Obj. 2. Short Term Mitigation
(Insecticide based management benefits and challenges)

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Funding

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Collaborating Institutions

University of Delaware
ARS
Penn State
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Washington State University
Cornell University
University of Maryland
Virginia Tech
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BMSB Toxicity Testing
Lethality Index

$$\text{Lethality Index} = \left[\frac{\left(\text{BMSB Alive} \times 0.0\right)_{\Sigma \text{ Day } 0\text{-}7} + \left(\text{BMSB Moribund} \times 0.5\right)_{\Sigma \text{ Day } 0\text{-}7} + \left(\text{BMSB Dead} \times 1.0\right)_{\Sigma \text{ Day } 0\text{-}7}}{240} \right] \times 100$$

The maximum value of the Lethality Index for each material is 100.0; the minimum value is 0.0, and compounds are ranked in descending order of value.

* After testing ~45 materials, the Lethality Index was modified to accommodate four conditional categories: Alive (0.0); Affected (0.25); Moribund (0.75); and Dead (1.0). This change in conditional interpretation does not change the comparability of Lethality Index across tested materials.

BMSB Toxicity Testing
Lethality Index (laboratory vial bioassays)

Active Ingredient	Trade Name	Lethality Index	Active Ingredient	Trade Name	Lethality Index
Chlorpyrifos/Gamma-Cyhalothrin	~~Cobalt~~	**95.4**	Oxamyl	Vydate	**46.8**
Dimethoate	~~Cygon~~	**93.3**	MBI-203	MBI-203	**43.4**
Malathion	Malathion	**92.5**	Esfenvalerate	Asana	**43.3**
Bifenthrin	~~Brigade~~	**91.5**	Imidacloprid	Provado	**40.0**
Endosulfan	~~Thionex~~	**90.4**	Tolfenpyrad SC	Tolfenpyrad SC	**36.5**
Methidathion	~~Supracide~~	**90.4**	MBI-205	MBI-205	**35.7**
Methomyl	Lannate	**90.1**	Tolfenpyrad EC	Tolfenpyrad EC	**33.3**
Chlorpyrifos	~~Lorsban~~	**89.0**	Pyrifluquinazon	Pyrifluquinazon	**28.3**
Acephate	~~Orthene~~	**87.5**	Kaolin Clay	Surround	**23.1**
Fenpropathrin	Danitol	**78.3**	Diazinon	Diazinon	**20.4**
Permethrin	Permethrin	**77.1**	Phosmet	Imidan	**20.0**
Azinphosmethyl	~~Guthion~~	**71.3**	Acetamiprid	Assail	**18.8**
Dinotefuran	~~Safari~~	**67.3**	Thiacloprid	Calypso	**18.3**
Kaolin Clay/Thiamethoxam	Particle Delivery	**66.7**	Abamectin	Agri-Mek	**16.3**
Formetanate HCl	~~Carzol~~	**63.5**	Indoxacarb	Avaunt	**11.3**
Gamma-Cyhalothrin	Proaxis	**59.0**	Spirotetramat	Movento	**9.8**
Zinc Dimethyldithiocarbamate	Ziram	**57.5**	Carbaryl	Sevin	**9.2**
Thiamethoxam	Actara	**56.3**	Water	Control 6	**9.2**
Clothianidin	Clutch	**55.6**	Flonicamid	Beleaf	**7.7**
Beta-Cyfluthrin	Baythroid	**54.8**	Water	Control 2	**6.9**
Lambda-Cyhalothrin	Warrior	**52.9**	Water	Control 3	**6.3**
Zeta-Cypermethrin	Mustang Max	**52.1**	Water	Control 5	**6.0**
Cyfluthrin	Tombstone	**49.0**	Water	Control 4	**4.2**
MBI-206	MBI-206	**48.4**	Cyantraniliprole	Cyazypyr	**1.7**

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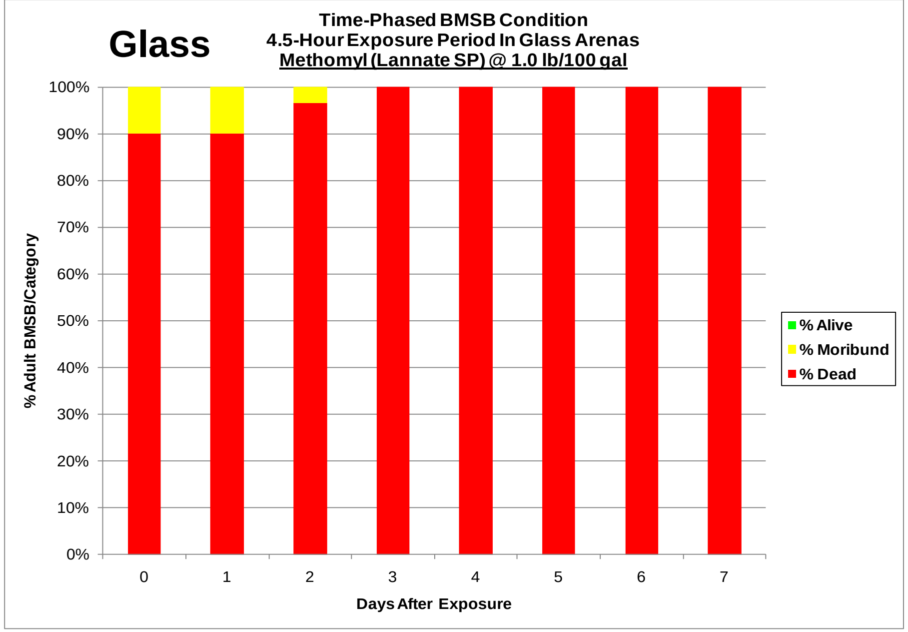
Field-Based Residual Trials

- Exposure Intervals *(uptake via feeding and residue)*
  - 0 DAY (after application) for 24h
  - 3 DAY for 24h
  - 7 DAY for 24h
- Daily Mortality Assessments for 7 Days

Leskey et al. (2013)

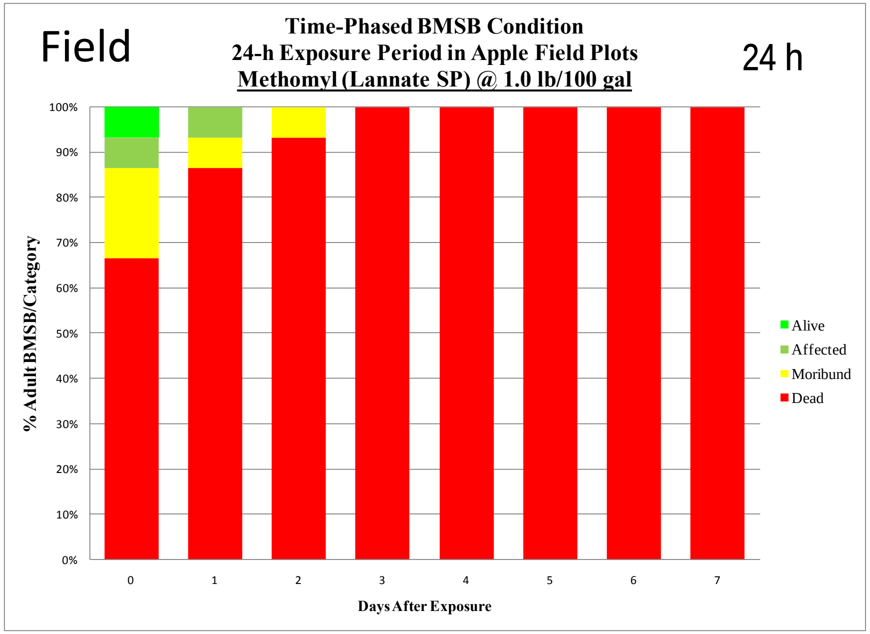
Lab vs. field residual bioassays

Glass



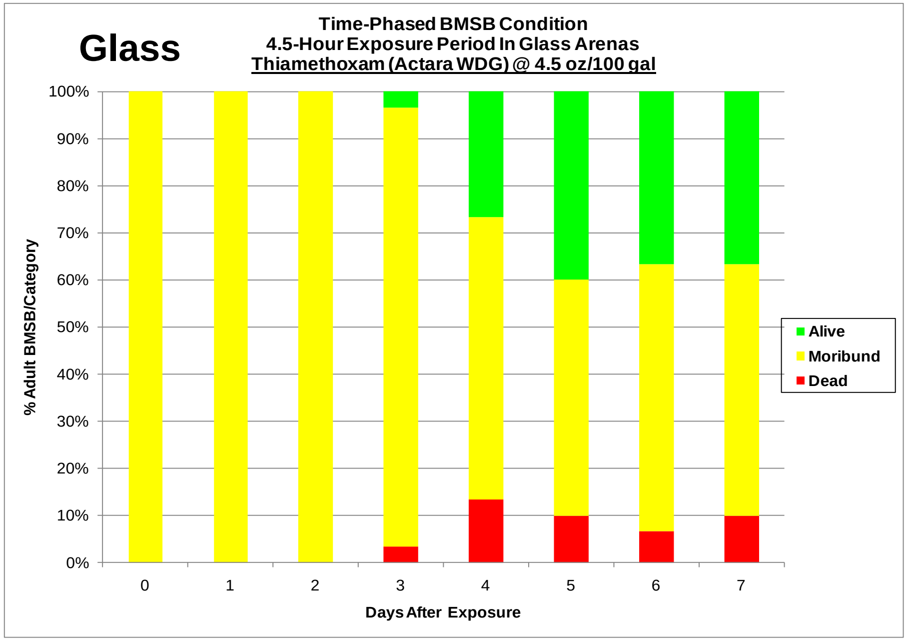
Field

24 h



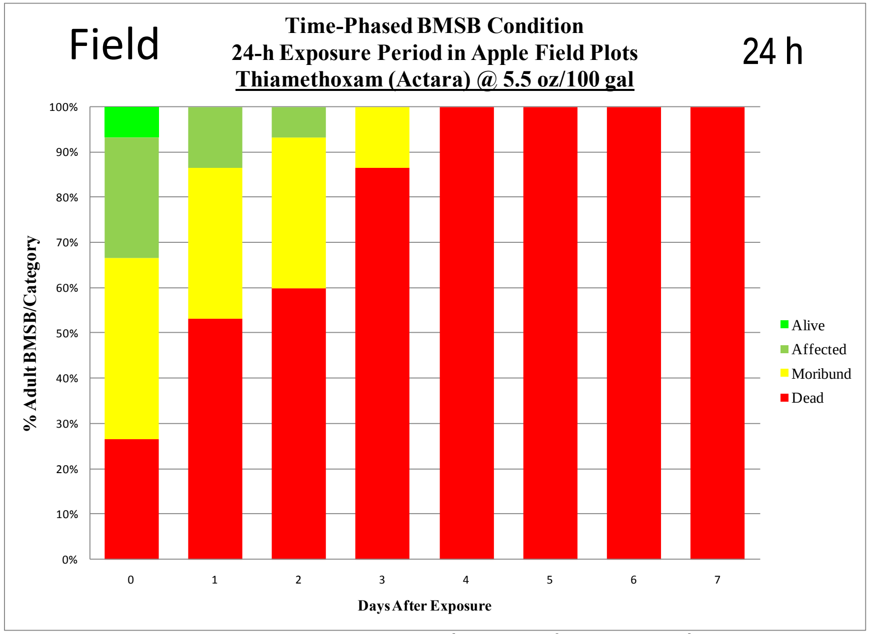
Lannate

Glass



Field

24 h



Actara

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BMSB Toxicity Testing
Lethality Index BMSB Adults

(USDA ARS Bioassays)

Active Ingredient	Trade name	Glass bioassays	Field residual bioassays (0d)	Difference
malathion	Malathion	92.5	59.6	*32.9*
bifenthrin	Brigade	91.5	88.8	*2.7*
methomyl	Lannate	90.1	96.9	*- 6.8*
fenpropathrin	Danitol	78.3	29.0	*49.3*
dinotefuran	Scorpion	67.3	76.6	*- 9.3*
thiametoxam	Actara	56.3	91.0	*-34.7*
clothianidin	Belay	55.6	76.1	*-20.5*
L-cyhalothrin	Warrior	52.9	46.5	*6.4*
cyfluthrin	Tombstone	49.0	14.6	*34.4*
Control (water)	N/A	6.0	0.0	*6.0*

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Lethality Index: Residual Field Studies BMSB Adults

(USDA ARS bioassays)

Active ingredient	Trade name	Day 0	Day 3	Day 7
malathion	Malathion	96.9	0.8	0.8
bifenthrin	Brigade	88.8	27.7	14.6
methomyl	Lannate	96.9	26.7	22.3
fenpropathrin	Danitol	29.0	5.9	0.0
dinotefuran	Scorpion	76.6	9.8	23.8
clothianidin	Belay	76.1	49.0	28.3
thiametoxam	Actara	91.0	38.5	40.8
L-cyhalothrin	Warrior	14.6	5.0	3.5
cyfluthrin	Tombstone	14.6	0.8	0.0
Control	N/A	0.0	2.8	0.3

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Green bean dip bioassays

- Insecticidal solution based on 100 gal / acre water output.
- Filter paper + one green bean were:
  - dipped in solution for 5 seconds.
  - Dried ½ hr under a fume hood.
  - Placed in a 9-cm Petri dish.
- 5 adults or 2nd to 3rd instars per dish.
- 4 Petri dishes per treatment for a total of 20 insects per bout.
- Mortality at 24, 48, and 72 hrs

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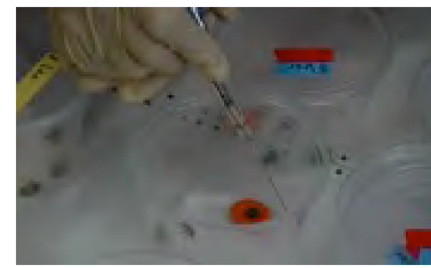
Insecticide activity against BMSB

Direct contact topical bioassays

Subject

- BMSB from overwintering colony
- Male and female adults tested separately

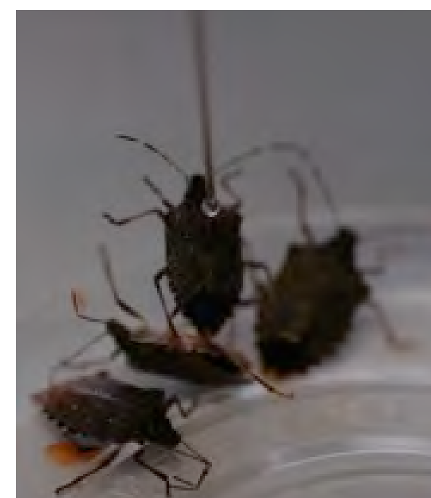


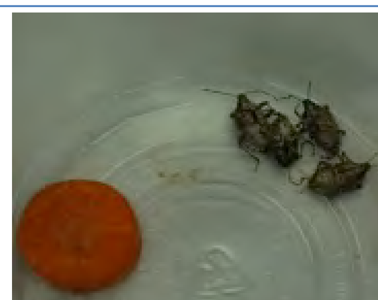
Test

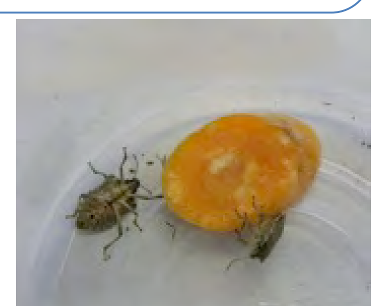
- Commercial grade insecticide solutions at field rate, surfactant added;
- Each individual bug treated with 2 µl of solution

Results

- Mortality assessed at 4, 24, 48, 72, 96 and 120 hour after treatment
- Surviving individuals kept for further observation







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BMSB Toxicity Testing
BMSB Mortality

(PSU and VA Tech Bioassays)

Active Ingredient	Trade name	Direct contact (topical)	Bean dip bioassays **Nymphs**	Adults	Percent control in field (2011)
malathion	Malathion	-	-	-	**-**
bifenthrin	Brigade	100.0	**100.0**	81.9	**56.3**
methomyl	Lannate	98.0	**66.7**	75.3	**62.2**
fenpropathrin	Danitol	82.0	**93.3**	42.5	**60.3**
dinotefuran	Scorpion	98.0	**100.0**	80.0	**46.0**
thiametoxam	Actara	95.0	**66.7**	81.0	**60.3**
clothianidin	Belay	100.0	**75.0**	67.5	**66.7**
L-cyhalothrin	Warrior	72.0	**100.0**	72.8	**38.0**
cyfluthrin	Tombstone	30.0	**92.5**	88.2	**52.8**
Control (water)	N/A	0.0	**0.0**	0.0	**-**

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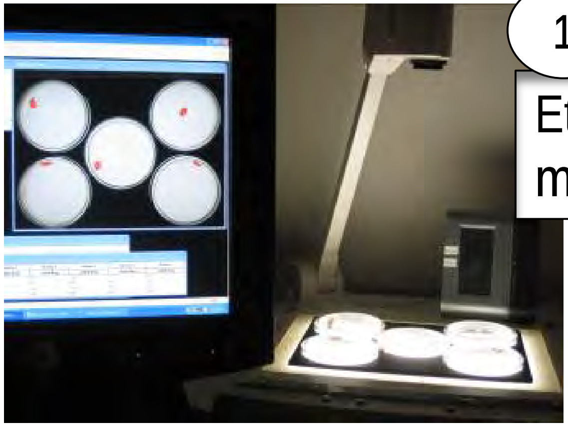
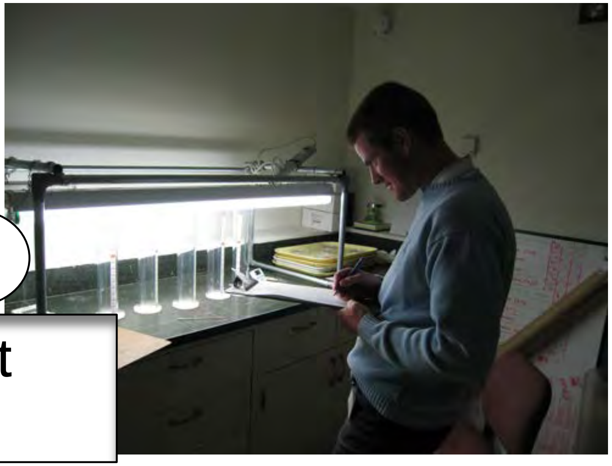
Experimental Trials



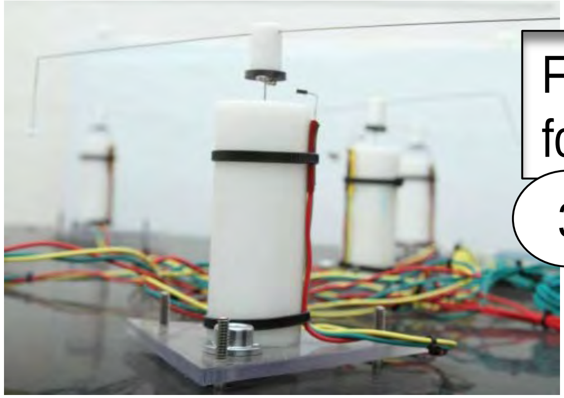
1

EthoVision trials for measuring **horizontal mobility** on insecticide-treated surfaces.



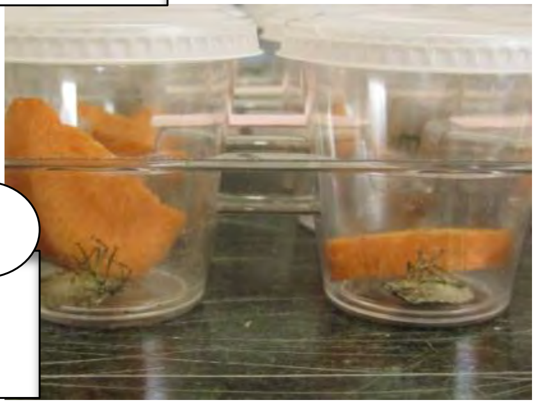
2

Direct observations of **vertical movement** capacity following insecticide exposure.



Fly mill observations of **flight capacity** following insecticide exposure.

3



4

Mortality tracked for 7-d followed by final vertical movement trial.

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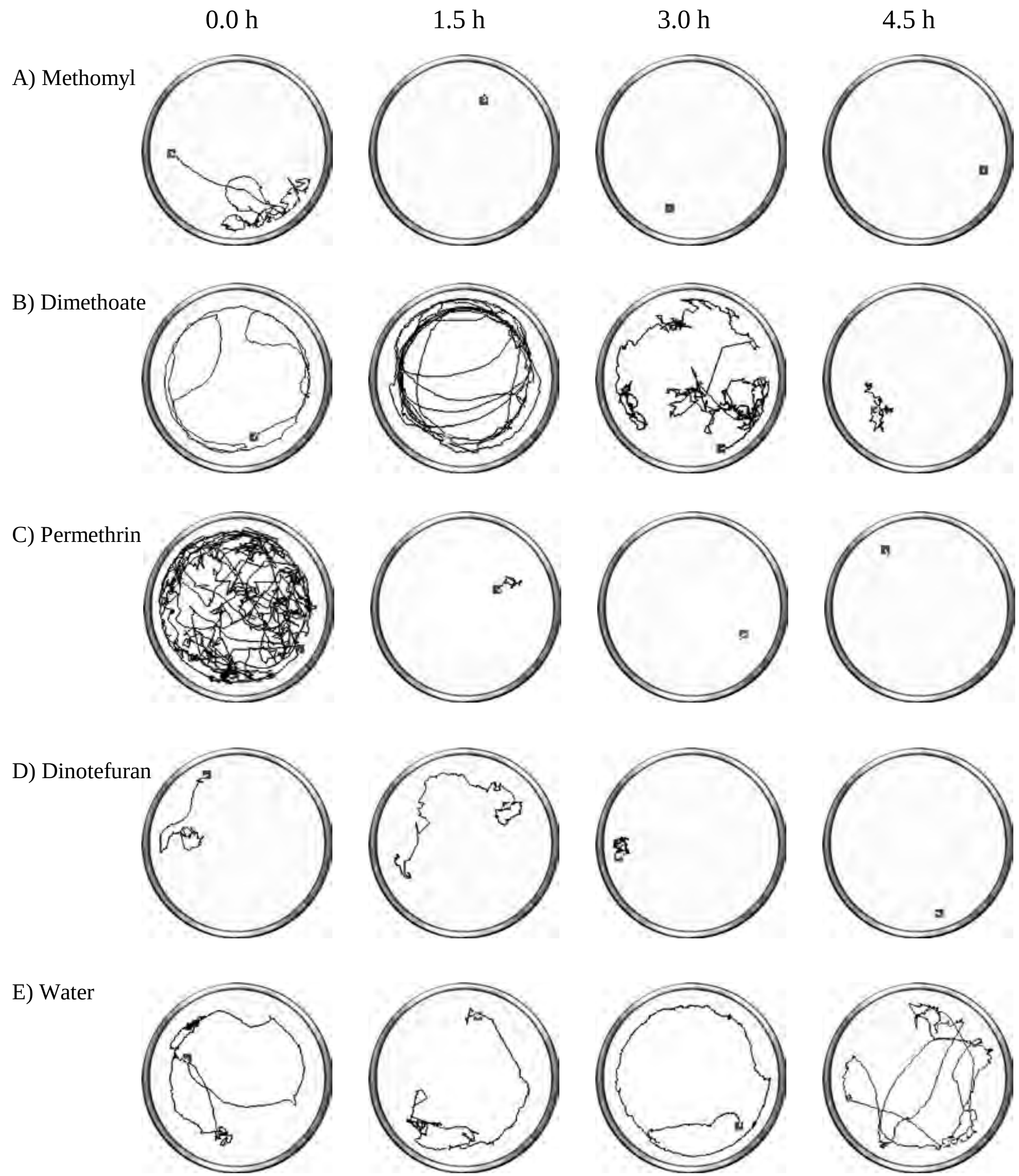
Horizontal Mobility



- Lee et al. 2014. Impact of organic insecticides on the survivorship and mobility of *H. halys* in the laboratory. Fl. Entomol. 97: 414-421.
- Lee et al. 2013. Impact of insecticide residue exposure on the invasive pest, *H. halys*: analysis of adult mobility. J. Econ. Entomol. 106: 150-158.
- Leskey et al. 2013. Efficacy of insecticide residues on adults *H. halys* mortality and injury in apple and peach orchards. Pest Manag. Sci. 70: 1097-1104.
- Leskey et al. 2012. Impact of insecticides on the invasive *H. halys*: analysis of insecticide lethality. J. Econ. Entomol. 105: 1726-1735.
- *Morrison et al. Consequences of sublethal doses of insecticide on the survivorship and mobility of H. halys. (in preparation)*

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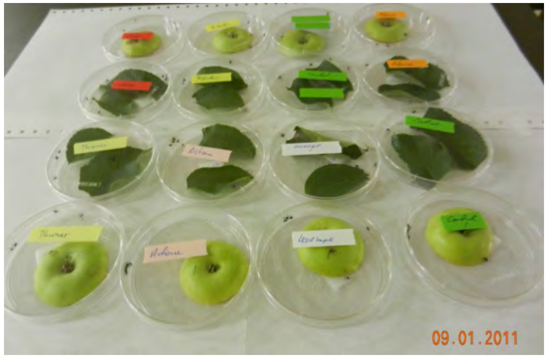
Field residual bioassays

BMSB field residual insecticide bioassays.

- Insecticide applications to whole trees in experimental orchard using back-pack sprayer
- BMSB 2nd instar nymphs from laboratory colony maintained at PSU FREC
- Leaves and fruit collected at 1d (4hours), 4 d, 7d, 12d and 15 days after field treatment.
- Mortality checked at 24 and 48 hours after placement into dish with treated material.
- Moribund nymphs counted as dead.



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Residual activity of insecticides against 2nd instar nymphs

PSU FREC 2011

1st set of bioassays (July 21, 2011)

Product	Rate		Days After Treatment (DAT)			
	Formulated per acre/100 gal	Active Ingredient/ 100 gal (by weight)	% Mortality at **0 days** after treat	% Mortality at **4 days** after treat	% Mortality at **7 days** after treat	% Mortality at **12 days** after treat
			48h	**48h**	**48h**	**48h**
Control	N/A	N/A	**4 c**	**11 b**	**7 c**	**7 b**
Lannate SP	9.0 oz	8.10 oz	**100 a**	**92 a**	**28 bc**	**N/A**
Lannate SP	16.0 oz	14.4 oz	**100 a**	**100 a**	**84 a**	**11 b**
Scorpion	6.0 fl oz	2.43 oz	**100 a**	**85 a**	**43 b**	**N/A**
Scorpion	12.0 fl oz	4.86 oz	**100 a**	**100 a**	**88 a**	**60 a**
Venom	3.0 oz	2.10 oz	**80 b**	**88 a**	**100 a**	**N/A**
Venom	6.0 oz	4.20 oz	**96 ab**	**96 a**	**100 a**	**56 a**

Means within the column followed by the same letter(s) are not different (Tukey HSD All-Pairwise Comparisons, $p \leq 0.05$)
During each individual count all moribund nymphs (i.e., erratic movement) classified as dead.

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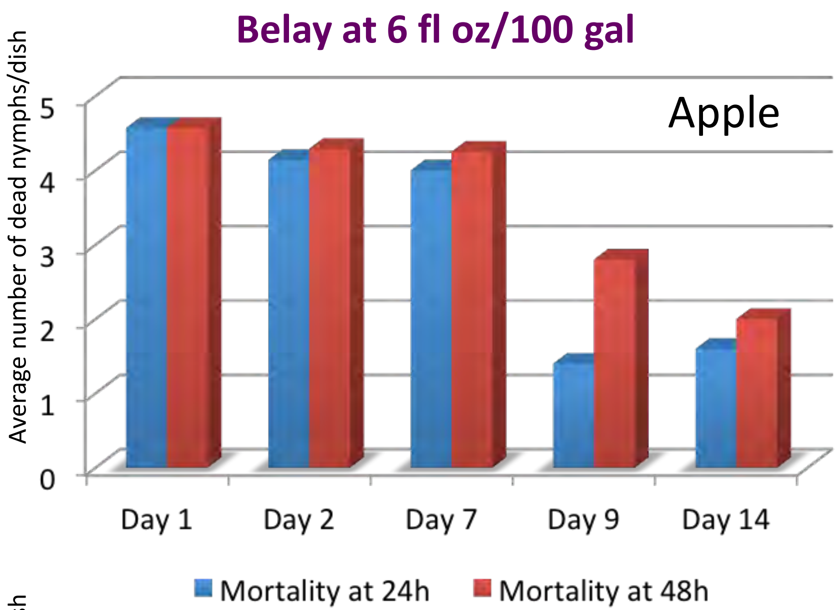
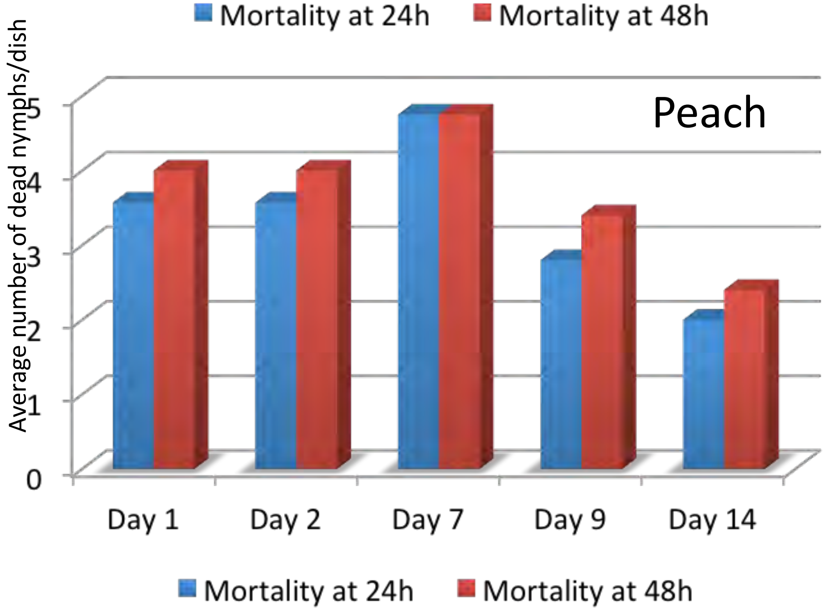
Determine Efficacy of BMSB Insecticide Residue

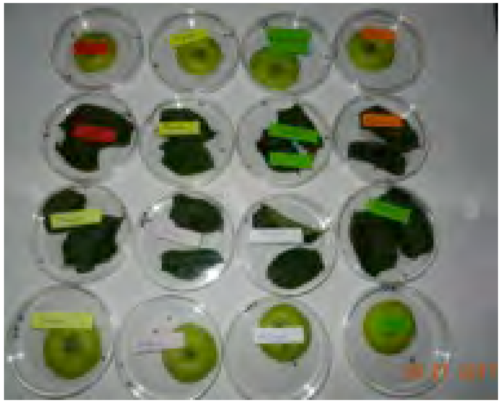




BMSB nymphal residual bioassays.
(2013 trial)

Apple and peach trees were sprayed with backpack sprayer and treated foliage was collected at 1, 2, 7, 9, and 14 day AT.
To eliminate the effect of precipitation trees were stored in a greenhouse

Five 2nd instar nymphs were placed per Petri dish and mortality was assessed at 24 and 48 hours after placement on treated foliage.
Seven dishes (35 nymphs) were used per collection.



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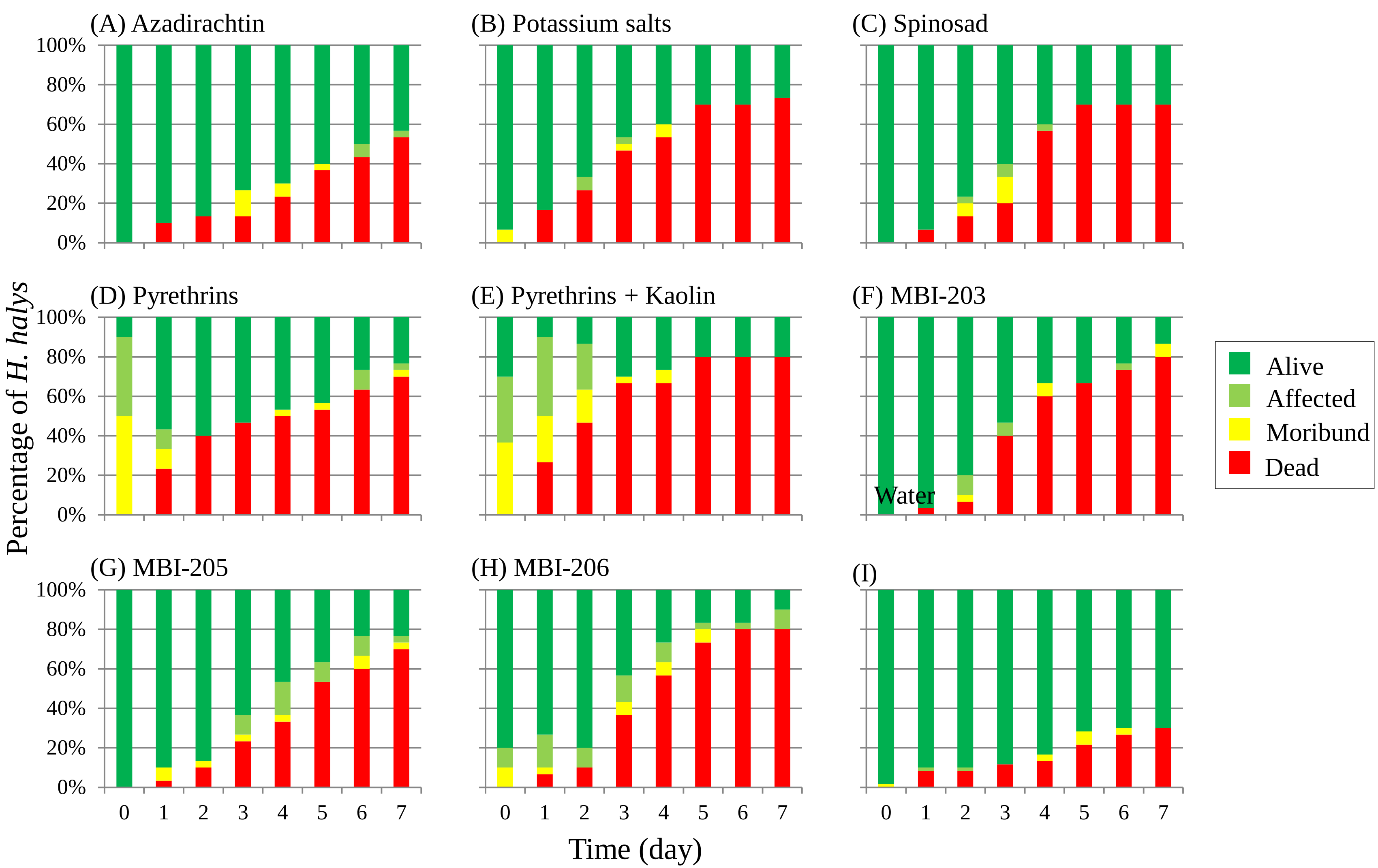
Organic Materials



Lee et al. (2014). Fl. Entomol.

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Organic insecticides and cyclaniliprole for control of BMSB in vegetable crops

Some biological insecticide options for organic growers

Veratran D (MGK)	Sabadilla seed alkaloids (.20%)
Pyganic (MGK)	Pyrethrins (5%)
Entrust SC (Dow Agrosciences)	Spinosad (22.5%)
Azera (MGK)	Azadiractins (1.2%) + Pyrethrins (1.4%)
Aza-Direct (Gowan)	Azadiractins (1.2%)
M Pede (Gowan)	Potassium salts of fatty acids (49%)
Venerate XC (Marrone Bioinnovations)	Burkholderia (94.4%)(Chromobacteria)

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- *Dept. of Entomology, Virginia Tech*

Virginia Tech College of Agriculture and Life Sciences
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Contact and bean-dip bioassays

TRT	Active ingredient	Rate / Acre	% mortality at 48 hrs from ≥3 assays			
			Contact		Bean dip	
			Mean ± SEM % mort.		Mean ± SEM % mort.	
			Nymphs	Adults	Nymphs	Adults
UTC		0	6.6 ± 0.09	5.0 ± 0.39	9.8 ± 0.19	1.0 ± 0.04
Veratran D	Sabadilla Alkaloids (.20%)	240 oz	75.0 ± 0.34	42.5 ± 1.98	41.0 ± 1.05	40.0 ± 1.35
Pyganic	Pyrethrins (5%)	17 fl oz	100.0 ± 0.00	100.0 ± 1.58	30.0 ± 0.57	80.0 ± 0.47
Blackhawk	Spinosad (33%)	2.2 oz	48.3 ± 0.64	40.0 ± 0.93	24.0 ± 0.24	45.0 ± 0.77
Azera	Azadiractin (1.20%), Pyrethrin (1.40%)	56 fl oz	95.2 ± 0.25	95.0 ± 0.22	29.4 ± 0.33	56.7 ± 0.95
Aza-Direct	Azadiractin (1.20%)	56 fl oz	75.0 ± 0.59	55.0 ± 1.27	5.0 ± 0.22	3.3 ± 0.15
M Pede	Potassium salts of fatty acids (49%)	86 fl oz	40.0 ± 0.98	73.3 ± 0.32	3.3 ± 0.14	13.3 ± 0.32
Neudorff 1138	K Salts + Spinosad	86 fl oz	96.7 ± 0.11	45.0 ± 0.34	20.0 ± 0.80	20.0 ±0.13
Venerate XC	Burkholderia (94.4%)	215 fl oz	3.3 ± 0.07	8.3 ± 0.37	0.0 ± 0.00	15.0 ± 0.56

Efficacy of organic insecticides

(weekly applications, field trials Blacksburg, VA, 2014 and 2015)

Cumulative % fruit with stink bug damage

Treatment	Rate / Acre	Peppers 2014*	Tomatoes 2014**	Peppers 2015***	Tomatoes 2015****
UTC	-	37.6 ± 4.7	62.0 ± 3.6	47.0 ± 12.0	65.0 ± 4.5
Veratran D	240 oz	17.0 ± 2.8	47.7 ± 4.7	27.0 ± 9.4	60.0 ± 11.1
Pyganic	17 fl oz	16.5 ± 1.8	53.3 ± 3.6	33.0 ± 5.7	56.5 ± 6.9
Blackhawk	2.2 oz	18.7 ± 3.9	61.7 ± 7.3	46.5 ± 6.1	40.5 ± 6.6
Azera	56 fl oz	22.8 ± 3.0	46.7 ± 6.4	26.0 ± 10.2	54.5 ± 5.1
Aza-direct	56 fl oz	29.0 ± 4.1	58.3 ± 4.5	34.0 ± 3.3	51.0 ± 2.6
M Pede	86 fl oz	24.3 ± 4.1	46.8 ± 0.9	35.0 ± 3.3	64.5 ± 7.6
Neudorff 1138	86 fl oz	29.7 ± 3.1	52.9 ± 3.6	44.0 ± 4.3	58.5 ± 5.1
Venerate	215 fl oz	38.5 ± 4.2	50.7 ± 4.4	48.5 ± 10.2	58.5 ± 4.3
P- Value from ANOVA		ns	ns	ns	ns

*Includes two harvest dates: 29 August and 17 Sept, 2014
** Includes three harvest dates: 29 Aug, 8, and 12 Sept, 2014
***Includes two harvest dates: 13, and 26 Aug, 2015
****Includes two harvest dates: 20, and 31 Aug, 2015

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Conventional Insecticides

Cyclaniliprole **bean dip bioassays**

Treatment	Product field rate (fl oz/A)	Equivalent Conc. (g ai/liter)	Mean % mortality (72 hrs) from ≥3 bioassays (n = 20 per assay)	
			Nymphs 3rd & 4th instars	**Adults**
Water control		0	1.7 ± 0.8	0.0 ± 0.0
Cyclaniliprole 50SL	11.0	0.127	81.7 ± 11.7	28.0 ± 2.5
Cyclaniliprole 50SL	16.4	0.190	69.2 ± 12.4	26.0 ± 11.6
Cyclaniliprole 50SL	22.0	0.254	84.2 ± 8.7	33.0 ± 4.4
Cyclaniliprole 50SL	44.0	0.58	98.8 ± 1.0	25.0 ± 0.0

Very good activity on BMSB nymphs, but not adults!

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Conventional Insecticides

Foliar-applied insecticides, bell peppers, Blacksburg, VA 2015.

Insecticides were applied 27 July, 3, 10 and 17 Aug

% fruit with stink bug damage

		% stink bug damaged fruit	
Treatment	Rate / acre	13-Aug (3 DAT3)	24-Aug (7 DAT4)
Untreated Control		18.0	31.0 a
Cyclaniliprole 50SL	16.4 fl. oz	16.0	13.0 ab
Cyclaniliprole 50SL	22 fl. oz	10.0	16.0 ab
Cyclaniliprole 50SL	44 fl. oz	18.0	13.0 ab
Closer SC (sulfoxaflor)	5 fl. oz	13.0	7.0 ab
Closer SC	7 fl. oz	12.0	6.0 ab
Beleaf 50SG (flonicamid)	2.8 oz	19.0	24.0 ab
Bifenture 2EC (bifenthrin)	6.4 fl. oz	6.0	2.0 b

Cyclaniliprole reduced BMSB damage, but not as well as bifenthrin.

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BMSB Management in Sweet Corn 2011 - 2015

•Identify New Products, Affect of a Synergist (PBO), Using 3 applications timed for tassel emergence, green silk and brown silk (2011- IR-4)

• Timing Studies : evaluated timings identified in Bill Cissel's Master's Thesis (2012-2015)

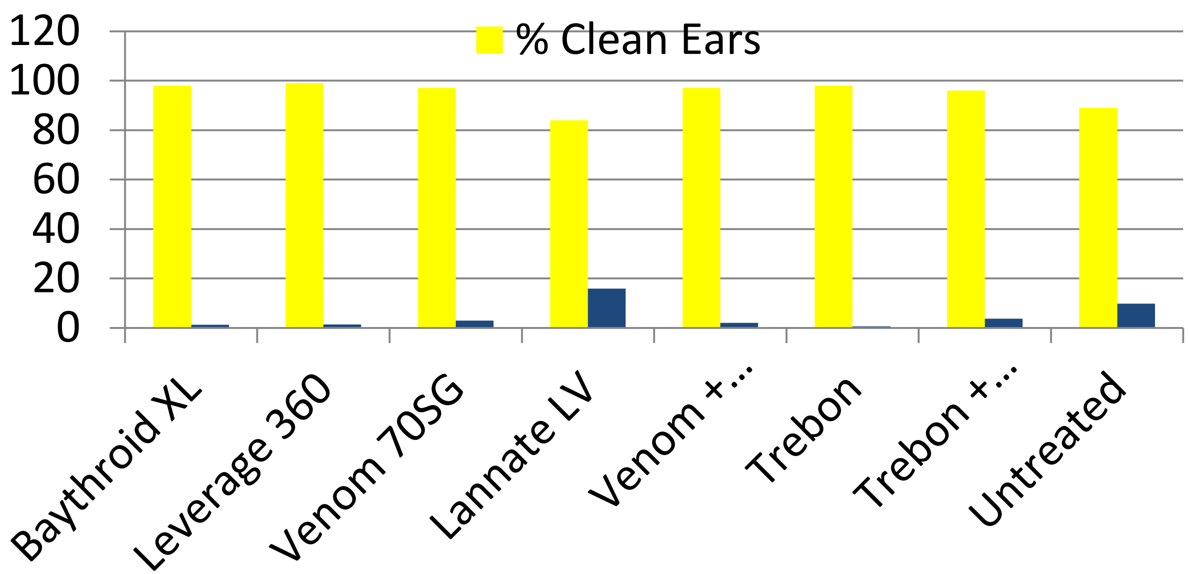
(a) 3 sprays : Silk, Blister and Milk Stages

(b) 2 sprays : Blister and Milk Stages

(c) 1 spray : Milk Stage

(d) Standard 3-4 day spray schedule – 6 sprays

Photos: Rutgers and B. Cissel - UD



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Extension IPM Specialist

BMSB Management in Sweet Corn - 2014

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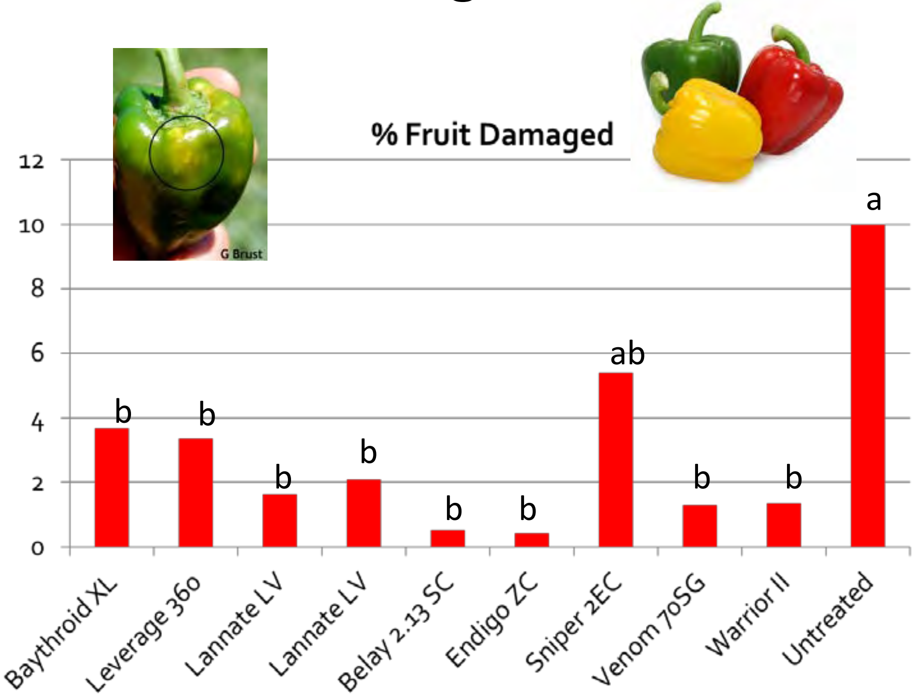
Extension IPM Specialist

- Multiple plantings – very low BMSB populations and in some plantings none found
- Mainly found Native Brown Stink Bugs – but also at low levels

Treatment	Application Timing	% Stink Bug Damaged Ears 2013	2014
Warrior II	Start at ear shank, 3-4 day schedule	0.00b	0.00b
Warrior II	Silk, blister and milk	0.00b	0.00b
Warrior II	Blister and Milk	0.00b	0.25ab
Warrior II	Milk	2.28ab	0.75ab
Hero EC	Start at ear shank, 3-4 day schedule	0.00b	0.00b
Hero EC	Silk, blister and milk	0.00b	0.00b
Hero EC	Blister and Milk	0.00b	0.00b
Hero EC	Milk	1.33ab	1.00ab
Untreated	-----	4.17a	2.75ab

BMSB Control in Peppers – DE
Aug 22, 2011 (5 DAT # 5) – part of the NE IPM Grant



Joanne Whalen U of Del
Extension IPM Specialist

Stink Bug Damage to Lima Beans

- Insecticide Trials in 2012 and 2013 – no BMSB in plots only native greens

PEAS

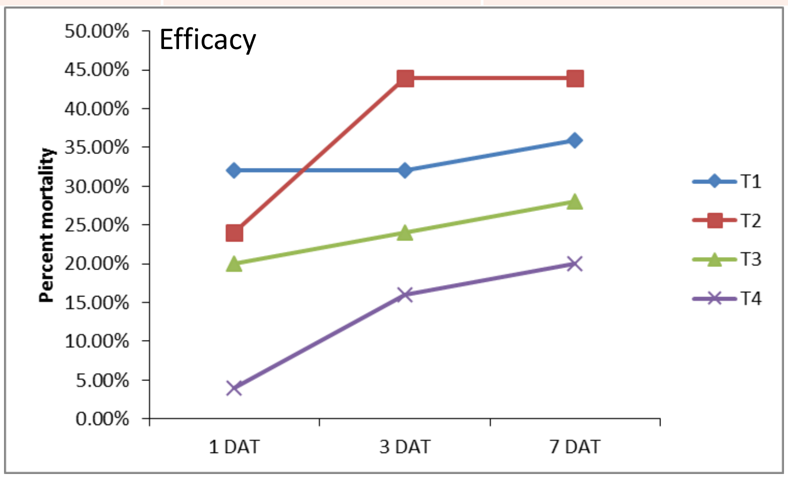
- Peas were planted 21 June 2015
- Variety 'Avalanche'
- Normal production followed
- Insecticides were applied 27 July
- Treatments were arranged in a RCBD. 20 feet long X 4 row wide
- After REI:
  - 3 sachets per plot containing 5 BMSB adults/sachet were released
- Data was collected 1, 3 and 7 Days After Treatment (DAT)
- Residual effect was also evaluated at 14, 21 and 28 DAT

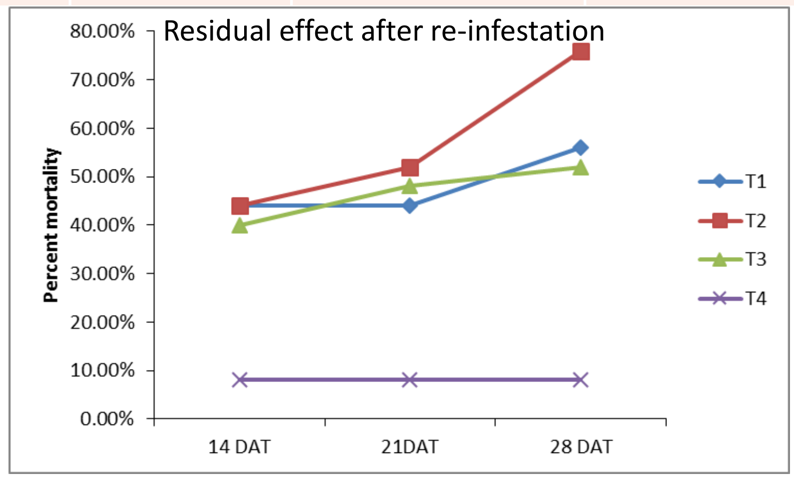
Peas at time of application, beginning pot formation, OSU-IAEP (Rondon)

Silvia I. Rondon
Oregon State University

TREATMENTS

Trt #	Product	a.i.	group	rate	acres
T1	Beleaf	flonicamid	9C	2.8 oz/a	0.014
T2	Transform	sulfoxaflor	4C	2.3 oz/a	0.014
T3	Asana XL	esfenvalerate	3	9.6 oz/a	0.014
UTC*=T4	Control		-	-	0.014





Peas

Under eastern OR conditions: T2 (Transform) provided better potency against BMSB compared to other treatments at 3 and 7 DAT. Control was partial (only up to 45% mortality).

Transform showed a good residual effect (up to 70% at 28 DAT), although abiotic factors may have contributed also with this effect (Temperatures above 100oF).

Silvia I. Rondon
Oregon State University

Corn Trials

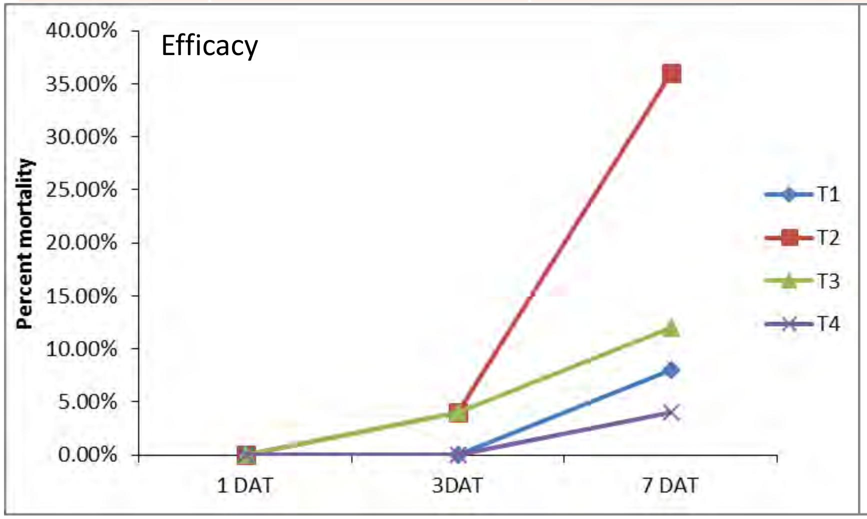
- Corn was planted 23 June 2015
- Normal production followed
- Insecticides were applied 3 August
- Treatments were arranged in a RCBD. 30 feet long X 4 row wide
- After REI:
  - 3 sachets per plot containing 5 BMSB adults/sachet were released
- Data was collected 1, 3 and 7 Days After Treatment (DAT)
- Residual effect was also evaluated at 14 DAT

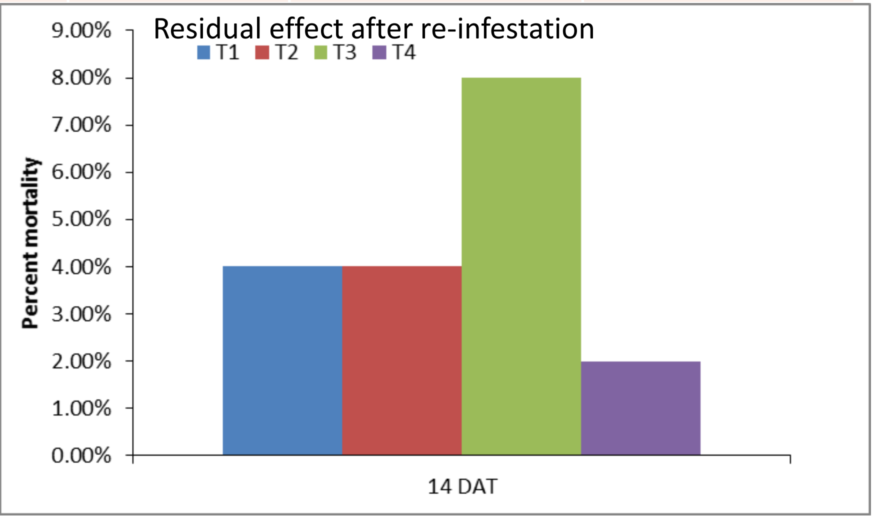
Corn at time of application, beginning pot formation, OSU-IAEP (Rondon)

Silvia I. Rondon
Oregon State University

TREATMENTS

Trt #	Product	a.i.	group	rate	acres
T1	Beleaf	flonicamid	9C	2.8 oz/a	0.014
T2	Transform	sulfoxaflor	4C	2.3 oz/a	0.014
T3	Asana XL	esfenvalerate	3	9.6 oz/a	0.014
UTC*=T4	Control		-	-	0.014





Corn

In general all chemicals were unable to control BMSB. Best results with Transform 3 and 7 DAT. The Asana treatment had better residual effect than the other treatments (8%); all performed poor (only up to 8% control).

Silvia I. Rondon
Oregon State University

2014 BMSB Insecticide resistance testing: Methods

Product	Rate	Max field rate
Assail 30SG	61.6 mg/100 ml	8 oz/A
Bifenture EC	0.103 ml/100 ml	12.8 fl oz/A
Endigo	0.034 ml/100 ml	5 fl oz/A
Lannate SP	123.1 mg/100 ml	16 oz/A
Warrior II	0.018 ml/100 ml	2.5 fl oz/A

Tested rates included 25%, 50% and 100% of full field rate

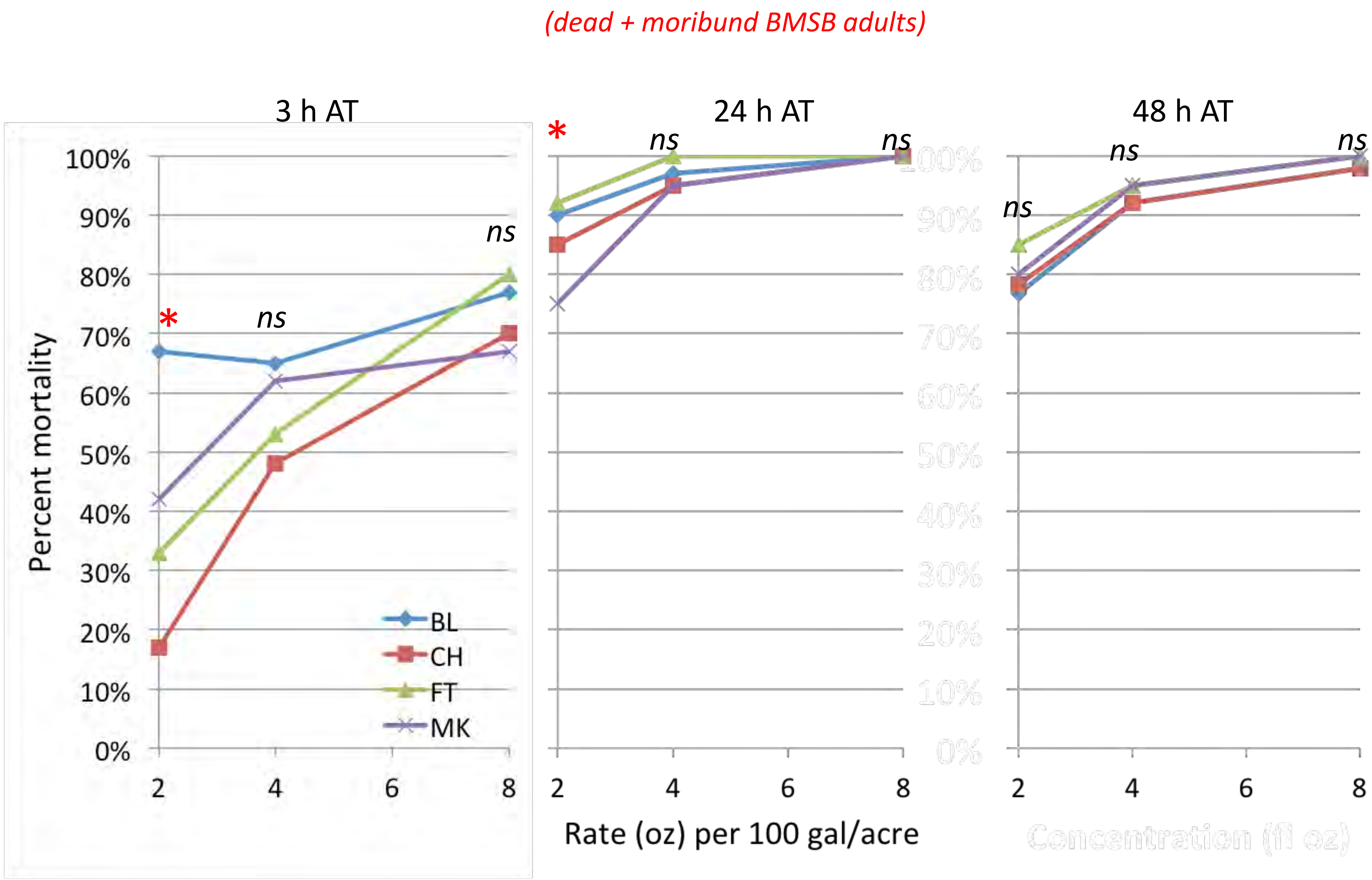
- Tested individuals — 30 males/females
- Response categories — Alive, dead & moribund
- Observation times — 3, 24 & 48 HAT

Four tested BMSB populations:
CH – commercial orchard; **TF** – commercial orchard;
MK – woods/commercial orchard; **BL** – residential setting

Greg Krawczyk, PSU

2014 BMSB insecticide resistance testing:

acetamiprid (Assail 35SG)



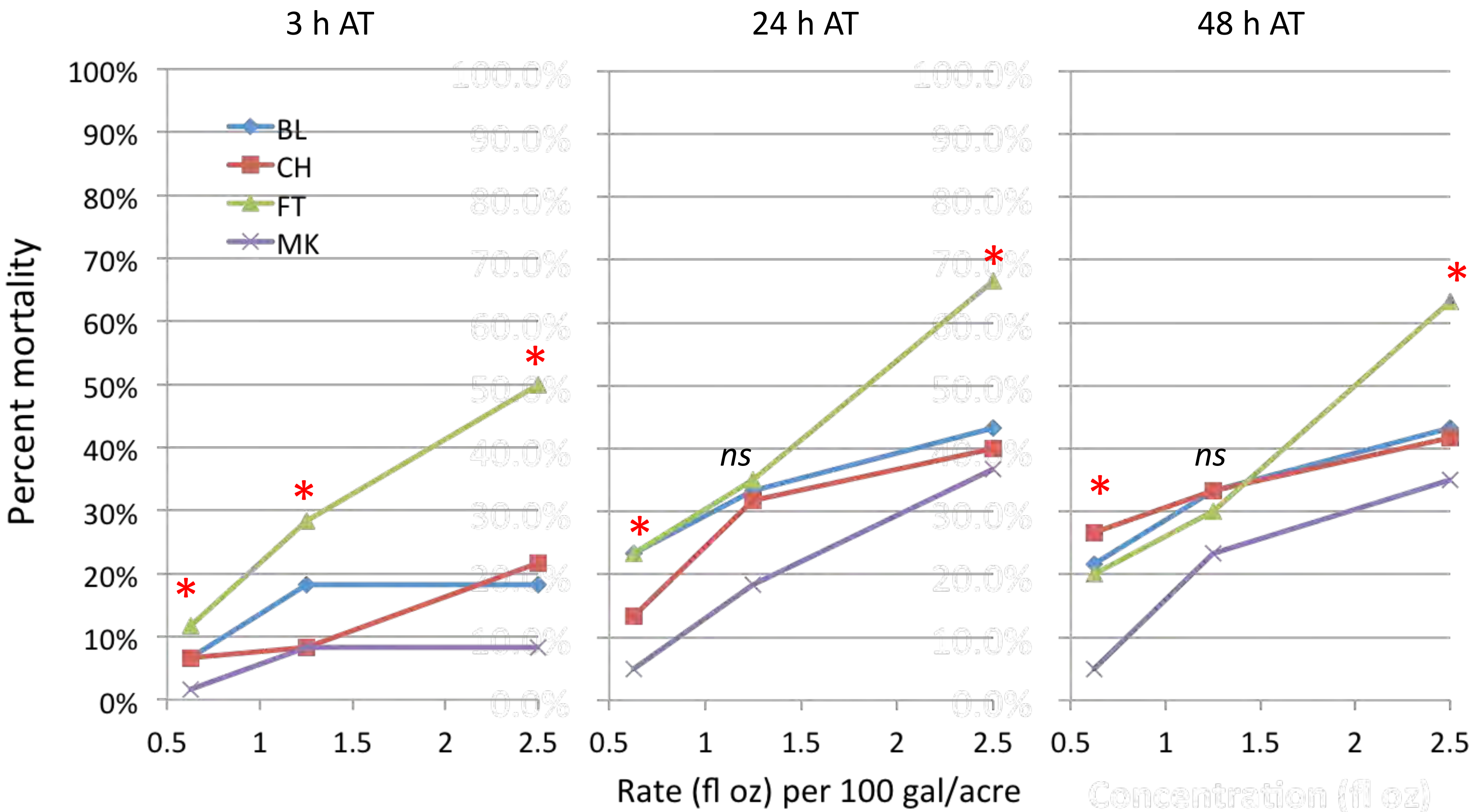
**- significant at P ≤ 0.05 (ANOVA, Fisher's Protected LSD, arcsin transformation)*

Greg Krawczyk, PSU

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)*

Greg Krawczyk, PSU

Most effective insecticides against BMSB

(based on combined data from T. Leskey, T. Kuchar and G. Krawczyk)

PYRETHROIDS

IRAC Group 3A

- bifenthrin **(Brigade)**
- fenpropathrin **(Danitol)**
- cyfluthrin **(Baythroid)**
- λ-cyhalothrin (**Warrior**)

NEONICOTINOIDS

IRAC Group 4A

- dinotefuran **(Venom, Scorpion)**
- thiametoxam **(Actara)**
- clothianidin **(Belay)**
- imidacloprid **(Provado, Admire Pro)**
- acetamiprid **(Assail)**

OTHER

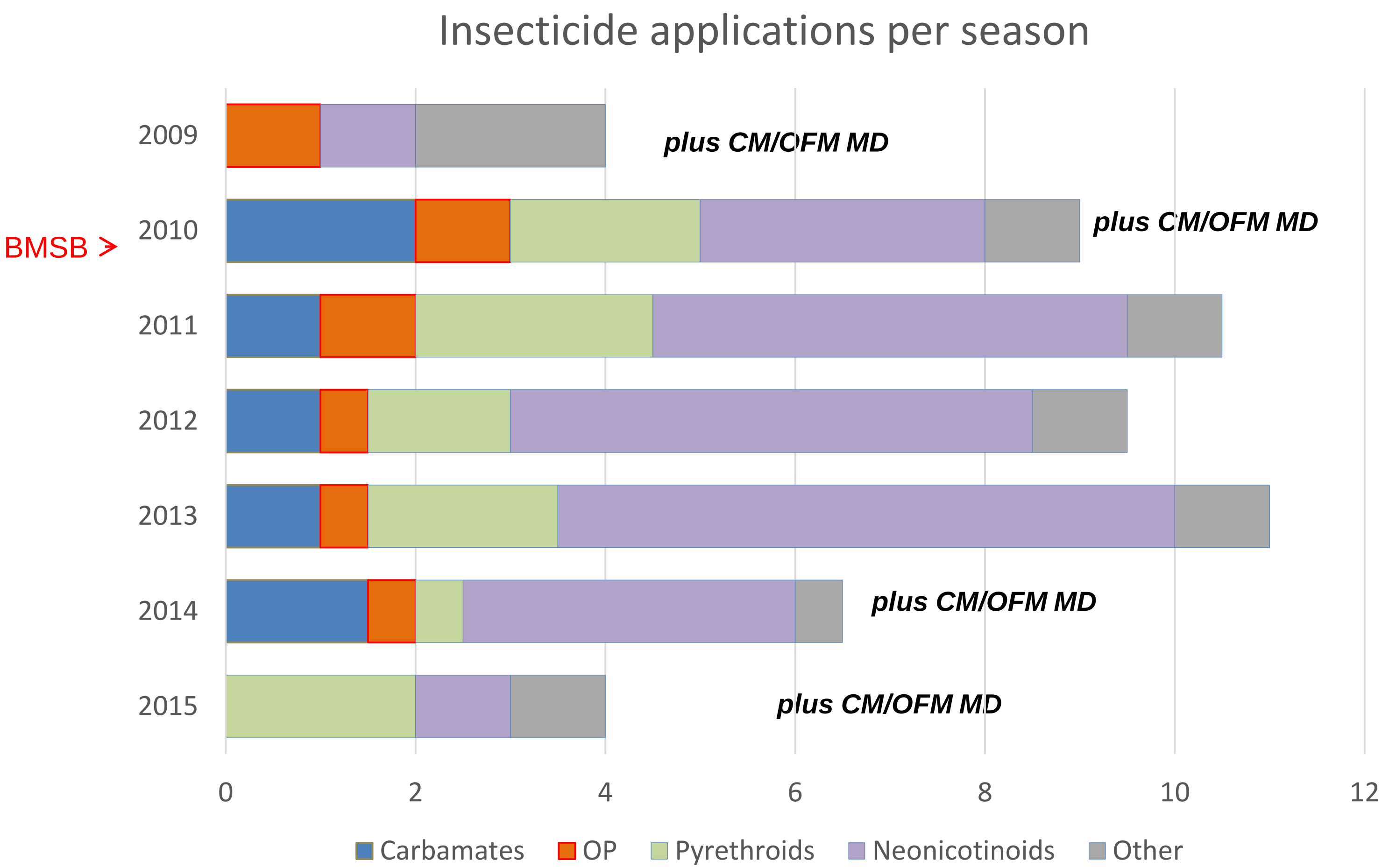
(IRAC Groups 1A, 1B, 2A

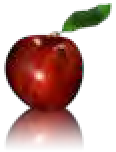
- methomyl (carbamate) **(Lannate LV and SP)**

Changes in seasonal insecticide applications - apples

2009-2015 seasons

(Commercial orchard, PA)





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.

G. Krawczyk, 2015