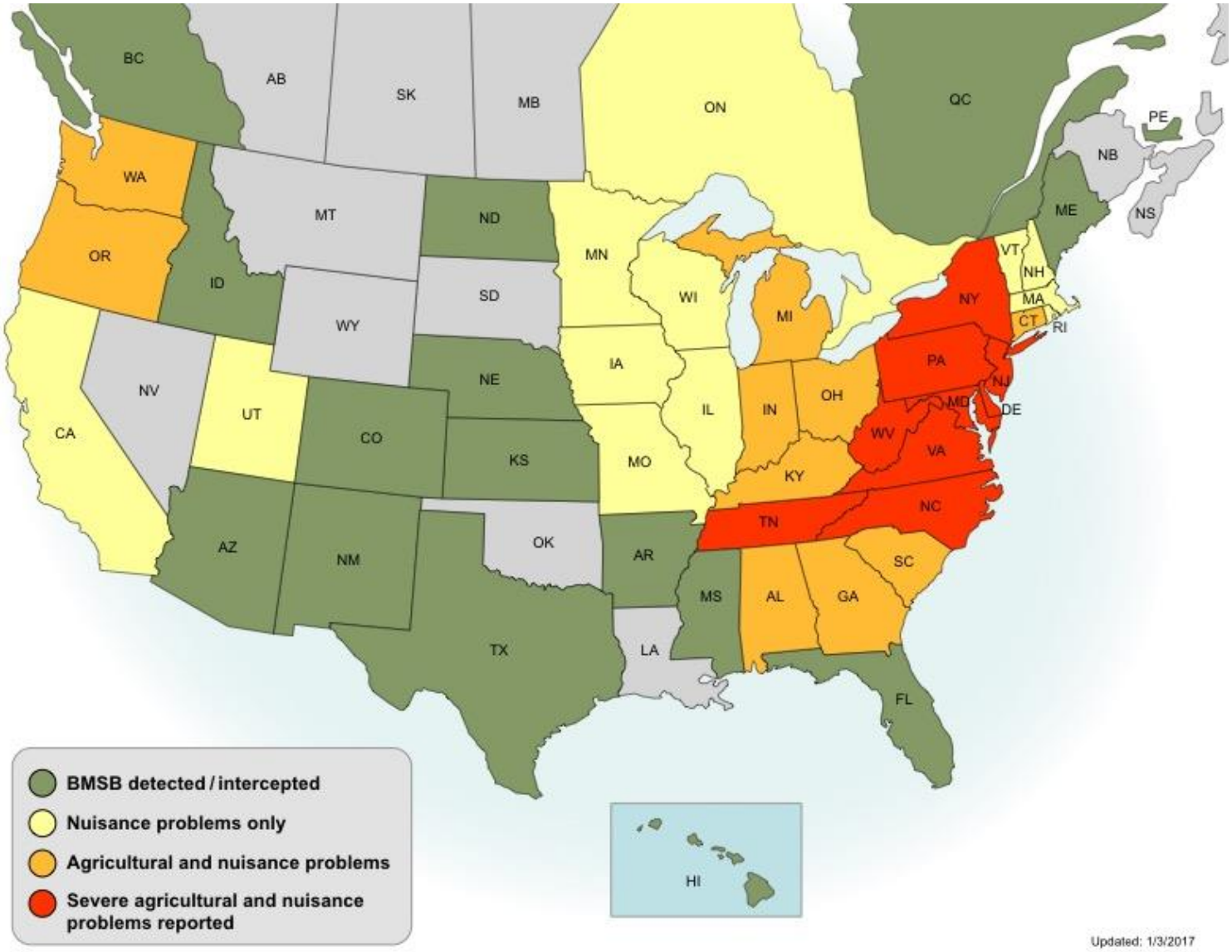
BMSB distribution – January 2017



G. Krawczyk, Hershey, PA. Jan 31, 2017

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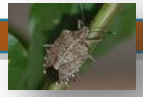
BMSB biology

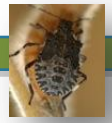


Fruit injury risk period


Diapause in dwellings


Diapause in dwellings

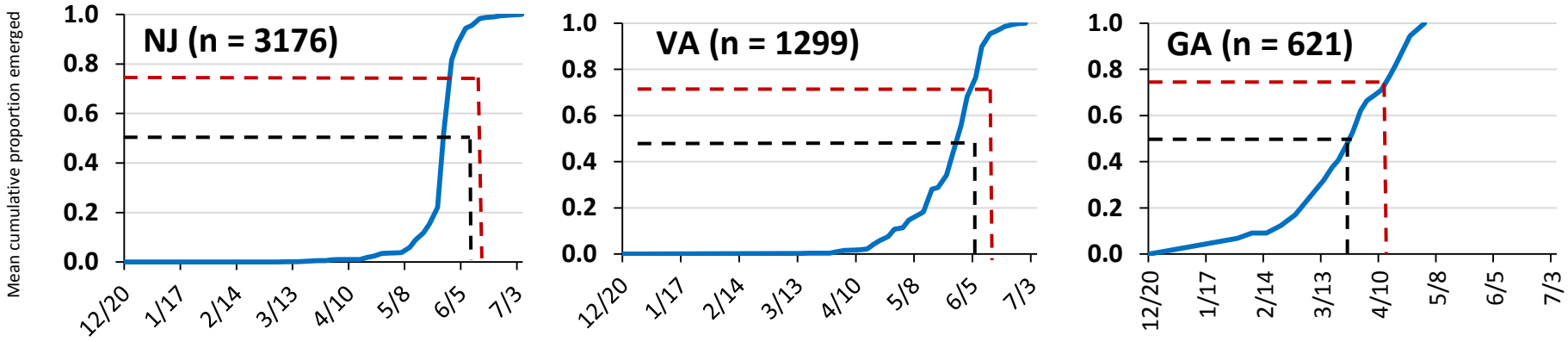

Adult stink bugs *(2 generations)*


Nymphs

April | May | June | July | Aug | Sep | Oct

Chris Bergh

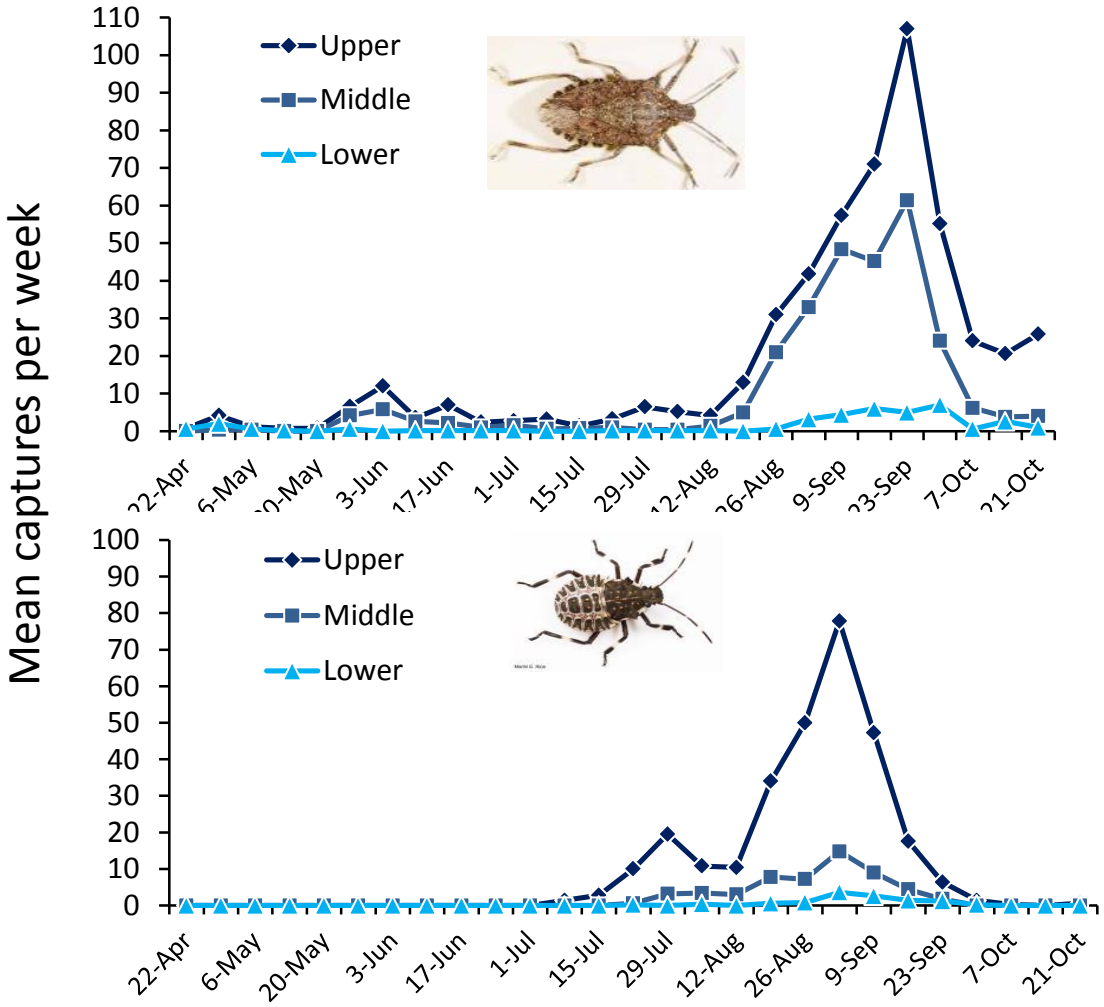
BMSB Cumulative Emergence from overwintering sites 2016



Black dashed line = 50% emergence; Red dashed line =75% emergence.

Chris Bergh &
Nicole Quinn

BMSB distribution and the search for the **samurai wasp** *Trisolcus japonicus*



BMSB captures suggest that BMSB is the most abundant in the middle and upper part of the canopy

T. japonicus recovered using both sentinel egg masses and yellow sticky traps, but (preliminarily) traps appear to be more effective/efficient

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BMSB biological control – sentinel egg project

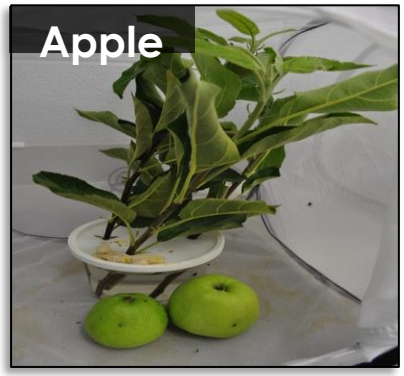
PSU FREC 2016 *(data from Hillary D. Morin – graduate student)*

Date	BMSB egg masses		Predated		Parasitized	
	Fresh	Frozen	Fresh	Frozen	Fresh	Frozen
21 Jun	0	12	0	0	0	3
28 Jun	10	10	1	1	0	1
05 Jul	3	13	0	1	0	1
12 Jul	20	13	5	4	0	0
13 Jul	8	0	3	0	0	0
16 Jul	9	13	0	2	1	0
26 Jul	9	10	3	6	0	1
02 Aug	1	7	0	2	0	0
09 Aug	1	10	0	4	0	0
Total	**61**	**88**	**12**	**20**	**1**	**6**

Angel Acebes-Doria &
Chris Bergh

BMSB food preference and development

Single host diets vs Mixed host diets



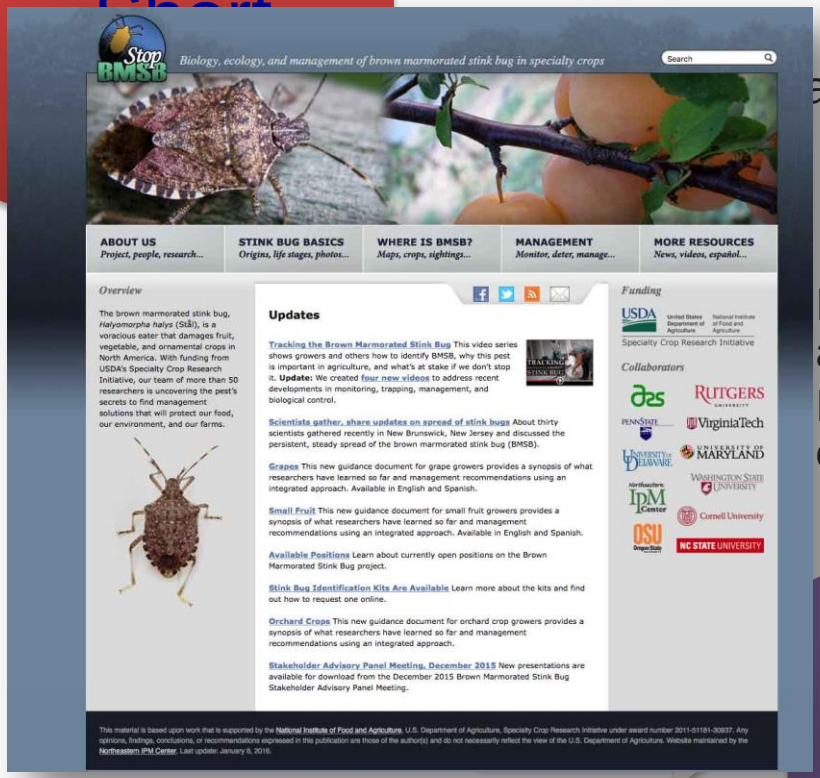
- Laboratory studies demonstrating the relative suitability of Tree of Heaven, catalpa, apple, and peach for nymphal development and survival. Peach alone was highly suitable, but apple was not. Tree of Heaven was a relatively poor host early in the season but much more suitable later in the season. Mixed host diets (e.g. apple + Tree of Heaven) significantly improved nymphal performance compared with either alone.

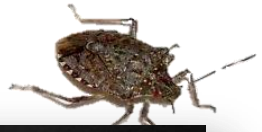
Acebes-Doria, A. L., *et al*. 2016 Environ. Entomol. 45: 663-670

Coordinated research involving USDA ARS and Land Grant Universities
NIFA SCRI CAP funded proposal
(USDA NIFA SCRI # 2011-51181-30937)

Initial cooperative effort

- Insecticidal control





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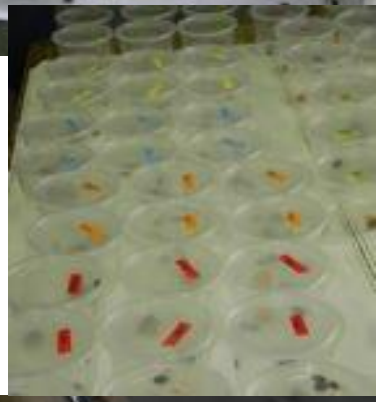
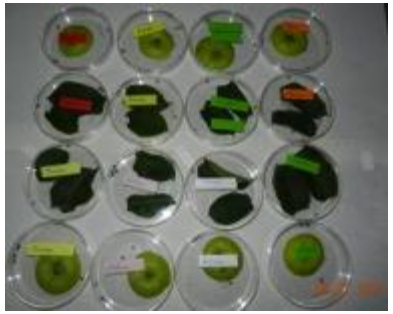
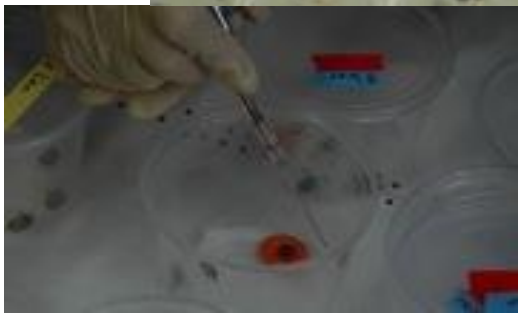
Evaluations of insecticide efficacies against BMSB

2010 - 2013







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Most effective insecticides against BMSB

Compiled data based on research info from T. Leskey (USDA ARS), T. Kuchar (VTech) and G. Krawczyk (PSU)

PYRETHROIDS

IRAC Group 3A

- **bifenthrin**
- **fenpropathrin**
- **cyfluthrin**
- **λ-cyhalothrin**

NEONICOTINOIDS

IRAC Group 4A

- **dinotefuran**
- **thiametoxam**
- **clothianidin**
- **imidacloprid**
- **acetamiprid**

OTHER

(IRAC Groups 1A, 1B, 2A

- **methomyl** (carbamate)

Products approved for organic pest management ???

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2014-2015 BMSB Insecticide resistance testing:

Methods

Product	Rate (equivalent of max field rate)	
acetamiprid (Assail 30SG)	61.6 mg/100ml	**(8.0oz/ac)**
bifenthrin (Bifenture EC)	0.103 ml/100ml	**(12.8 fl oz/ac)**
λ-cyhalothrin (Warrior II)	0.018 ml/100ml	**(2.5 fl oz/ac)**
λ-cyhalothrin/thiametoxam (Endigo ZC)	0.034 ml/100ml	**(5 fl oz/ac)**
methomy (Lannate SP)	123.1 mg/100ml	**(16 oz/ac)**

Rates at equivalent of 25%, 50% and 100% of full field rate

Four tested BMSB populations:

CH – commercial orchard; **TF** – commercial orchard;
MK – woods/commercial orchard; **BL** – residential setting

Insecticide activity against BMSB

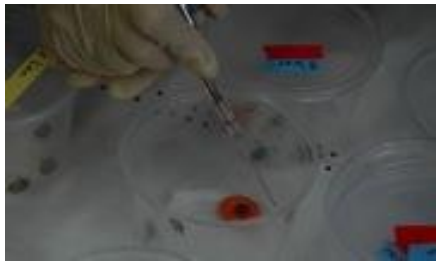
Direct contact topical bioassays - 2014

Subject

- Field collected BMSB adults
- Four geographically distinct populations
- Male (n=30) and female (n=30) tested separately, 5 per cup

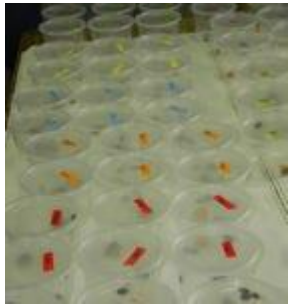
Test

- Commercial grade insecticide solutions at equivalent of field rate (100 gal/acre), surfactant added;
- Each individual bug treated directly with 2 µl of solution



Results

- Mortality assessed at 3, 24 and 48 hours after treatment
- Response categories – live, dead, moribund



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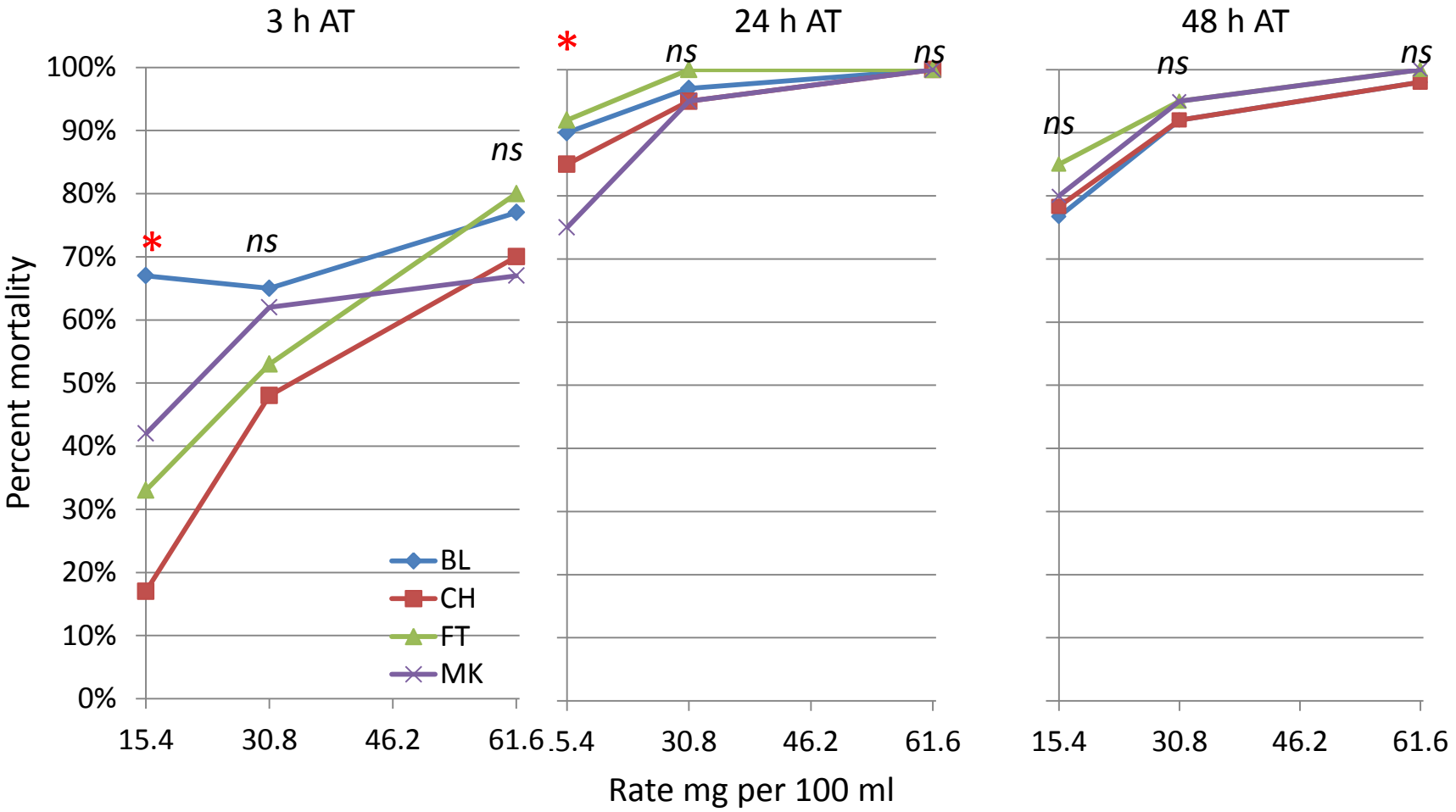
2014 BMSB insecticide resistance testing

acetamiprid (Assail 35SG)

(dead + moribund BMSB adults)



*- significant at $P \leq 0.05$ (ANOVA, Fisher's Protected LSD, arcsin transformation)

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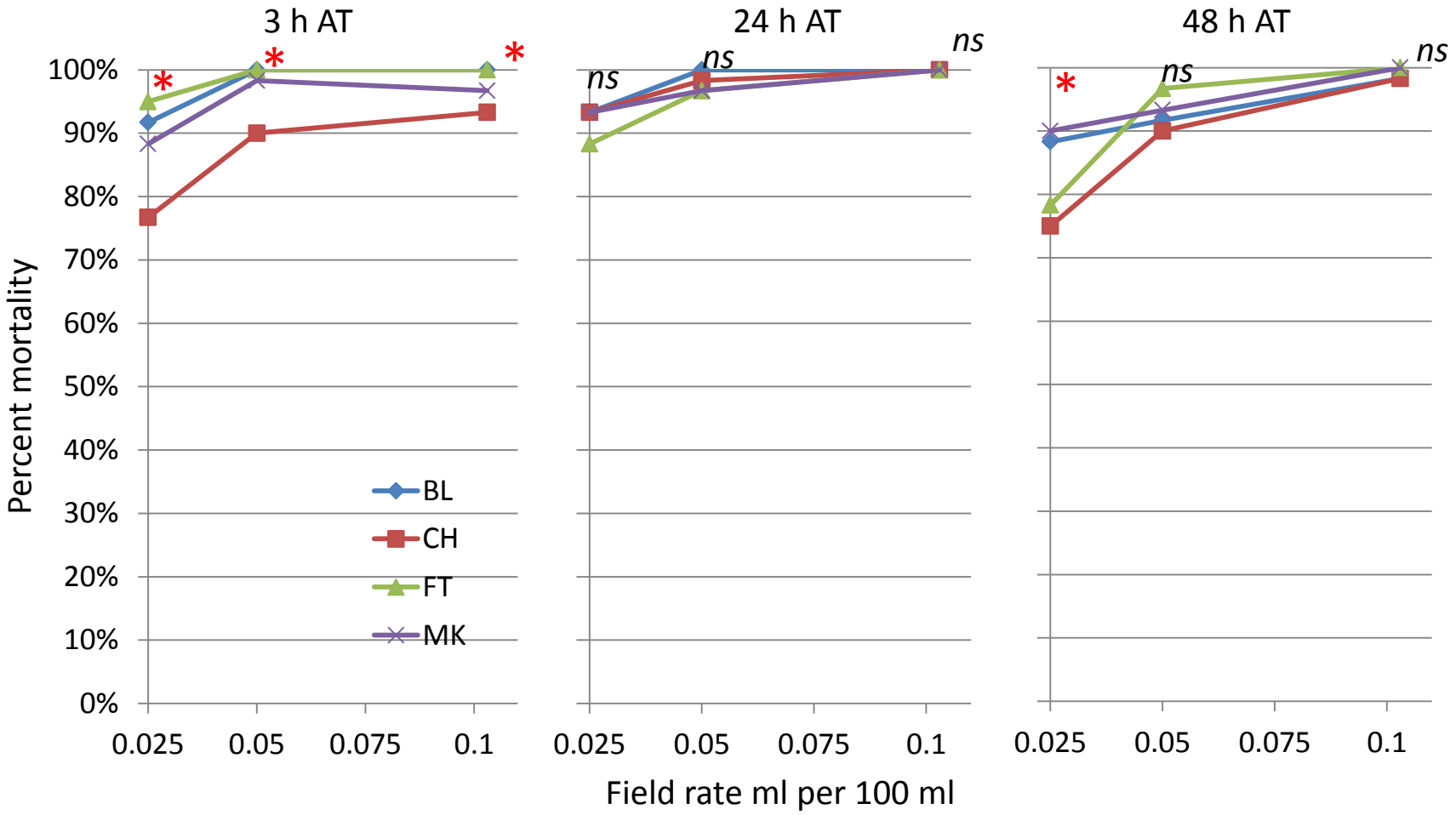
2014 BMSB insecticide resistance testing

bifenthrin (Bifenture EC)

(dead plus moribund BMSB adults)



* - *significant at P ≤ 0.05 (ANOVA, Fisher's Protected LSD, arcsin transformation)*

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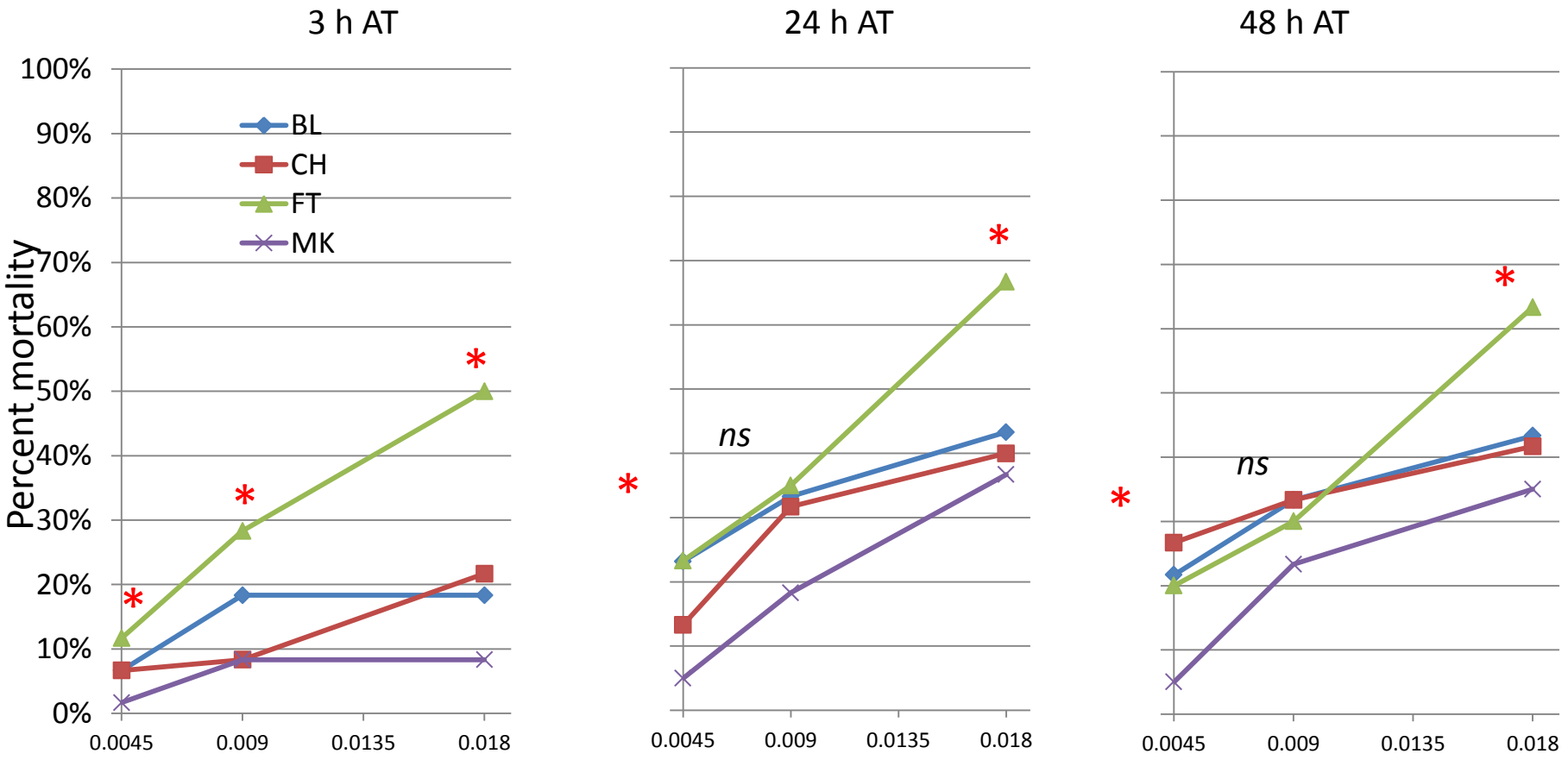
2014 BMSB insecticide resistance testing

λ-cyhalothrin (Warrior II)

(dead plus moribund BMSB adults)



* - *significant at P ≤ 0.05 (ANOVA, Fisher's Protected LSD, arcsin transformation)*

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Where do we go from here….?

Methods of application:

ARM, complete, border, spot treatment, trap crops ?

Timings of application:

preventive, curative, threshold based ?

Use of insecticide products against BMSB…

Impact on system IPM:

selectivity, resistance, secondary pests ?

New and alternatives:

nets, attract and kill, etc …. ?

Field and laboratory tests of bio-rational products

PSU FREC 2016 (from Marcelo Zanelato Nunes)

Product	BMSB stage	Bioassay	
		laboratory	Field
Product X	adult, nymph	Yes	Yes
natural pyrethrins	adult, nymph	Yes	Yes
azadirachtin	adult, nymph	Yes	No
Burkholderia spp.	adult, nymph	Yes	Yes
Chromabacterium subtsugae	adult, nymph	Yes	No

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Challenges with monitoring of BMSB

Trap placement?

Trap designs?

Light traps?

Experimental lures?

Over 150 BMSB traps serviced per each season

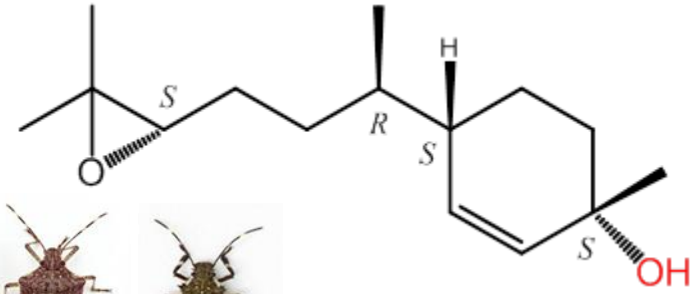
Treatment threshold development…?

Traps – 10 plus different traps designs
Lures – 7 plus BMSB lures

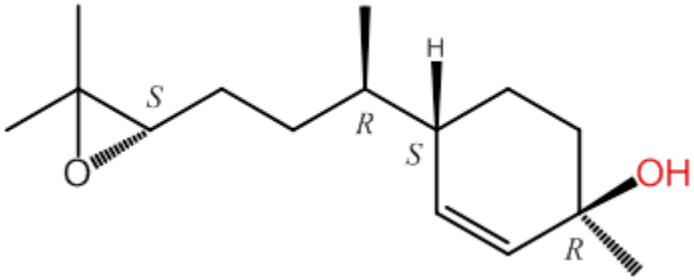
BMSB attractant

Slide courtesy of Dr. Tracy Leskey, USDA ARS

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

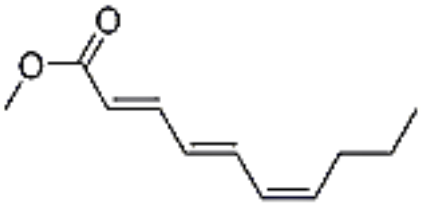


Minor component of BMSB aggregation pheromone
(3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol



+

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



= Synergism

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Trap comparison for monitoring BMSB

PSU FREC 2015

Traps lure combinations:

- Dead – Inn Pyramid trap (Ag-Bio) x Ag-Bio BMSB X-tra lure
- Clear sticky trap (AlphaScent) x Rescue lure
- Rescue Stink Bug Trap (Sterling Int.) x Rescue lure

Project description:

- Two commercial fruit orchards
- Three replicates per orchard
- Two locations (inside/outside) for each trap/lure combination per replicate

Observations period : May 01 - Oct 14, 2015

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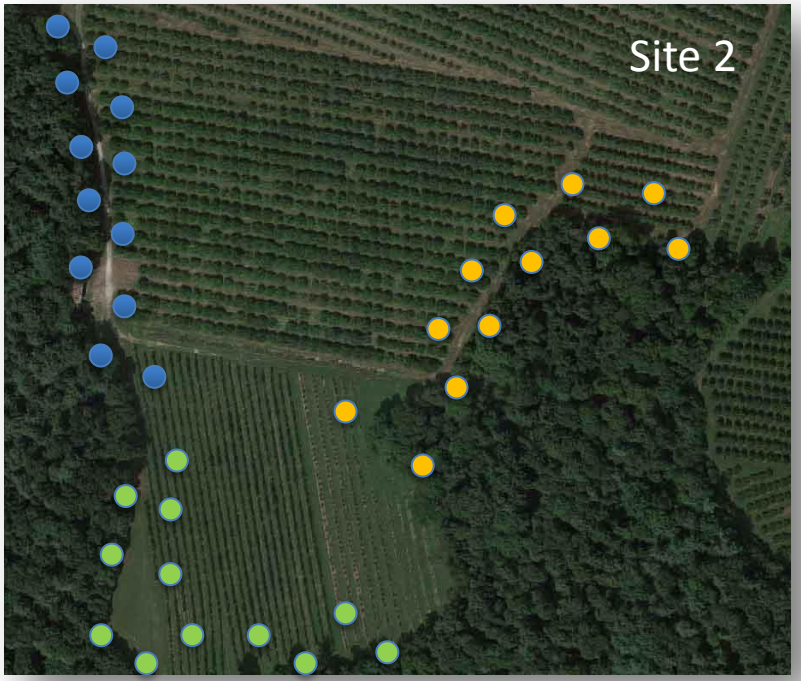
2015 BMSB trap locations

PSU FREC



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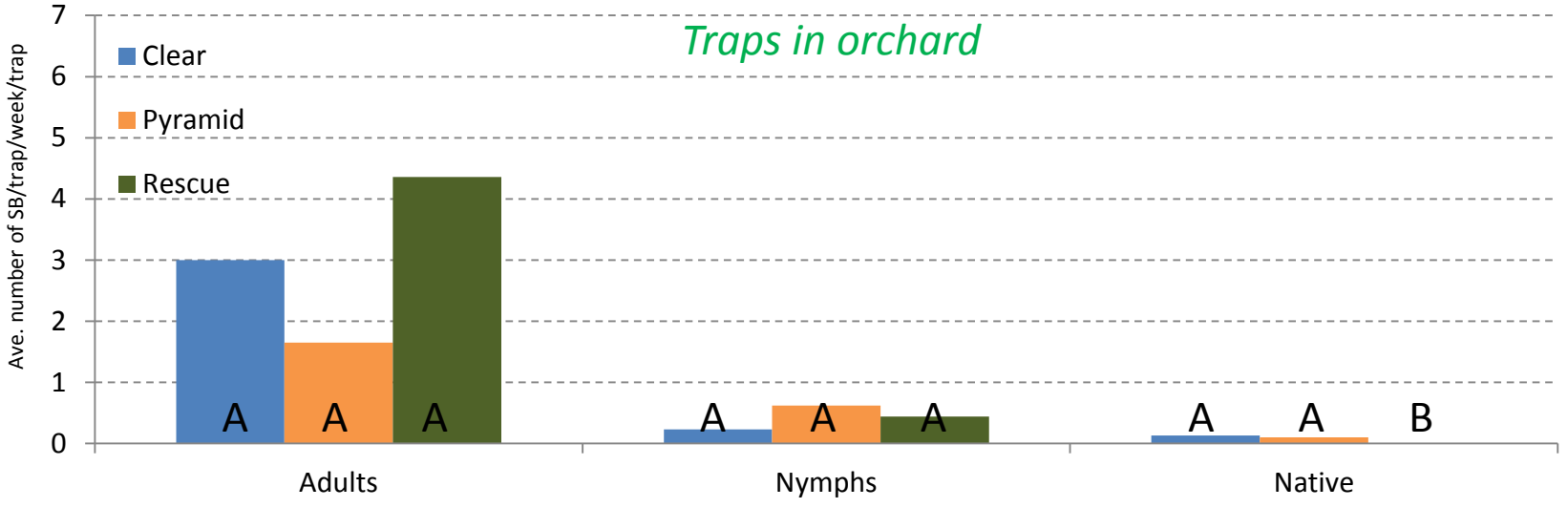
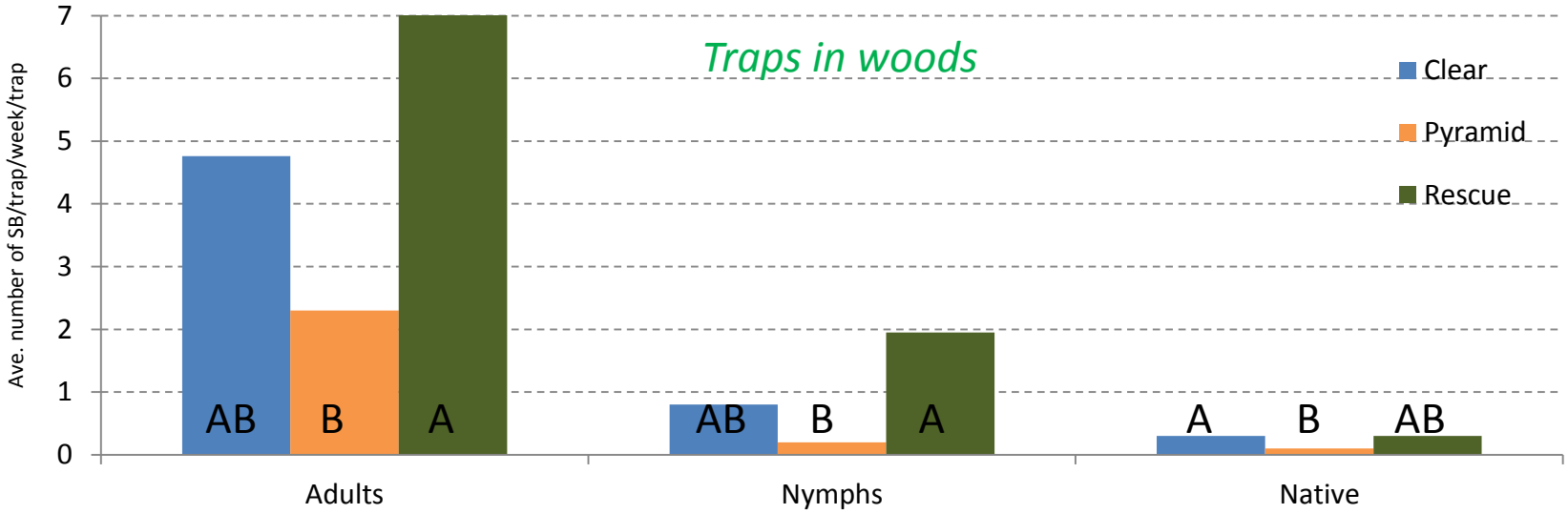
2015 PSU BMSB Trap Comparison Project

Orchard 1





Trap data from all traps combined, n=6 traps per location;
Bars within the same category (i.e., adults, nymphs and native) with the same letter are not different (ANOVA, sqrt transformation, LSD All pairwise, $p < 0.05$)

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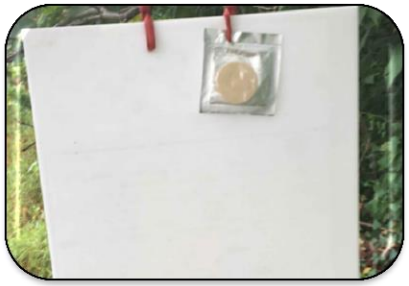
2016 BMSB trap comparison

PSU FREC 2016

Sticky clear traps



Sticky color traps

Other traps

Current standard traps

Commercial BMSB lures:

Trece®, Ag-Bio®, Rescue®, Hercon®, AlphaScent®, Scentry® and more…

Commercial BMSB traps:

Dead-Inn (Ag-Bio), Rescue (Sterling), clear sticky (AlphaScent, Ag-Bio, Trece), cylinder (Trece), and more...

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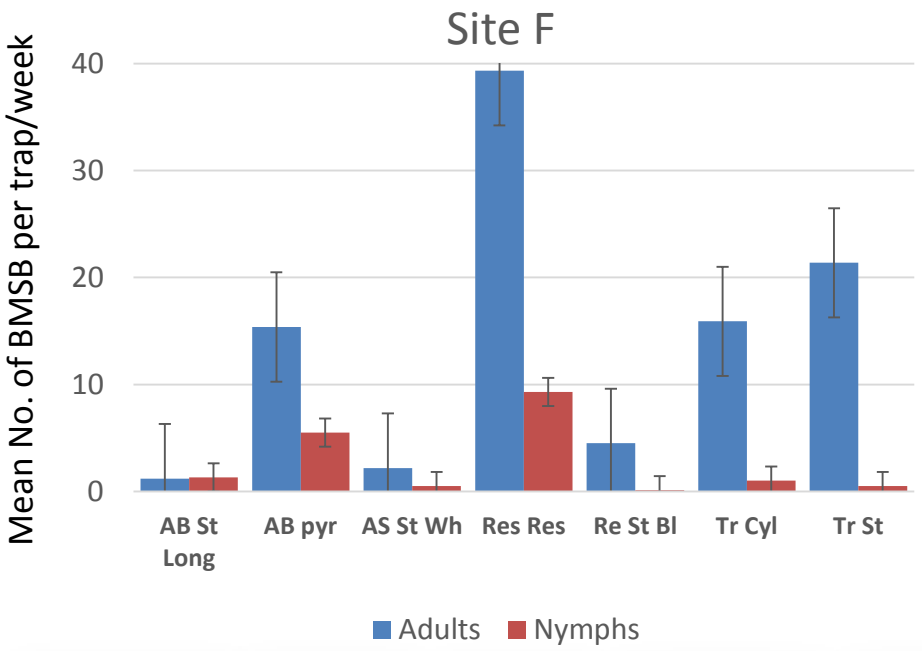
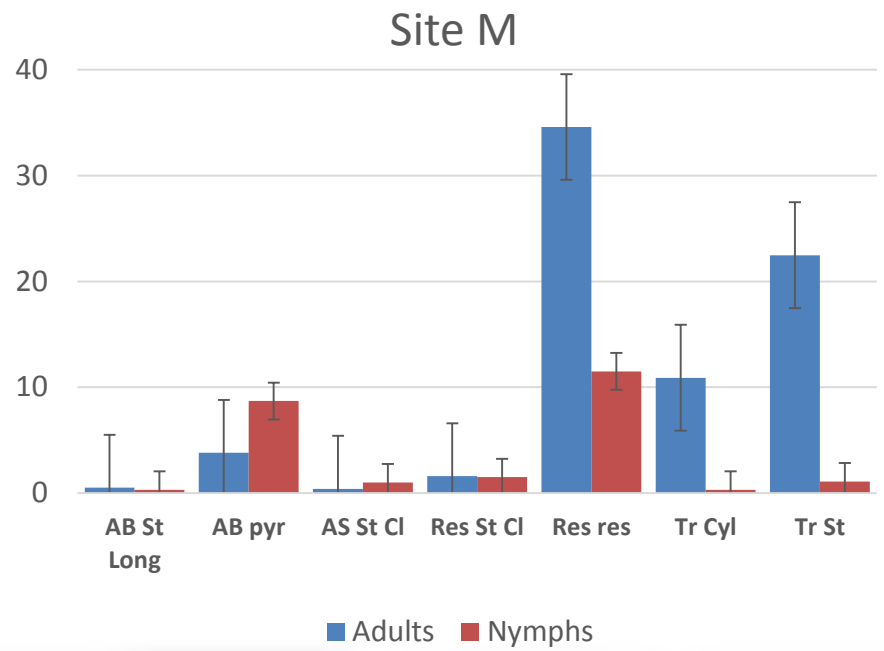
2016 BMSB trap comparison

Average BMSB captures per trap/week, PSU FREC 2016





AB pyr	AB ST Long	Re St Bl	AS St Cl	AS St Wh	Res St Cl	Tr Cyl	Tr St
Ag-Bio	Ag-Bio	AlphaScent	AlphaScent	AlphaScent	AlphaScent	Trece	Trece
Ag-Bio	Ag-Bio	Rescue	AlphaScent	AlphaScent	Rescue	Trece	Trece
Pyramid	*Sticky long*	*Sticky blue*	*Sticky clear*	*Sticky white*	*Sticky clear*	*Cylinder*	*Sticky clear*

T. Leskey *et al.*

Coroplast trap vs. all other pyramid traps

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

(Morrison et al. 2015)

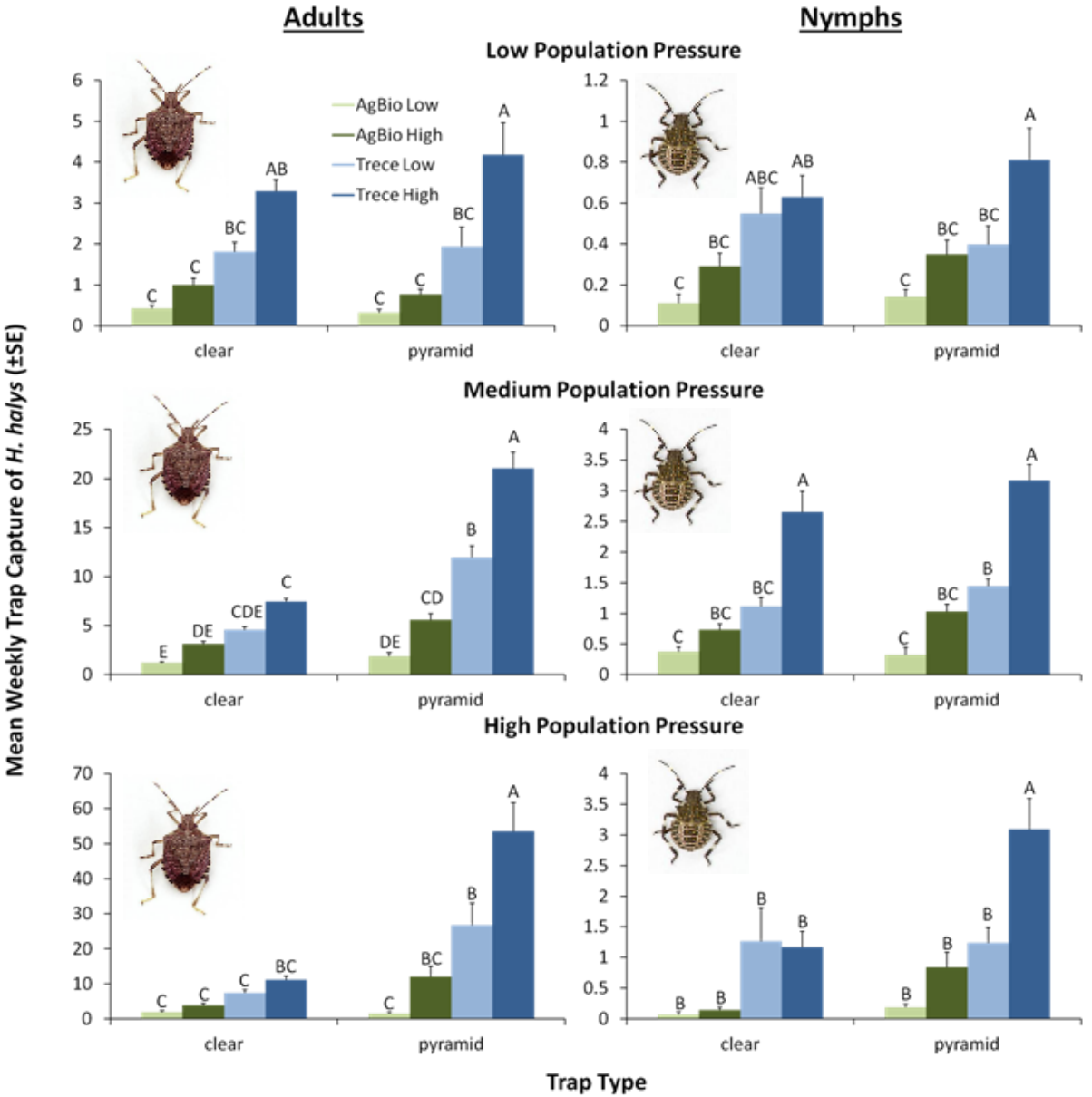
T. Leskey *et al.*

Standard Pyramid vs. All Others

Standard Coroplast Pyramid	Delta Trap	Yellow Sticky Card	Small Black Pyramid	Pipe Trap	Modified Jar Top Pyramid
					
SIG.	SIG.	SIG.	SIG.	SIG.	SIG.
	NS	NS	SIG.	SIG.	SIG.

Rice et al. in prep

BMSB monitoring: clear sticky traps vs pyramid trap



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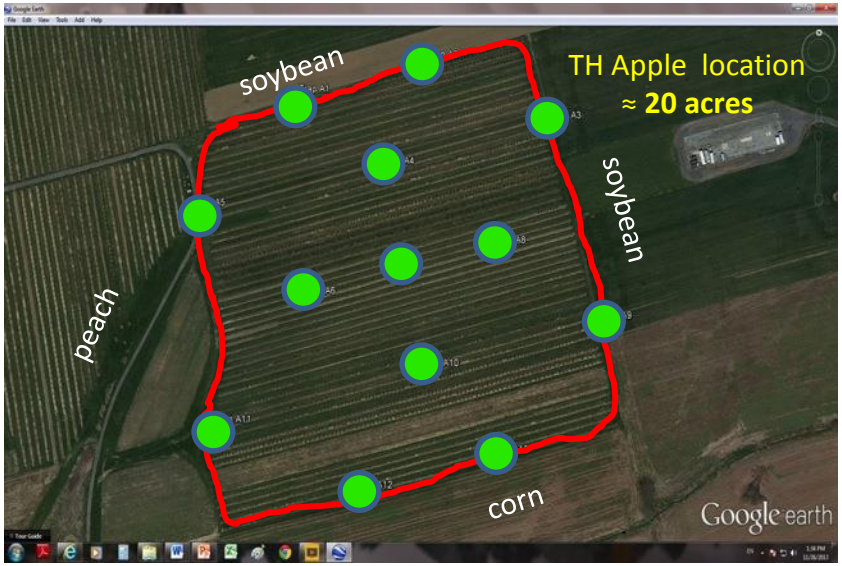
2013 - 2015 BMSB Trap Placement Grid Evaluations

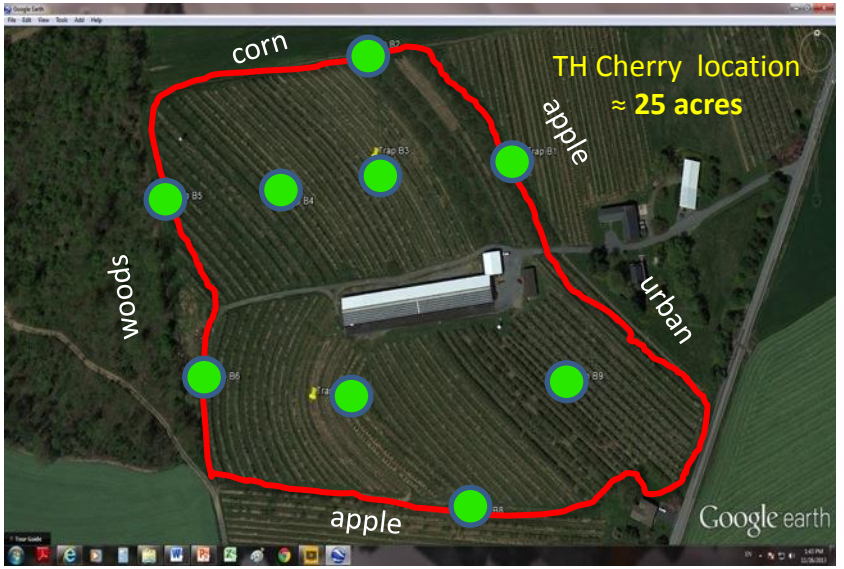
TH apple location:

1. USDA ARS #20 lure in Ag-Bio tall Black trap,
2. Edge traps (4x2) and interior trap (4 + 1); total 13 traps,
3. Weekly trap and 12 min visual observations,
4. Fruit evaluations at 1, 3 and 5 tree from trap and 1 and 2 rows from trap.
5. **Full insecticide programs**



TH cherry location:

1. Rescue BMSB lures in Rescue traps,
2. Edge traps (5) and interior trap (4); total 9 traps,
3. Weekly trap capture and 12 min visual observations around each trap
4. **Low insecticides during the trial (post-harvest)**



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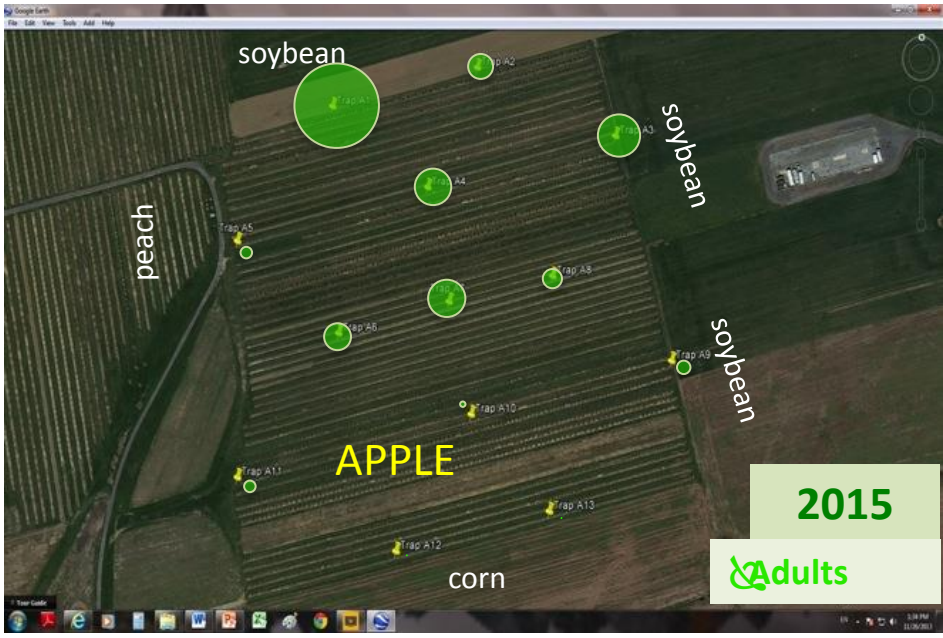
2013-15 BMSB Trap Placement Grid Evaluations

BMSB pressure distribution (apples)

BMSB ADULTS PER TRAP/SEASON (cumulative)

217
BMSB

Size proportional to the number of collected BMSB



Number of BMSB per trap/season

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2013-15 BMSB Trap Placement Grid evaluations

BMSB pressure distribution (apples)

BMSB NYMPHS PER TRAP/SEASON (cumulative)

Size proportional to the number of collected BMSB

Number of BMSB per trap/season

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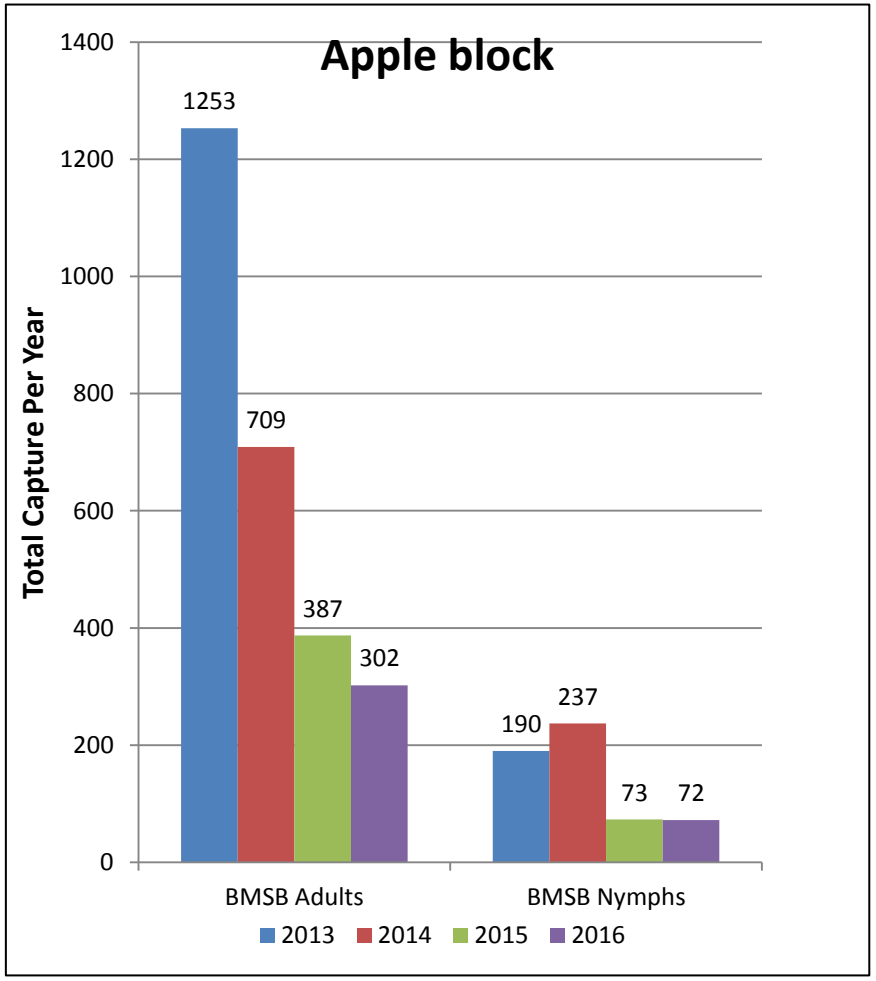
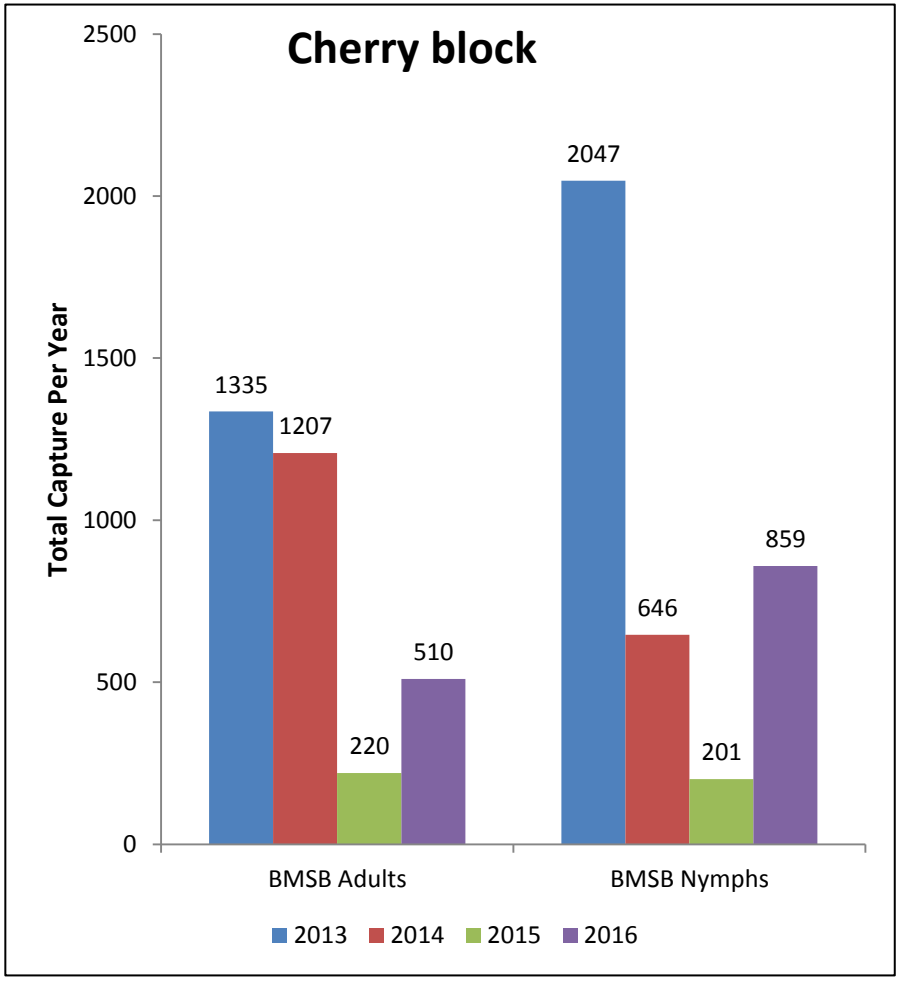
2013 – 2016 BMSB Trap Placement Grid

BMSB total captures per year





13 Ag-Bio tall pyramid traps baited with Ag-Bio BMSB Xtra lure

9 Rescue traps baited with Rescue stink bug lure

G. Krawczyk, Hershey, PA. Jan 31, 2017

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BMSB threshold challenge – apple orchard

Stage	Season	Number of weeks **threshold** met		Range of BMSB captured per trap (per season)		Actual number of insecticide applications
		Range based on single trap captures	Based on cumulative average (n=13 traps)			
Adults 	2013	0 - 10	7	9 - 217	(93.4)	10
	2014	0 - 6	4	1 - 104	(54.7)	5
	2015	0 - 4	2	3 – 96	(29.8)	2
Nymphs	2013	0 - 5	6	0 - 31	(14.6)	10
	2014	1 - 5	6	3 - 45	(18.3)	5
	2015	0 - 2	1	0 – 28	(5.6)	2

Provisional thresholds:

ADULTS - cumulative 10 BMSB adults per individual trap (USDA ARS);

NYMPHS – cumulative 5 nymphs per traps, or two consecutive weeks with nymphs present

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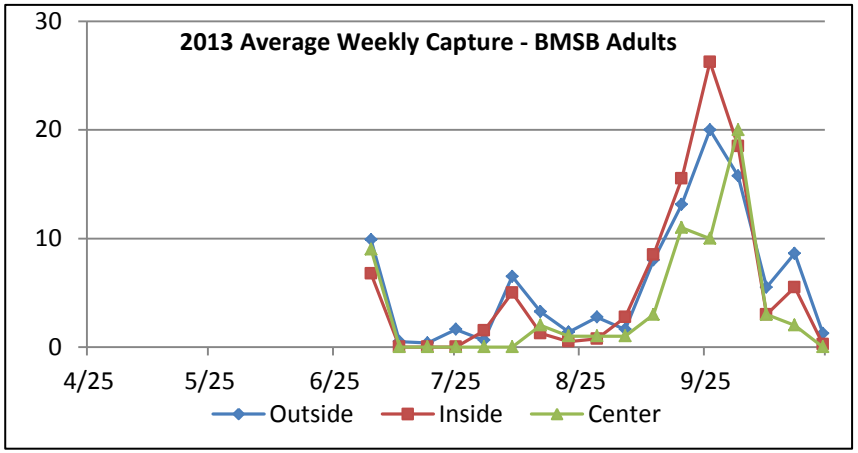
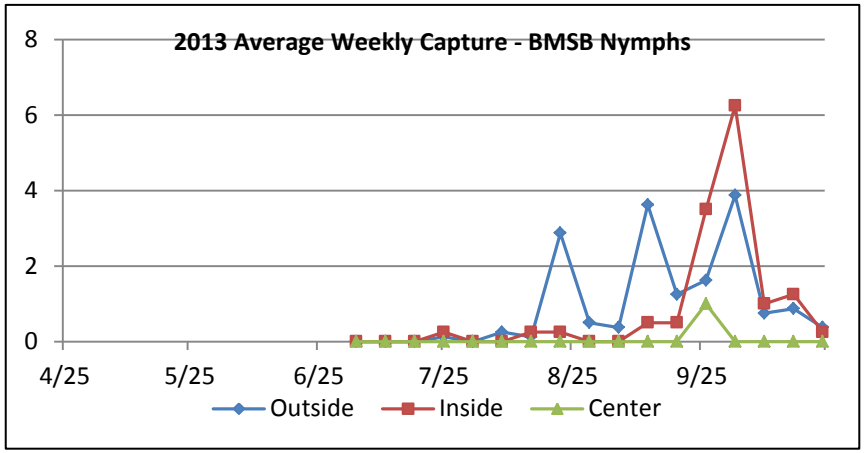
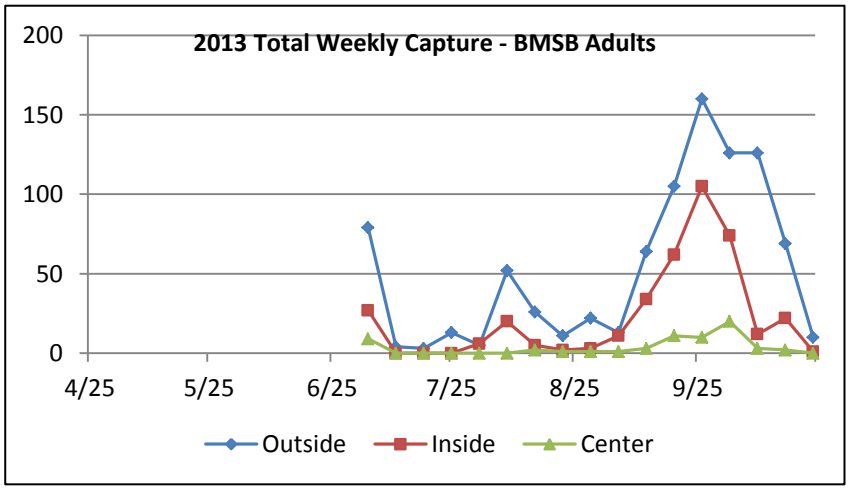
2013 BMSB Trap Placement Grid

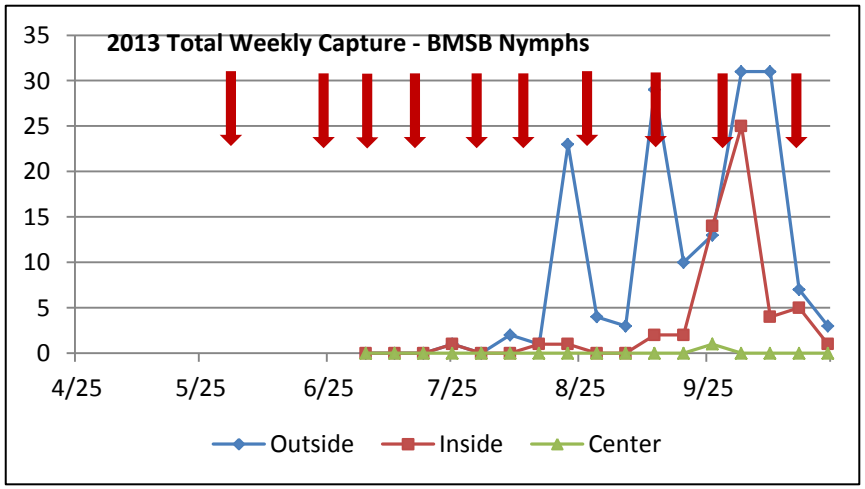
BMSB total captures per week





Average weekly captures of BMSB adults and nymphs





Total weekly captures of BMSB adults and nymphs

- BMSB Insecticide applications

Outside – 8 traps; inside - 4 traps; center – 1 trap

G. Krawczyk, Hershey, PA. Jan 31, 2017

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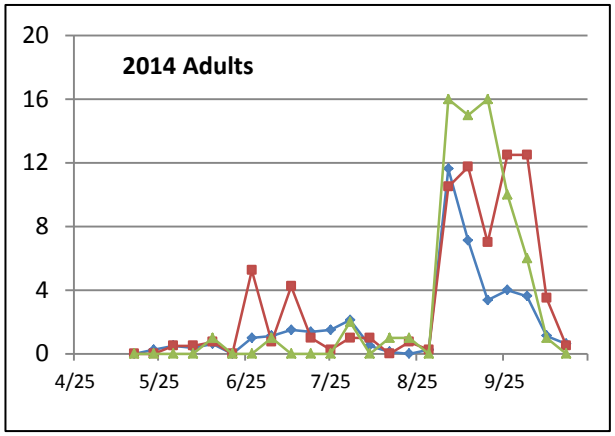
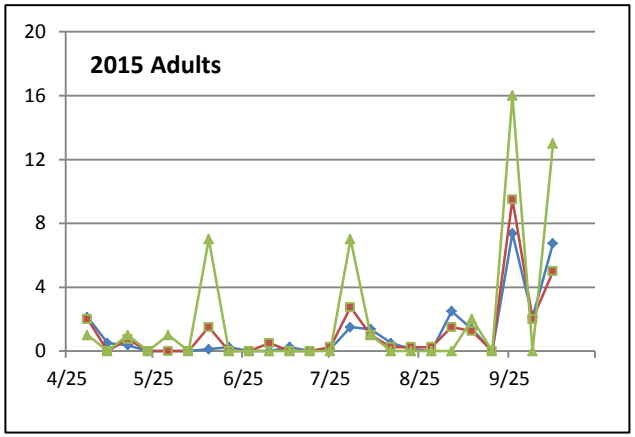
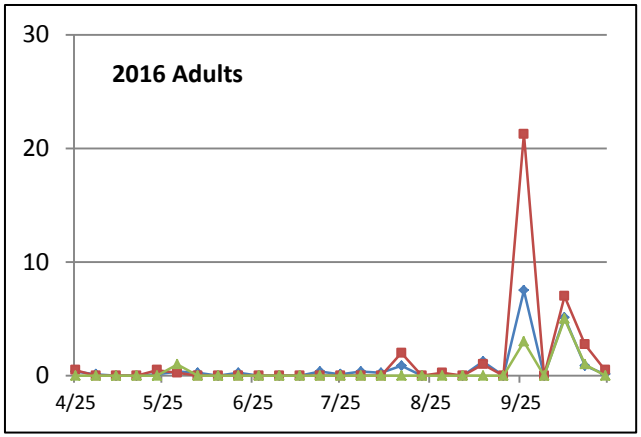
2014 – 2016 BMSB Trap Placement Grid

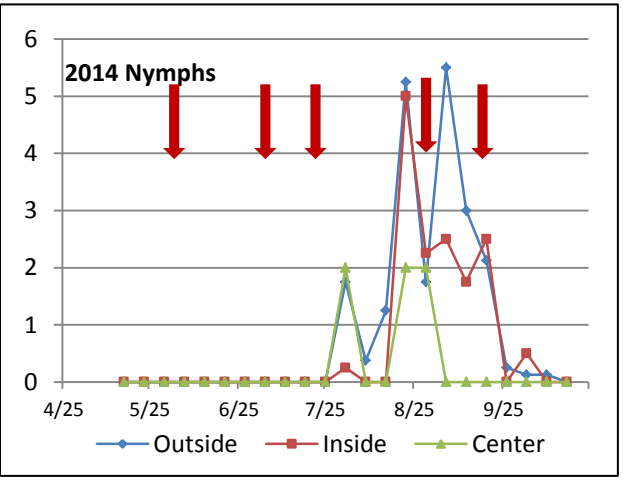
BMSB adults and nymphs average captures per week/trap

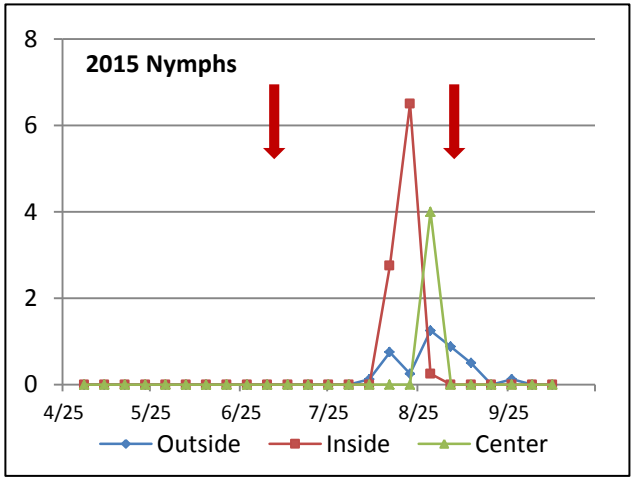


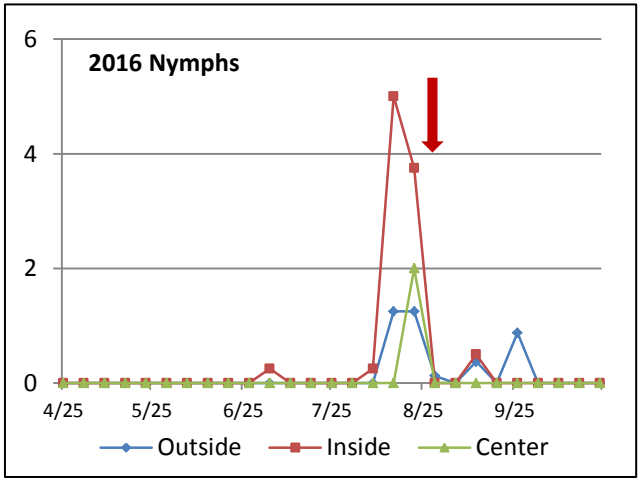




Average weekly captures of BMSB adults per trap







Average weekly captures of BMSB nymphs per trap

↓ - BMSB Insecticide applications

Outside – 8 traps; inside - 4 traps; center – 1 trap

G. Krawczyk, Hershey, PA. Jan 31, 2017

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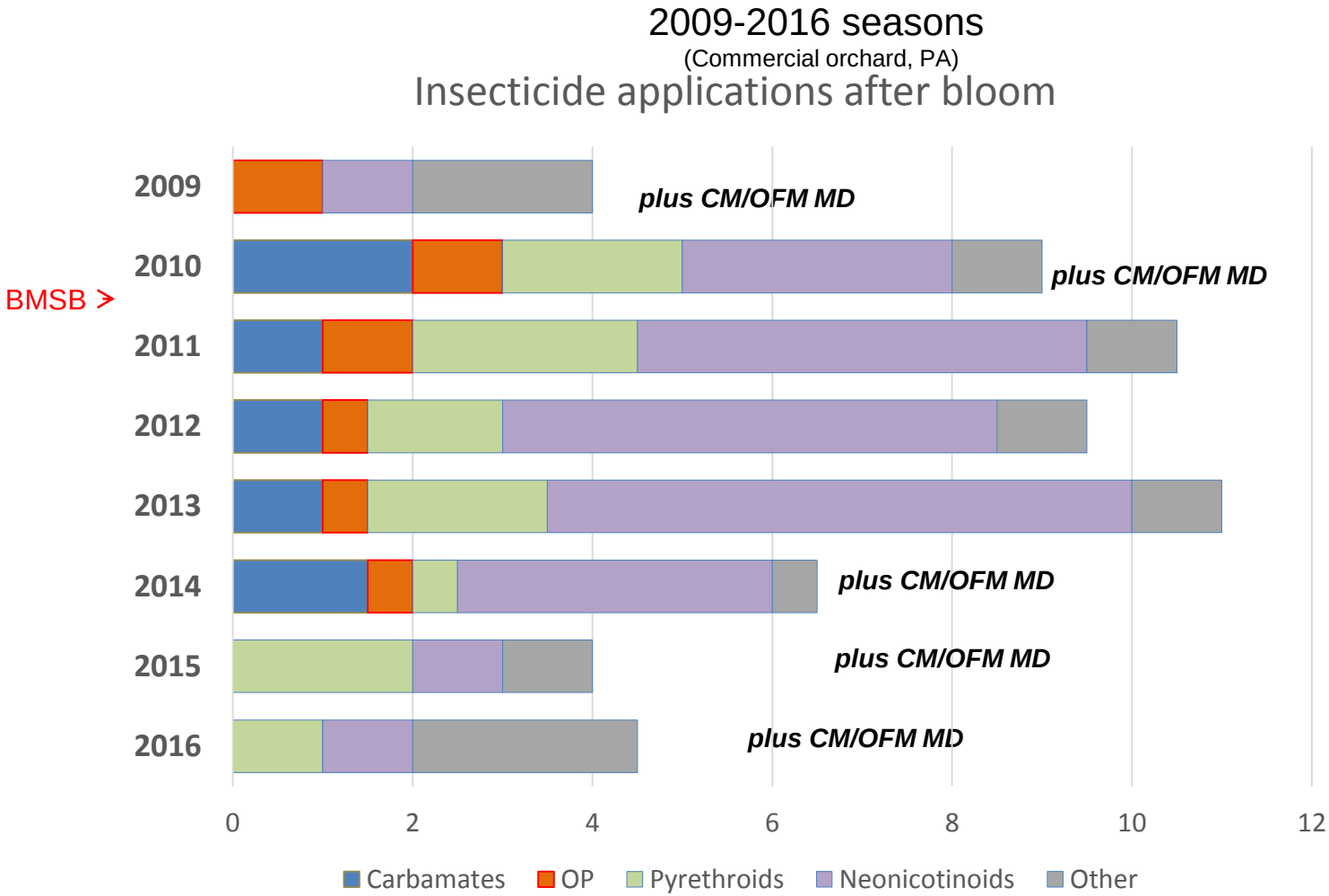
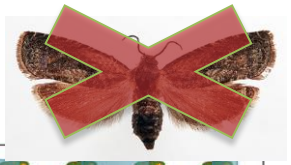
Changes in seasonal insecticide applications - apples

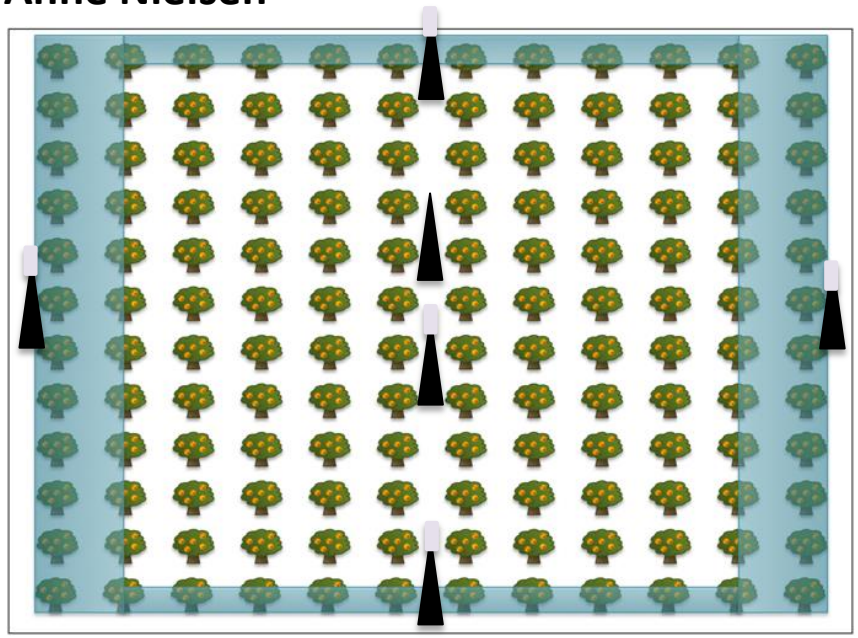


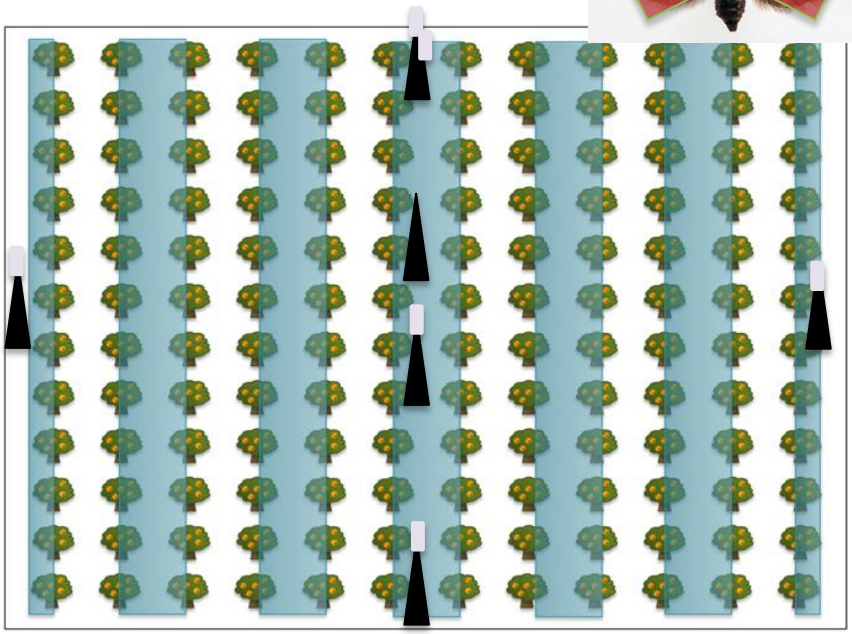
Insecticides:
Carbamates (IRAC Group 1A) – methomyl,
Organophosphates (IRAC Group 1B) – phosmet,
Pyrethroids (IRAC Group 3A) – fenpropathrin, lambda cyhalothrin, bifenthrin,
Neonicotinoids (IRAC Group 4A) – acetamiprid, clothianidin, thiametoxam, dinotefuran, thiacloprid,
Other (IRAC Groups 5, 18, 28) – methoxyfenozide, spinetoram, rynaxypyr.

IPM-Crop Perimeter Restructuring

Anne Nielsen







Pesticide application

Border spray blocks:

- Mating disruption for internal worms (CM & OFM)
- Herbicide Stinger applied to row middles to remove flowering weeds
- BMSB managed with border sprays
  - Orchard border + 1st full row = area of insecticide application
    - Triggered by trap-based threshold for BMSB (apple)

Grower standard:

- All other pests managed using standard practices
- BMSB managed using full block/Complete sprays or ARM
  - Triggered by trap-based threshold for BMSB

IPM-Crop Perimeter Restructuring

Anne Nielsen

Evaluated for 3 years on commercial peach farms in NJ

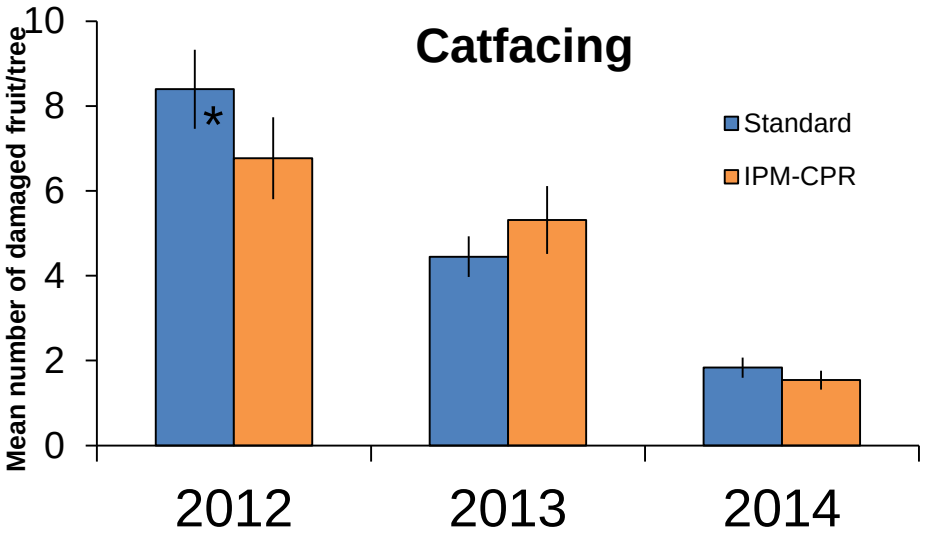
Evaluated for 2 years on commercials apple orchards in NJ

Evaluated for 1 year on commercial apple in WV & VA

Generally, growers applied same insecticide on both blocks

In peaches, applied weekly after DD timing

In apple, applications initiated on threshold (10 cumulative adults per trap)



kg/A	Farm	IPM-CPR	ARM
2012	1	0.98	3.69 **(3.7x)**
	2	1.19	1.96 **(1.6x)**
	3	0.57	2.01 **(3.5x)**
2013	1	0.71	2.36 **(3.3x)**
	2	1.61	2.86 **(1.8x)**
	3	1.03	2.25 **(2.2x)**

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BMSB alternative management trials

Net exclusion trials

- net barrier between crop and potential source of BMSB infestation
- utilize existing deer fences

Crop trapping *(work of Deonna Soergel, former graduate student)*

- based on differences in attractiveness of various crops
- sunflowers and pepper, sunflowers and peaches…

Attract and kill

- Individual border trees baited with BMSB attractants
- Baited net traps outside orchards

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Attract-and-Kill

as Alternative BMSB Management Strategy

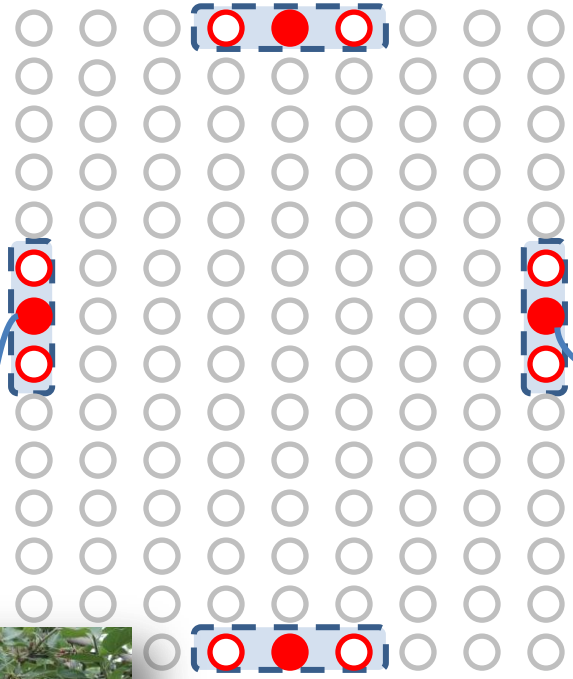
Tracy Leskey, Chris Bergh, Greg Krawczyk, Anne Nielsen and Rob Morrison.

NE SARE Project, 2015-2016

NORTHEAST SARE Sustainable Agriculture Research & Education

Attract-and-Kill Block

Grower Standard

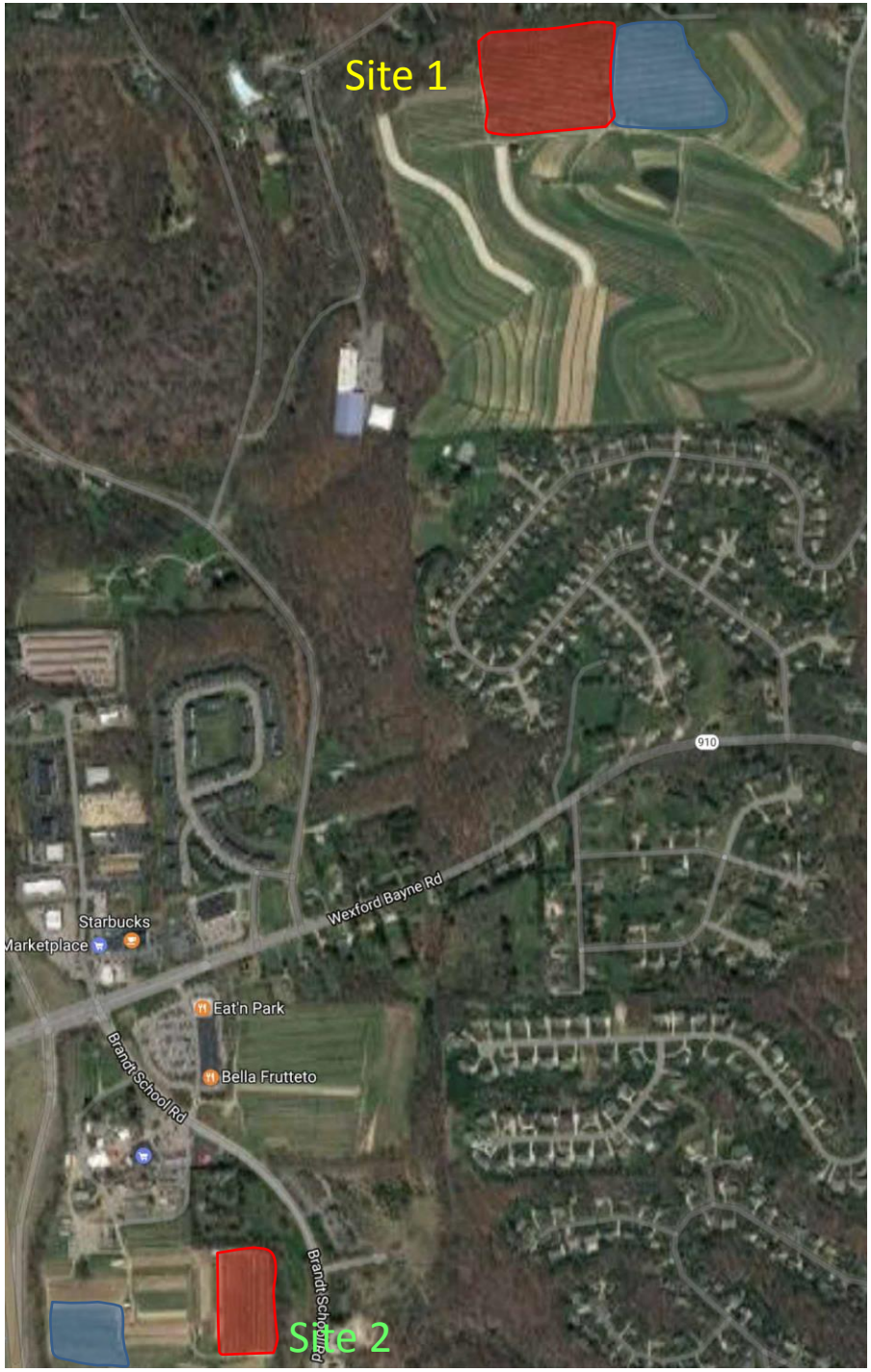


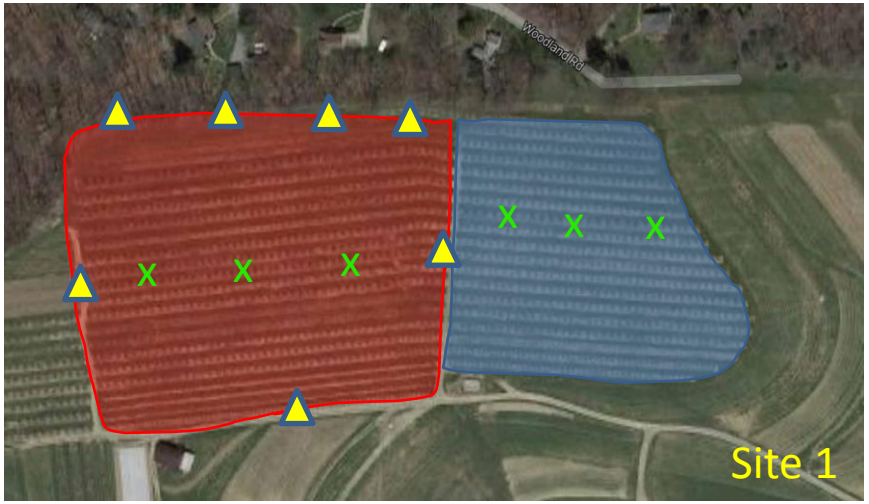
vs.

= Area treated with insecticides

Slide courtesy Rob Morrison, USDA ARS

Pennsylvania A&K sites





Attract and Kill orchard

Control orchard

X BMSB traps

AK stations

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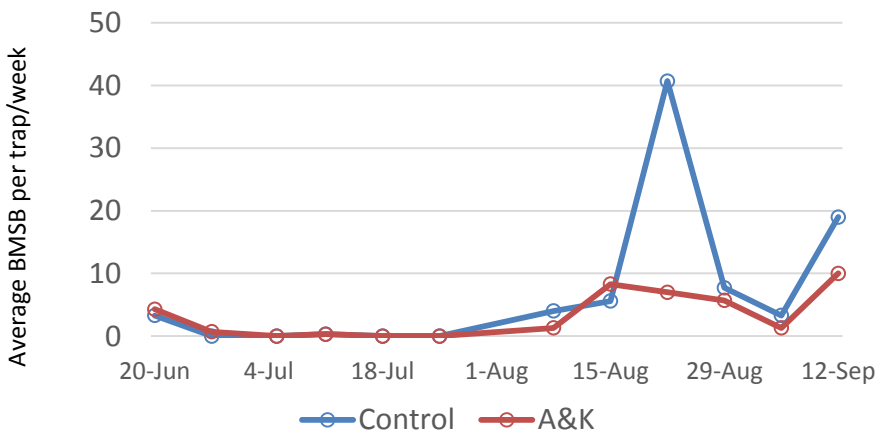
Pennsylvania A&K Project

BMSB captures in traps, Site 2, 2016 season

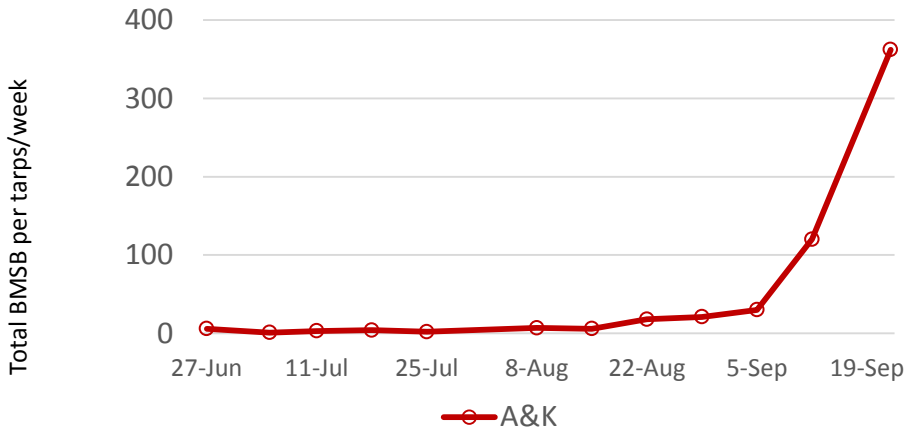


Average captures of BMSB per trap/week:

Ctr – 6.95 a

A&K – 3.10 a

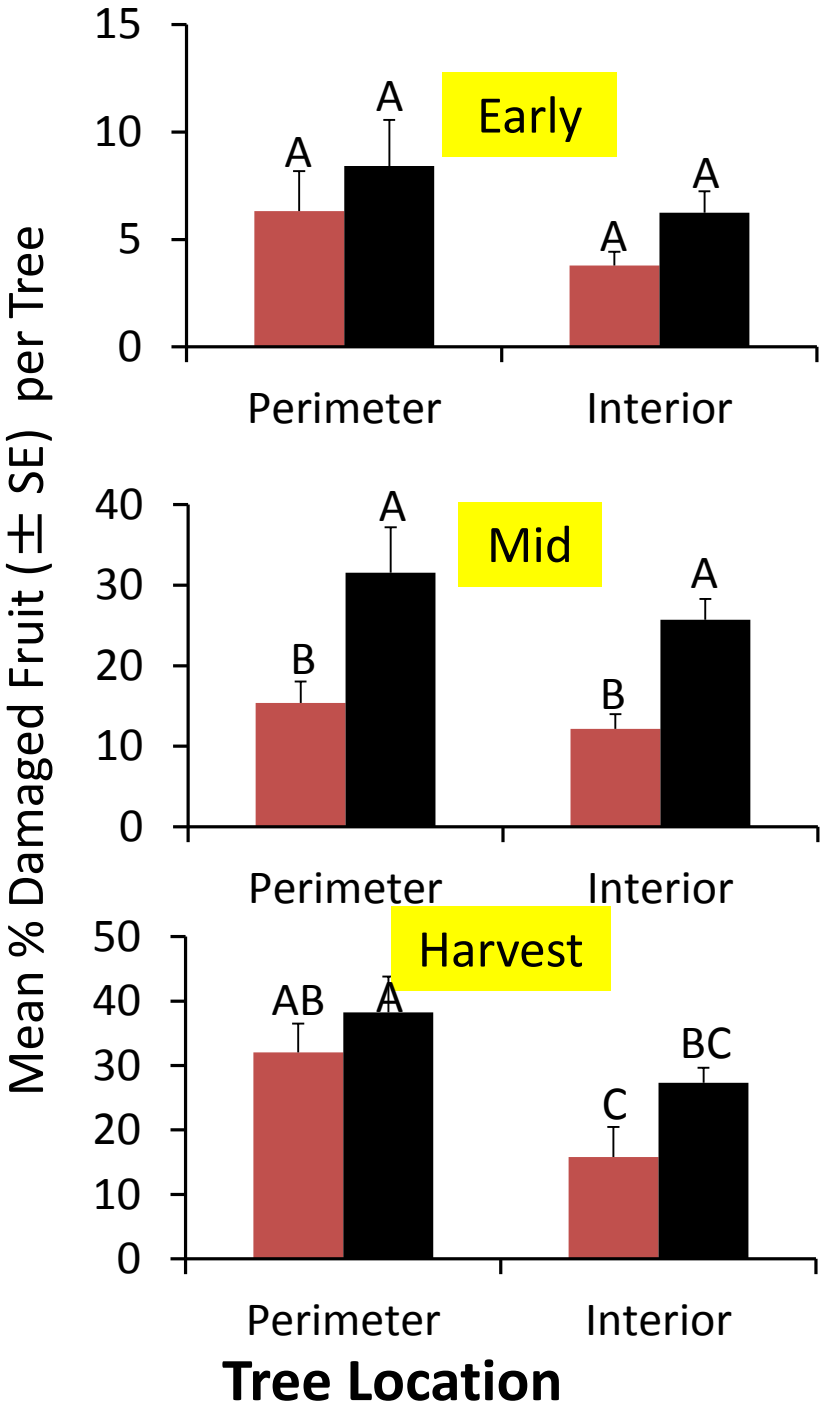
ANOVA, Tukey HSD, F=2.33, p=0.13



Total number of dead BMSB collected under A&K trees per week, (n=4)

Slide courtesy Rob Morrison, USDA ARS

2016 Results: Fruit Damage Frequency



Early Before Jun 15th

Mid Jun 15th-Aug 15th

Harvest After Aug 15th

- Attract-and-Kill
- Grower Standard

GLM
Binomial Likelihood Ratio Treatment
$\chi^2 = 9.12$, $df = 1$, $P < 0.003$
Location
$\chi^2 = 4.22$, $df = 1'$ $P < 0.04$
Period
$\chi^2 = 119.5$, $df = 2$, $P < 0.0001$
Chi-square w/Bonferroni correction

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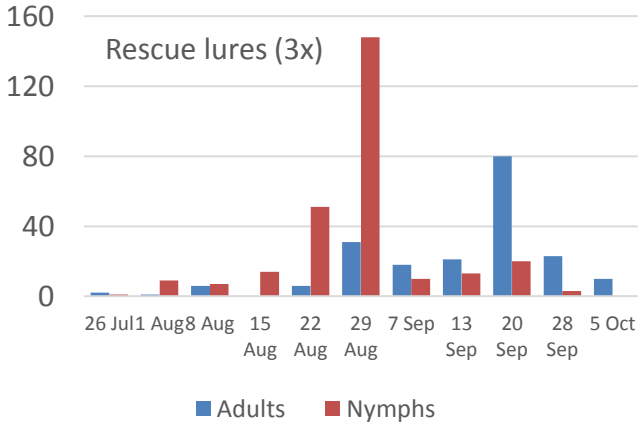
Evaluation of “ghost “ net trapping

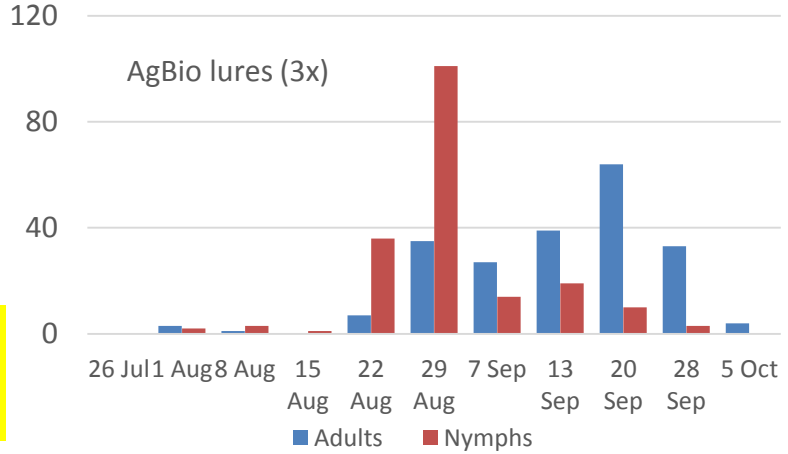
2014 - Grower made insecticide treated net

2015 - Nets treated with bifenthrin insecticide – season long project

2016 – PermaNet® commercial net from Vestergaard Frandsen Inc.



2016 season
- 3 ”ghost” traps for each lure combination



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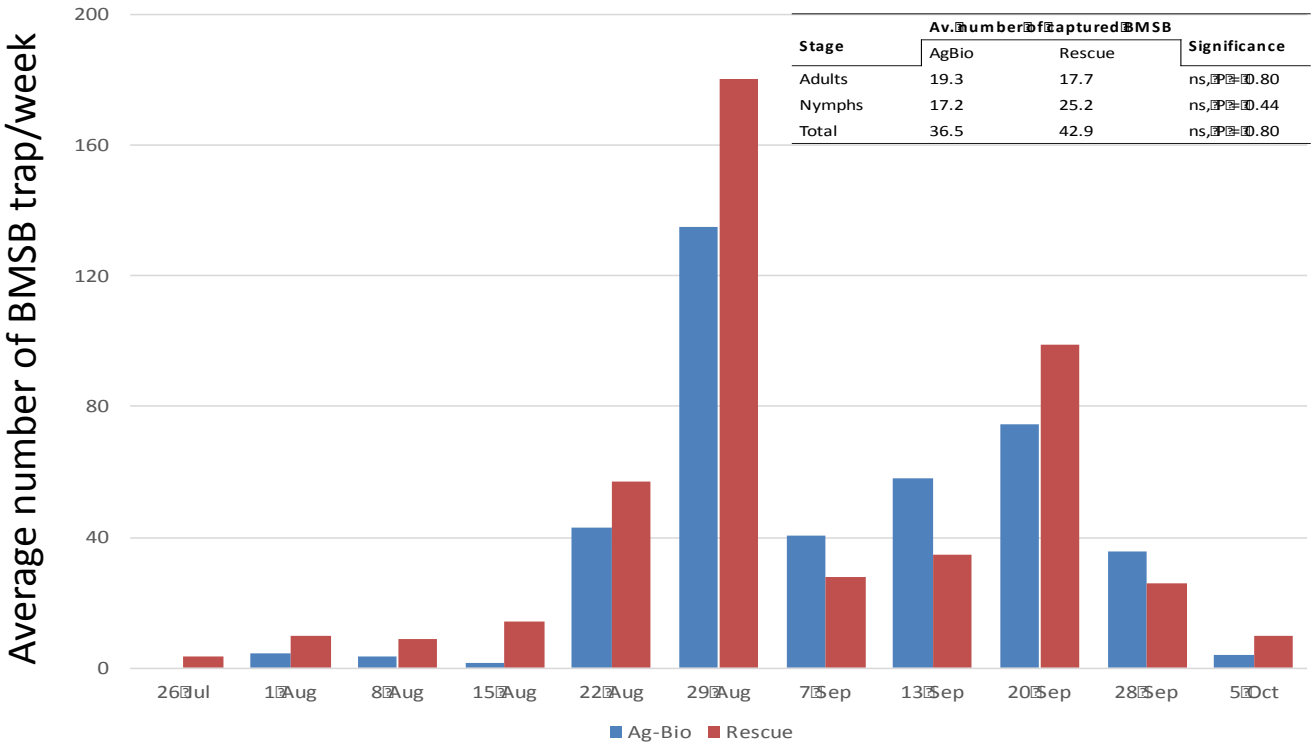
Evaluation of “ghost “ net trapping



Stage	Av. number of captured BMSB		Significance
	AgBio	Rescue	
Adults	19.3	17.7	ns, P=0.80
Nymphs	17.2	25.2	ns, P=0.44
Total	36.5	42.9	ns, P=0.80

ZeroFly® Permanet® net from Vestergaard Frandsen Inc. placed along the orchard edge on Jul 19, 2016

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Summary…

BMSB lures and traps are effective in detecting the presence of BMSB and should be used to decide if BMSB treatments are needed

The placement of traps is affecting attractiveness of lures to BMSB adults and nymphs. Understanding of “active space” for various BMSB lure/trap combinations is crucial for the development of practical trapping recommendations.

Use of bio-rational insecticides and utilization of biological control agents are crucial for the development of complex BMSB management programs.

Alternative BMSB management options such as attract and kill or “ghost” nets are needed to support IPM based fruit pest management programs

Continuous research and extension under

Management of BMSB in US Specialty Crops 2016 - 2021

Main goals:

- BMSB risk prediction based on agroecology and landscape ecology.
- Implementation of biological control including exotic parasitoids and native natural enemies.
- Development of management tools compatible with biological control.
- Economic validation of management tools.
- Outreach program

Stop BMSB.org

Funding

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

Specialty Crop Research Initiative

Collaborating Institutions

ars · NC STATE UNIVERSITY · PennState · OSU Oregon State · University of Maryland · University of Georgia · Washington State University · Northeastern IPM Center · Cornell University · UtahStateUniversity. · Rutgers University · The Ohio State University · University of Kentucky. · UCDAVIS · University of Minnesota · VirginiaTech · Berkeley · Michigan State University · UCRIVERSIDE

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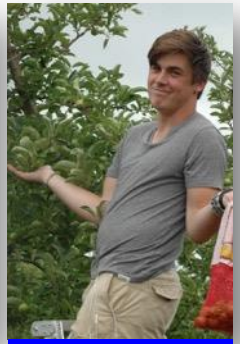
Thank you

Ally
Lock Haven University

Chandler
Penn State University



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