Synergy of aggregation pheromone with MDT in trapping of brown marmorated stink bug

Donald C. Weber, Ashot Khrimian

USDA ARS Invasive Insect Biocontrol & Behavior Laboratory, Beltsville, Maryland

Tracy C. Leskey

USDA ARS Applachian Fruit Research Station, Kearneysville, West Virginia

Guillermo Cabrera Walsh

Fundación para el Estudio de Especies Invasivas, Buenos Aires, Argentina

Plautia stali Brown-winged green stink bug

ggregation pheromone is methyl (*E,E,Z*)-2,4,6-decatrienoate (MDT); produced by male and attractive to both males and females

IDT attracts other insects which do not

produce it! Halyomorpha halys

Glaucias subpunctatus

Chinavia hilare

+ several tachinid species

DT attracts other pentatomids which do not produce it. This cross-attraction is not uncommon and includes other stink bug species; why?

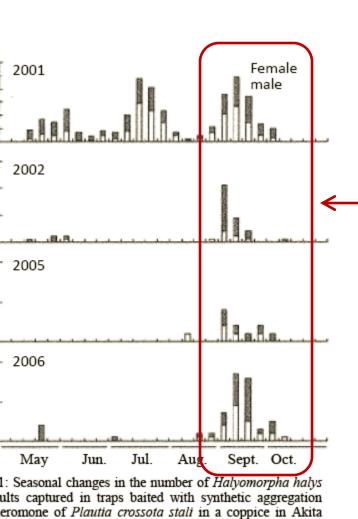


food signal for polyphagous species overwintering site signal promotes aggregation which passively protects them from natural enemies

Asian native responsive to MDT

... but in most years, almost exclusively late in the season





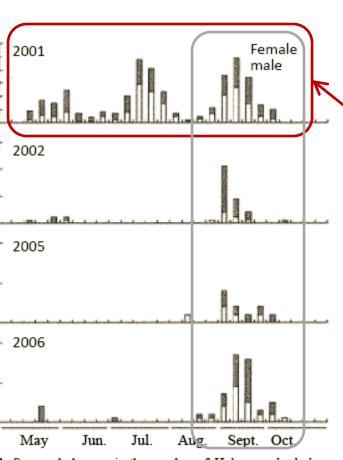
efecture in 2001, 2002, 2005 and 2006. Bars: total number

adults captured in 6 traps.

Asian native responsive to MDT

... or, during outbreak years (axis is 60 vs. 10 to 30 in subsequent years)



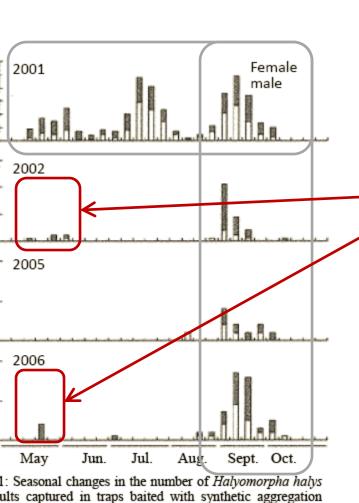


 Seasonal changes in the number of Halyomorpha halys ults captured in traps baited with synthetic aggregation eromone of Plautia crossota stali in a coppice in Akita efecture in 2001, 2002, 2005 and 2006. Bars: total number adults captured in 6 traps.

Asian native responsive to MDT

... and occasionally in the early season





eromone of *Plautia crossota stali* in a coppice in Akita efecture in 2001, 2002, 2005 and 2006. Bars: total number

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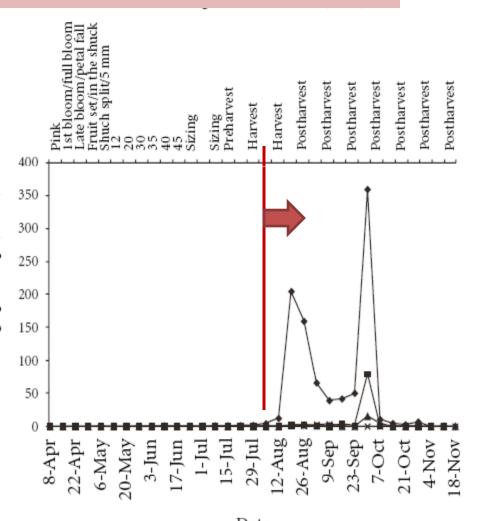
tures using black pyramid s baited with MDT (50mg) A & MD apple orchards, 2011

Halyomorpha halys Brown marmorated stink bug



but usually only after harvest of apple crop, in late season





scovery & availability of BMSB pheromone in quantities useful for field bioassays by early 2012

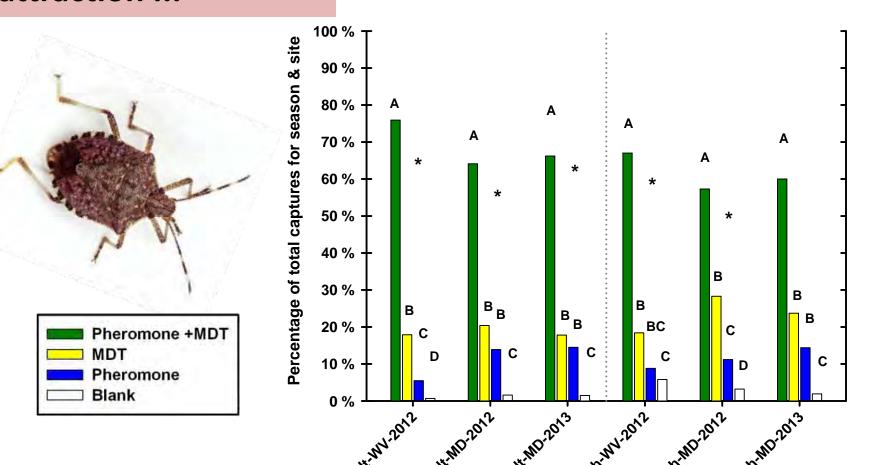
10,11-epoxy-1-bisabolen-3-ol total 16 stereoisomers

- ith... knowledge of seasonally-limited attraction of MDT d... discovery & availability of BMSB pheromone an isomer mixture which we knew had comparable attractiveness to pure isomers ...
- e set up a simple factorial experiment:
- BMSB pheromone (mixed isomers with ~2mg of SSRS)
- **MDT (66mg)**
- **Both**
- Neither

black pyramid traps, MD 2012-13 and WV 2012, RCB layout, season-long)

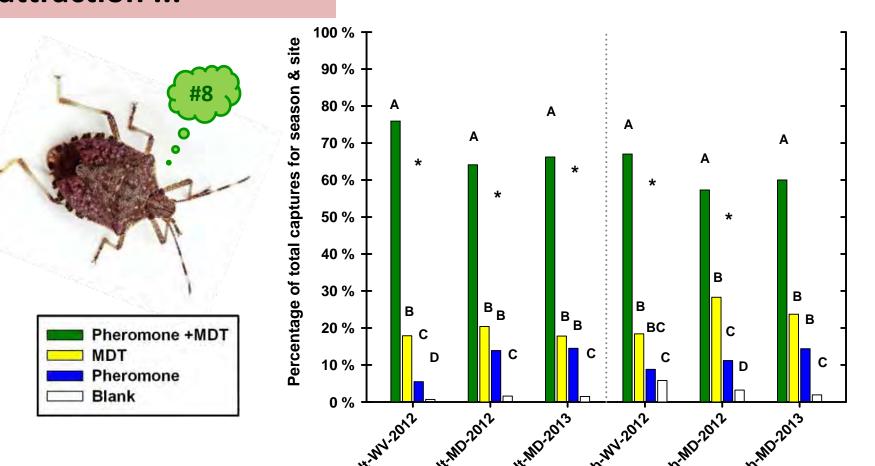
e of pheromone together with MDT produces synergistic attraction ...

Halyomorpha halys Brown marmorated stink bug



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Halyomorpha halys Brown marmorated stink bug



mprovement in captures (season-long totals) and Synergism (greater-than-additive) effect from use of combined pheromone plus MDT lures

	<u>Arden '</u>	WV 2012		<u>Beltsvi</u>	lle MD 20	012	Beltsville MD 2013					
<u>ıre</u>	adult s	eason tot	<u>al</u>	<u>adult s</u>	eason to	tal	adult season total					
ombined	4231	<u>ratio</u>	95% c.i.	3783	<u>ratio</u>	95% c.i.	1821	<u>ratio</u>	95% c.i.			
ИDT	999	4.24	(3.95, 4.54)	1203	3.14	(2.95, 3.36)	510	3.57	(3.24, 3.95)			
heromone	304	13.93	(12.39, 15.69)	822	4.60	(4.27, 4.97)	383	4.75	(4.26, 5.32)			
ynergism		3.25	(3.05, 3.46)		1.87	(1.77, 1.97)		2.04	(1.88, 2.21)			

compared to MDT alone

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compared to pheromone alone

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And Synergism (greater-than-additive) effect
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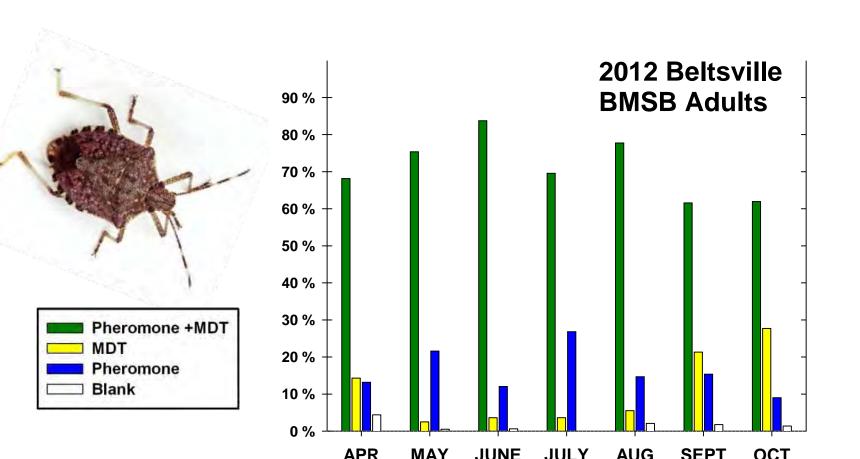
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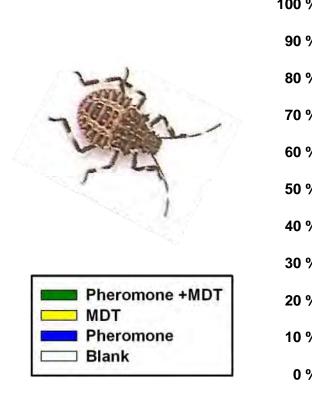
mbined lure is superior over the entire season for adults

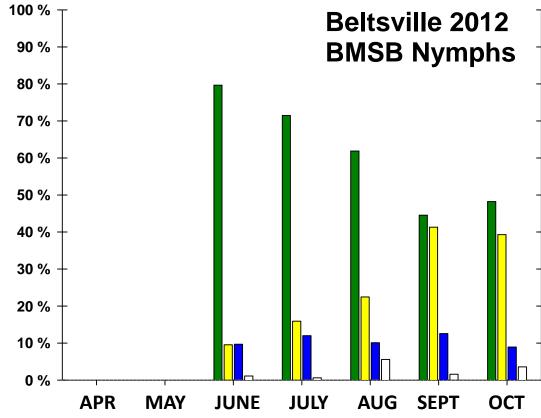
Halyomorpha halys Brown marmorated stink bug



and also provides superior season-long attraction in nymphs

Halyomorpha halys Brown marmorated stink bug





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					Pheroi						Comb					
, Marylan	<u>ıd</u>	<u>Unbaited</u>	control		(BMS	SB2)		MDT (N	<u> MDT2)</u>		MDT2+E	BMSB2				
DATES	capture for 4	<u>adults ca</u>	ptured		adults ca	aptured		adults ca	aptured	adults captured						
	traps / trtmt	<u>(% of t</u>	otal)		<u>(% of t</u>	total)		<u>(% of total)</u>			<u>(% of total)</u>					
ril	13-day total	0	0.0%		2	14.3%		0	0.0%		12	85.7%				
10 May	15-day total	0	0.0%	b	3	33.3%	b	0	0.0%	b	6	66.7%	а	*		
ay	13-day total	0	0.0%	С	12	17.9%	b	7	10.4%	С	48	71.6%	а			
June	15-day total	0	0.0%	d	27	21.4%	b	9	7.1%	С	90	71.4%	а	*		
е	14-day total	0	0.0%	b	26	45.6%	а	3	5.3%	b	28	49.1%	а			
- 5 July	14-day total	0	0.0%	С	18	12.5%	b	6	4.2%	bc	120	83.3%	а	*		
У	14-day total	0	0.0%	b	13	40.6%	b	0	0.0%	b	19	59.4%	а	*		
2 Aug	14-day total	2	0.9%	С	36	16.3%	b	6	2.7%	С	177	80.1%	а	*		
g	14-day total	2	4.0%	b	8	16.0%	b	1	2.0%	b	39	78.0%	а	*		
g	14-day total	3	0.9%	b	42	12.9%	b	37	11.4%	b	243	74.8%	а	*		
Sept	14-day total	6	0.9%	С	90	13.7%	b	153	23.3%	b	408	62.1%	а			
pt	13-day total	23	0.0%	С	73	10.4%	bc	206	29.2%	b	403	57.2%	а			
3 Oct	12-day total	4	1.2%	С	28	8.4%	b	79	23.6%	b	224	66.9%	а	*		
	16-day total	1	7.7%		5	38.5%		3	23.1%		4	30.8%				
24 Oct	TOTAL	41	1.5%	С	383	13.9%	b	510	18.5%	b	1821	66.1%	а	*		

. halys		======================================												
					Pheroi	mone					Comb	<u>ined</u>		
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ATES	traps / trtmt	<u>(% of t</u>	otal)		<u>(% of t</u>	total)		<u>(% of t</u>	total)		<u>(% of t</u>	otal)		
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4														

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traps / trtmt	(% of total)			(% of total) (% of total)				otal)		<u>(% of t</u>	otal)		
13-day total	0	0.0%		2	14.3%		0	0.0%		12	85.7%		
15-day total	0	0.0%	b	3	33.3%	b	0	0.0%	b	6	66.7%	а	*
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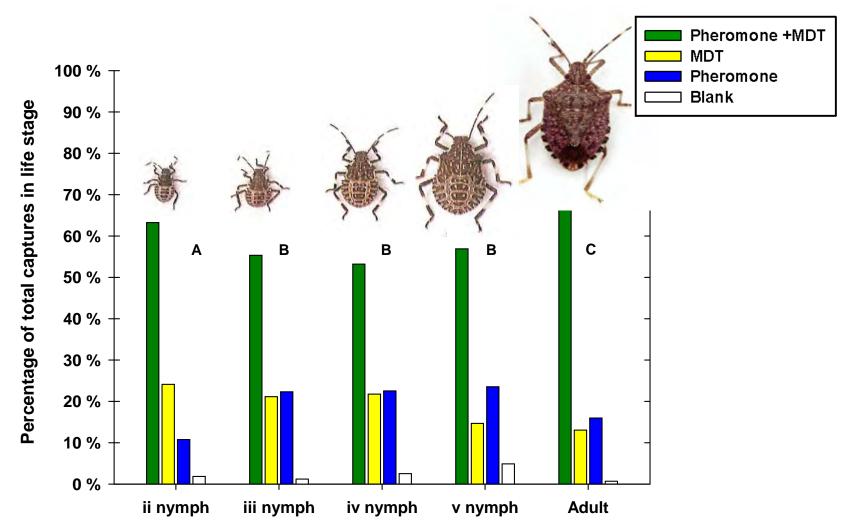
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<u>d</u>	<u>Unbaited</u>	control		(BMS	SB2)		MDT (N	<u>/IDT2)</u>		MDT2+	3MSB2		
capture for 4	adults ca	ptured		adults ca	ptured		adults captured			adults ca	ptured		
traps / trtmt	<u>(% of t</u>	otal)		<u>(% of t</u>	total)		<u>(% of t</u>	total)		<u>(% of t</u>			
13-day total	0	0.0%		2	14.3%		0	0.0%		12	85.7%		
15-day total	0	0.0%	b	3	33.3%	b	0	0.0%	b	6	66.7%	a	*
13-day total	0	0.0%	С	12	17.9%	b	7	10.4%	С	48	71.6%	а	
15-day total	0	0.0%	d	27	21.4%	b	9	7.1%	С	90	71.4%	a	*
14-day total	0	0.0%	b	26	45.6%	а	3	5.3%	b	28	49.1%	а	
14-day total	0	0.0%	С	18	12.5%	b	6	4.2%	bc	120	83.3%	a	*
14-day total	0	0.0%	b	13	40.6%	b	0	0.0%	b	19	59.4%	а	*
14-day total	2	0.9%	С	36	16.3%	b	6	2.7%	С	177	80.1%	а	*
14-day total	2	4.0%	b	8	16.0%	b	1	2.0%	b	39	78.0%	а	*
14-day total	3	0.9%	b	42	12.9%	b	37	11.4%	b	243	74.8%	a	*
14-day total	6	0.9%	С	90	13.7%	b	153	23.3%	b	408	62.1%	а	
13-day total	23	0.0%	С	73	10.4%	bc	206	29.2%	b	403	57.2%	а	
12-day total	4	1.2%	С	28	8.4%	b	79	23.6%	b	224	66.9%	a (*
16-day total	1	7.7%		5	38.5%		3	23.1%		4	30.8%		
ΤΟΤΔΙ	//1	1 5%	_	383	13 9%	h	510	18 5%	h	1821	66 1%	a	*
ISIAL	71	1.5/0		303	13.370	D	310	10.570	D	1021	00.170	a	
	capture for 4 traps / trtmt 13-day total 15-day total 15-day total 15-day total 14-day total	capture for 4 adults ca traps / trtmt (% of t 13-day total 0 15-day total 0 15-day total 0 15-day total 0 14-day total 0 14-day total 0 14-day total 0 14-day total 2 14-day total 2 14-day total 3 14-day total 6 13-day total 23 12-day total 4 16-day total 1	capture for 4 traps / trtmt adults captured (% of total) 13-day total 0 0.0% 15-day total 0 0.0% 13-day total 0 0.0% 15-day total 0 0.0% 14-day total 0 0.0% 14-day total 0 0.0% 14-day total 0 0.0% 14-day total 2 0.9% 14-day total 2 4.0% 14-day total 3 0.9% 14-day total 6 0.9% 13-day total 23 0.0% 12-day total 4 1.2% 16-day total 1 7.7%	capture for 4 traps / trtmt adults captured (% of total) 13-day total 0 0.0% 15-day total 0 0.0% 13-day total 0 0.0% 15-day total 0 0.0% 14-day total 2 0.9% 14-day total 2 4.0% 14-day total 3 0.9% 14-day total 6 0.9% 13-day total 23 0.0% 12-day total 4 1.2% 12-day total 7.7%	capture for 4 traps / trtmt adults captured (% of total) adults captured (% of total) adults captured (% of total) 13-day total 0 0.0% 2 15-day total 0 0.0% b 3 13-day total 0 0.0% c 12 15-day total 0 0.0% d 27 14-day total 0 0.0% b 26 14-day total 0 0.0% c 18 14-day total 0 0.0% b 13 14-day total 2 0.9% c 36 14-day total 2 4.0% b 8 14-day total 3 0.9% b 42 14-day total 6 0.9% c 90 13-day total 23 0.0% c 73 12-day total 4 1.2% c 28 16-day total 1 7.7% 5	capture for 4 traps / trtmt adults captured (% of total) adults captured (% of total) 13-day total 0 0.0% 2 14.3% 15-day total 0 0.0% 2 17.9% 15-day total 0 0.0% 12 17.9% 15-day total 0 0.0% 12 17.9% 15-day total 0 0.0% 2 2 14.3% 14-day total 0 0.0% 12 17.9% 15-day total 0 0.0% 2 27 21.4% 14-day total 0 0.0% 2 2 4.6% 14-day total 0 0.0% 2 36 45.6% 14-day total 2 0.9% 2 36 16.3% 14-day total 2 4.0% 8 16.0% 14-day total 3 0.9% 42 12.9% 14-day total 6 0.9% 90 13.7% 13-day total 23 0.0% 73 10.4% 12-day total 4 1.2% 2 28 8.4% 16-day total 1 7.7% 5 38.5%	Capture for 4 traps / trtmt 13-day total 15-day total 14-day total 14-day total 14-day total 2	Capture for 4 traps / trtmt (% of total) (% o	Capture for 4 traps / trtmt (% of total) (% o	Capture for 4 traps / trtmt 13-day total 0 0.0% 0	Capture for 4 traps / trtmt (% of total) (% o	Combined MDT2+BMSB2 MDT (MDT2) MDT2+BMSB2 MDT2-BMSB2 MDT2-BMS2 MDT2-BMSB2 MDT2-BMSB2 MDT2-BMS2 MDT2-BMS2 MDT2-BMS2 MDT2-BMS2 MDT2-BMS2 MDT2-BMS2 MDT2-BMS2 MDT2-BMS2 M	Pheromone Amount Pheromone Amount Amou

H. halys		======================================												
					Pheror						Comb			
Marylan	<u>d</u>	Unbaited	control		(BMS	SB2)		MDT (N	MDT2)		MDT2+E	BMSB2		
ATES	capture for 4	nymphs o	aptured		nymphs c	aptured		nymphs captured			nymphs captured			
	traps / trtmt	(% of t	total <u>)</u>		<u>(% of t</u>	total <u>)</u>		(% of t	total <u>)</u>		<u>(% of t</u>	otal)		
ril	13-day total	0			0			0			0			
10 May	15-day total	0			0			0			0			
y	13-day total	0			0			0			0			
lune	15-day total	0			0			0			0			
е	14-day total	1	33.3%		1	33.3%		1	33.3%		0	0.0%		
5 July	14-day total	5	0.3%	С	97	5.5%	bc	531	29.9%	b	1143	64.4%	а	
/	14-day total	1	0.4%	С	113	45.0%	ab	28	11.2%	bc	109	43.4%	а	
2 Aug	14-day total	21	3.0%	b	177	25.4%	ab	92	13.2%	ab	408	58.5%	а	
B	14-day total	39	8.6%	b	114	25.1%	а	135	29.7%	ab	166	36.6%	а	
g	14-day total	28	1.9%	С	156	10.3%	bc	296	19.6%	b	1030	68.2%	а	*
Sept	14-day total	4	1.1%	С	72	19.7%	b	111	30.4%	b	178	48.8%	а	
ot	13-day total	0	0.0%	b	3	14.4%	ab	12	28.6%	ab	27	64.3%	а	
Oct	12-day total	1	5.3%		10	52.6%		6	31.6%		2	10.5%		
	16-day total	0			0			0			0			
24 Oct	TOTAL	100	2.0%	С	743	14.5%	b	1212	23.7%	b	3063	59.8%	а	

H. halys		======	======	===:	=====	=======================================								
					Pheror	mone					Comb	<u>ined</u>		
Marylan	<u>d</u>	<u>Unbaited</u>	l control		(BMS	SB2)		MDT (N	/IDT2)		MDT2+E	BMSB2		
ATES	capture for 4	nymphs o		nymphs captured				nymphs captured			nymphs c			
	traps / trtmt	<u>(% of t</u>	total)		<u>(% of t</u>	total)		<u>(% of t</u>	otal)		<u>(% of t</u>	otal)		
ril	13-day total	0			0			0			0			
10 May	15-day total	0			0			0			0			
ıy	13-day total	0			0			0			0			
lune	15-day total	0			0			0			0			
е	14-day total	1	33.3%		1	33.3%		1	33.3%		0	0.0%		
5 July	14-day total	5	0.3%	С	97	5.5%	bc	531	29.9%	b	1143	64.4%	а	
/	14-day total	1	0.4%	С	113	45.0%	ab	28	11.2%	bc	109	43.4%	а	
2 Aug	14-day total	21	3.0%	b	177	25.4%	ab	92	13.2%	ab	408	58.5%	а	
g	14-day total	39	8.6%	b	114	25.1%	а	135	29.7%	ab	166	36.6%	а	
g	14-day total	28	1.9%	С	156	10.3%	bc	296	19.6%	b	1030	68.2%	а	*
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ot	13-day total	0	0.0%	b	3	14.4%	ab	12	28.6%	ab	27	64.3%	а	
Oct	12-day total	1	5.3%		10	52.6%		6	31.6%		2	10.5%		
	16-day total	0			0			0			0			
24 Oct	TOTAL	100	2.0%	С	743	14.5%	b	1212	23.7%	b	3063	59.8%	a	
I														

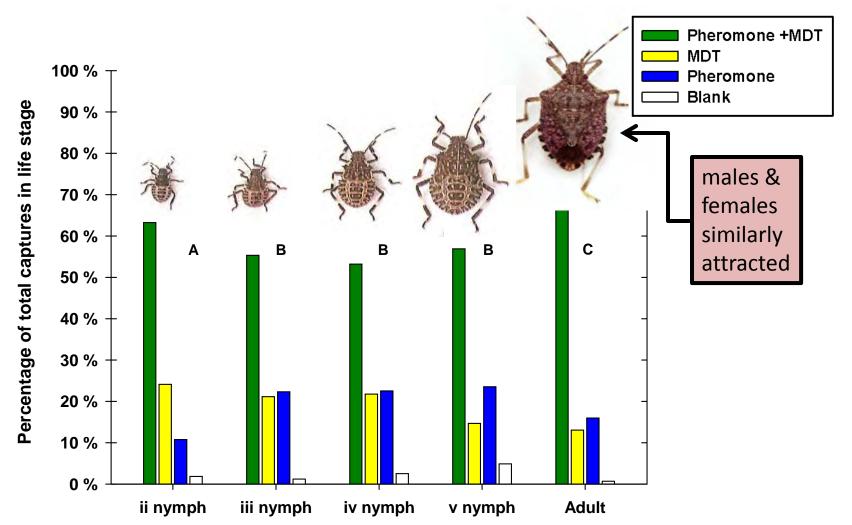
Amongst nymphal stages and adults, season-long differences are small

dataset: Beltsville 2013

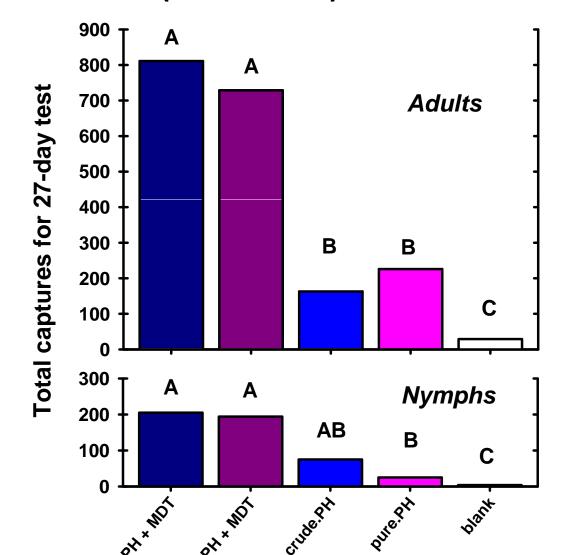


Amongst nymphal stages and adults, season-long differences are small

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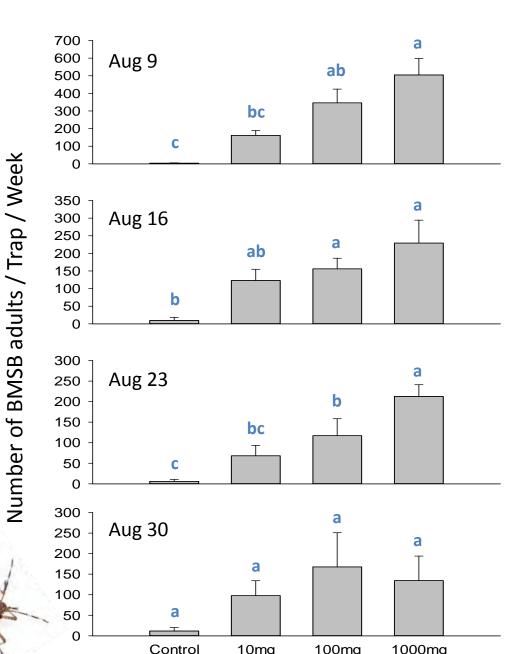
mparison of captures for crude (#20) pheromone mixture sus pure isomers (SSRS + RSRS) with and without 66mg MDT



ps with mixed-isomer eromone lures of 0, 10, 20, and 1000mg (!), with 66mg MDT

st 2013, soybean, West Virginia







tion on near-natural stone monument

attraction to outdoor lighting at a brick bank building

Halyomorpha halys Brown marmorated stink bug

distinct overwintering sites & behavior





*urgantia histrionica*Arlequin bug Brown marmorated stink bug

gregation pheromone for HQ bug "murgantiol" (Zahn et al. 2008)

tractive also to BMSB, as shown in preceding talk

ch species has pheromone with two stereoisomers;

both have as most abundant, (35,65,7R,105)-10,11-

epoxy-1-bisabolen-3-ol

t ... there are some KEY distinctions ...

urgantia histrionica arlequin bug

Halyomorpha halys
Brown marmorated stink bug



Key distinctions:



2nd isomer is SSRR ≠ 2nd isomer is RSRS

plant specialist ≠ extreme generalist

orth American native ≠ Asian native

ot responsive to MDT ≠ responsive to MDT

distinct overwintering ≠ distinct overwintering sites & behavior sites & behavior

urgantia histrionica arlequin bug



Halyomorpha halys Brown marmorated stink bug



Key distinctions:

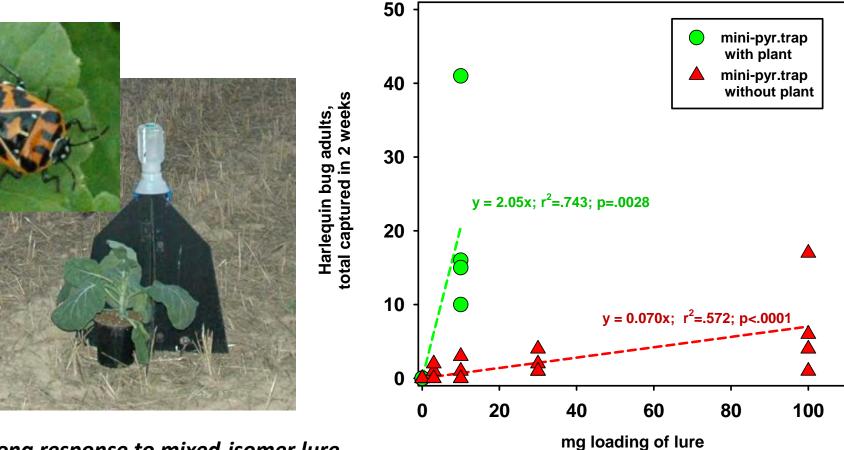


2nd isomer is SSRR ≠ 2nd isomer is RSRS

Murgantia histrionica: Harlequin bug

plant specialist (Brassicaceae & Capparaceae)

(Wallingford et al. 2012)



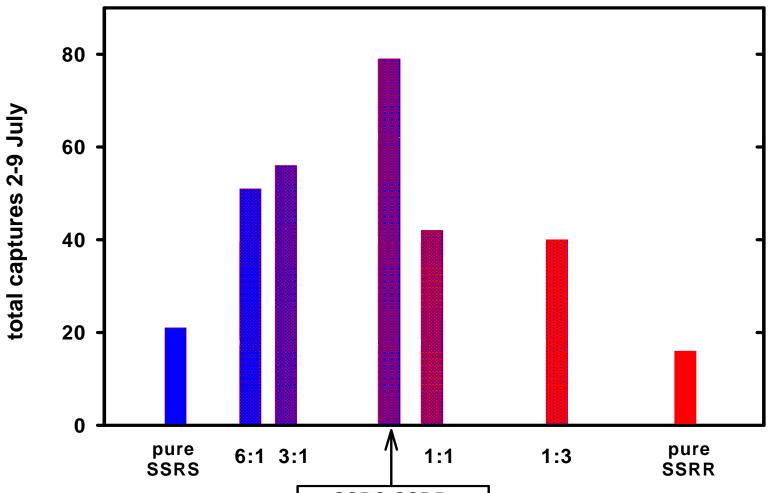
ong response to mixed-isomer lure pecially in combination with host plant

(0, 3, 10, 30, or 100mg without plant)



*Murgantia histrionica*Harlequin bug

Captures at trap collard plants with 4mg blends with varied isomer ratio 7-way field choice test 2-9 July 2013



hallenges to understanding and application of pentatomid semiochemicals – big picture

Knowledge of biology << knowledge of chemistry

Pheromone may have multiple functions depending on...

Other senses involved: visual and especially short-range substrateborne vibrational

Species are polyphagous and highly mobile; need to consider wild hosts and entire [agro]ecosystems

Additional attractants: other species' semiochemicals and also various phytochemicals

Natural enemies respond to pheromones

Making pest suppression work: general challenges with managing trap-cropping or mass trapping

Next steps with BMSB pheromone research

Individual isomers: determine optimal ratios (how much increased dose compensates for off-ratios)

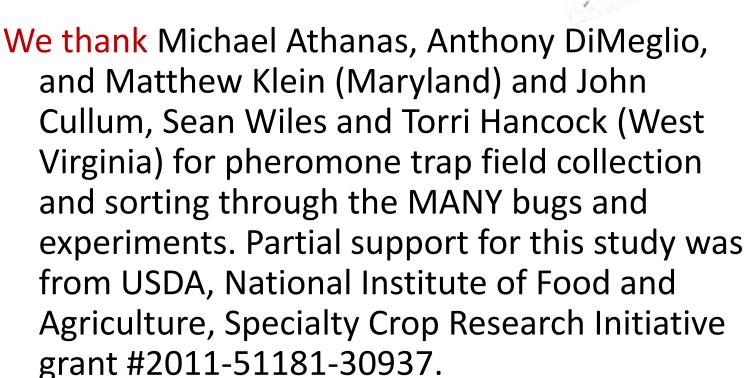
Combined lures: determine optimal doses and ratio of MDT to pheromone

Trap design, including toxin-free models

Making pest suppression work: implement trapcropping and/or mass trapping, while protecting natural enemies and other non-targets

Thank you!







We thank Michael Athanas, Anthony DiMeglio, and Matthew Klein (Maryland) and John Cullum, Sean Wiles and Torri Hancock (West Virginia) for pheromone trap field collection and sorting through the MANY bugs and experiments. Partial support for this study was from USDA, National Institute of Food and Agriculture, Specialty Crop Research Initiative grant #2011-51181-30937.





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