University of California
Agriculture and Natural Resources

Microbial Control of Endemic and Invasive Pests in California

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Integrated pest management

Host Plant Resistance	• Resistant/tolerant varieties • Other varietal traits
Cultural Control	• Adjusting planting dates • Modification of irrigation or nutrient management • Use of trap crops, crop rotation, etc.
Biological Control	• Conserving natural enemies • Releasing predators or parasitoids
Behavioral Control	• Baits or traps • Mating disruption
Physical/ Mechanical Control	• Netting and other exclusion options • Vacuuming
Microbial Control	• Entomopathogenic microorganisms • Microbial metabolites
Chemical Control	• Natural compounds from plants or other sources • Synthetic chemical compounds

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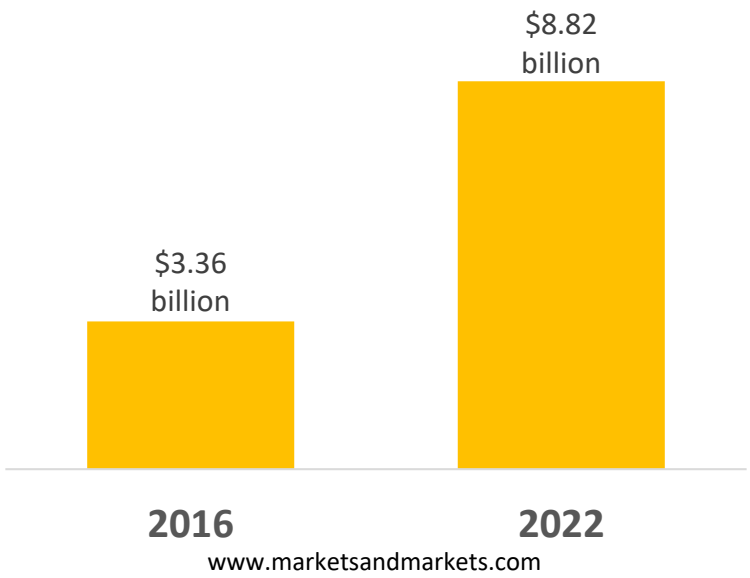
Increase in biopesticide market



Increase in IPM implementation?

Increase in organic acreage?

Goal

- Increase the use of microbial control in both organic and conventional agriculture to promote sustainable agriculture

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Reasons of limited entompathogen use

- Use is primarily in organic agriculture
- Only certain materials dominate in organic systems
- Not perceived to be as effective as chemical pesticides
- Higher expectations and critical perspective
- Higher cost and shorter shelf life
- Serpens oleum et seprens oleum institoribus
- Limited expertise to explore and explain their potential
- Limited scientific pool and efficacy data from universities
- Limited funding to support biopesticide research

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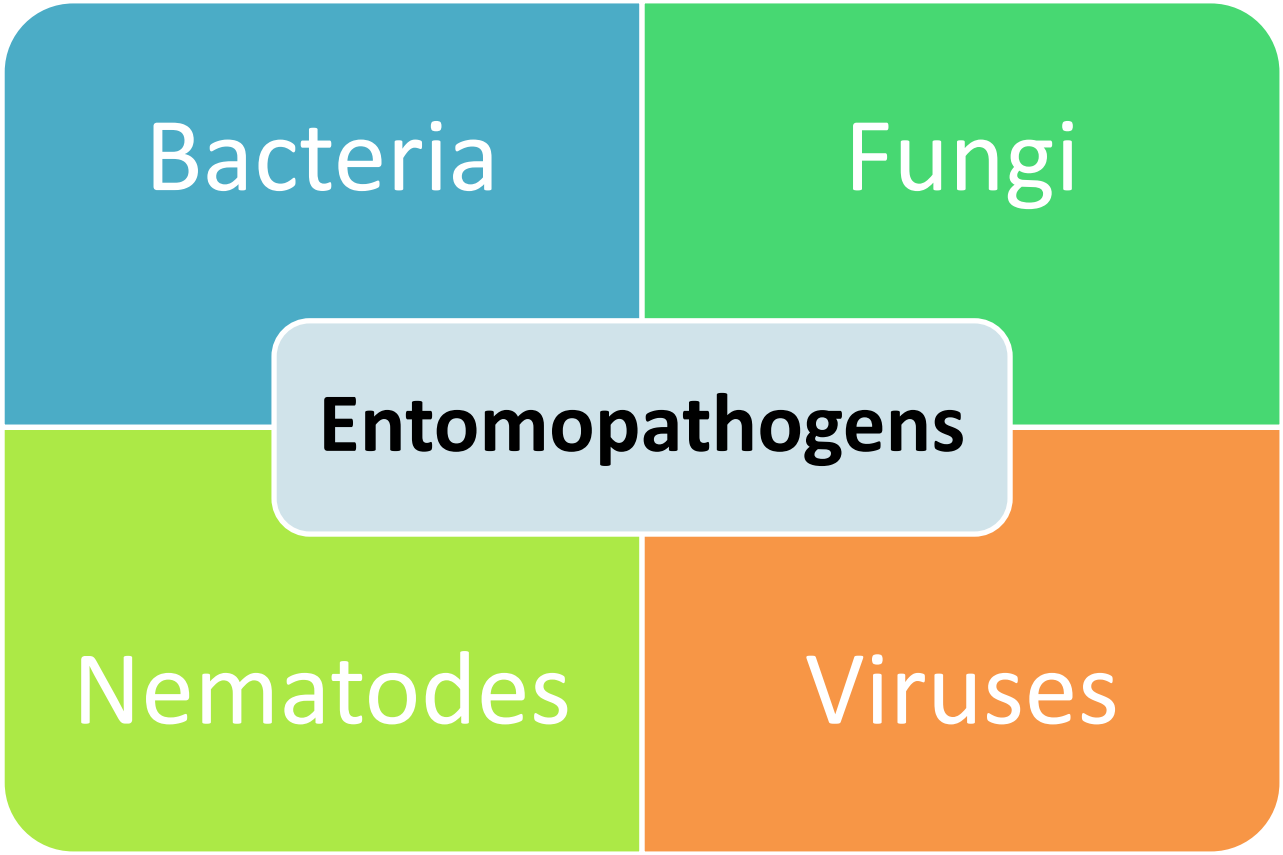
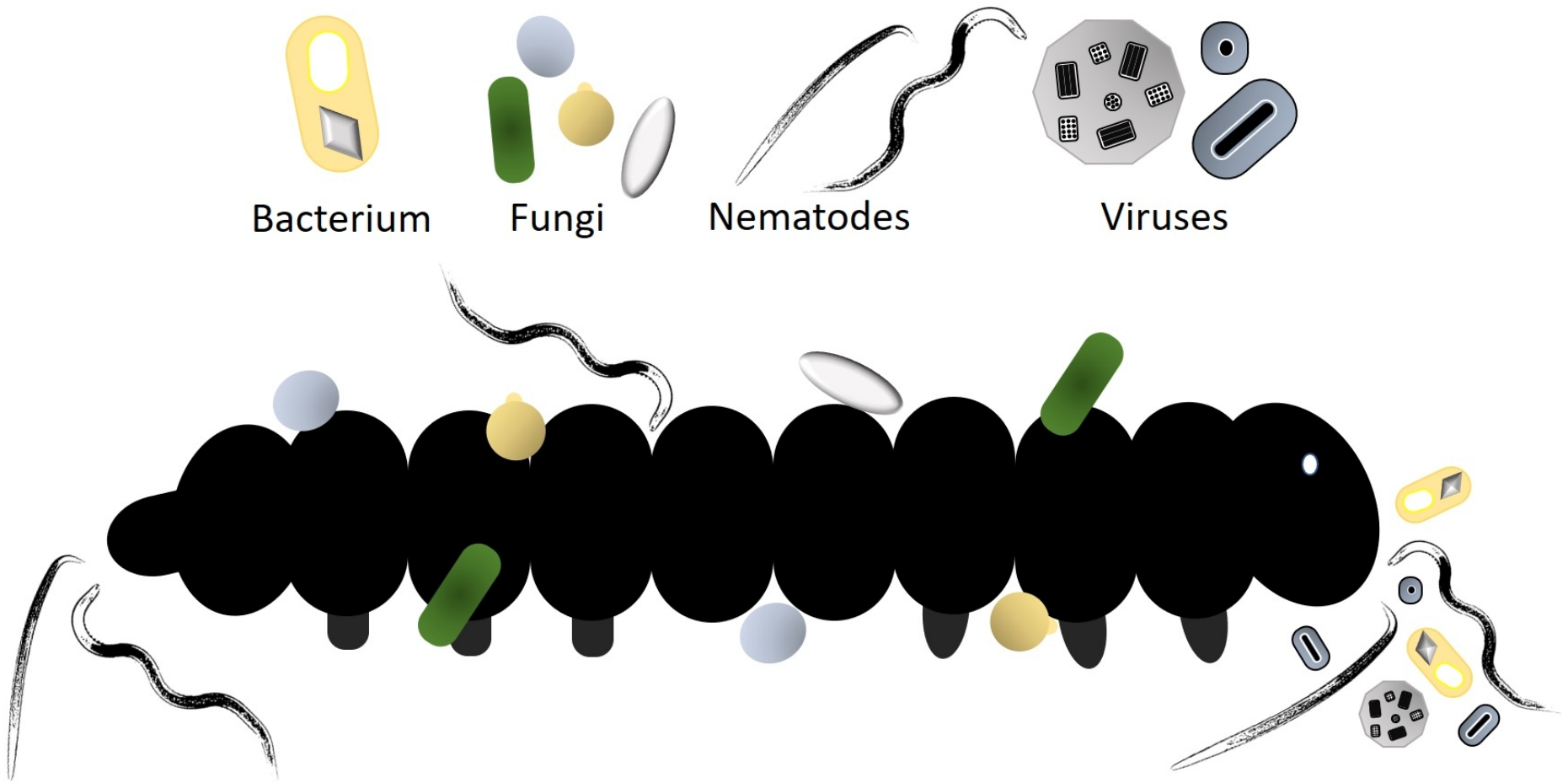
Microbial control with entomopathogens



Entomopathogen infection routes



Graphic: Surendra Dara

Infection routes of entomopathogens

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Entomopathogens and IPM

- Entomopathogens are an excellent choice for IPM programs in both conventional and organic systems
- Many are compatible with other control options
- Entomopathogen+botanical or entomopathogen+chemical combinations or entomopathogens rotated with chemicals can be effective strategies
- Entomopathogenic fungi are compatible with some fungicides
- Understand the organism, their mode of infection, target pests and their habitats and use them effectively
  - Fungi against chewing and sucking and foliar and soil pests
  - Bacteria and viruses against chewing pests
  - Nematodes against soil pests
- Entomopathogenic fungi also promote the plant growth and antagonize plant pathogens

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Examples of California field studies

- Western flower thrips on lettuce
- Green peach aphid and cabbage aphid on broccoli
- Bagrada bug on various crops
- Rice root aphid and honey suckle aphid on celery
- Twospotted spider mite and western tarnished plant bug on strawberry

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Western flower thrips on lettuce

Adult morphs

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Western flower thrips on lettuce

Treatments

1. Untreated control
2. Assail 30 SC (acetamiprid) 4 oz
   + DyneAmic (NIS) 0.1% v/v
3. Radiant SC (spinetoram) 8 fl oz
   + Dyne Amic 0.25%
4. BotaniGard 22 WP (*Beauveria bassiana*) 2 lb + DyneAmic 0.125%
5. Torac 15 EC (tolfenpyrad) 21 fl oz + DyneAmic 0.25%
6. Torac 15EC 21 fl oz + Lannate SP 0.75 lb + DyneAmic 0.25%
7. NNI-1171 21 fl oz (new ai) + DyneAmic 0.25%

Spraying 50* gal/acre at 70 psi with flat fan nozzle
(*100 gpa for BotaniGard)

Plot size 5 rows, 5.33’ wide 10’ long bed replicated 4 times

Planted on April 6, 2012

Treated on May 16 and 24 and June 6, 2012

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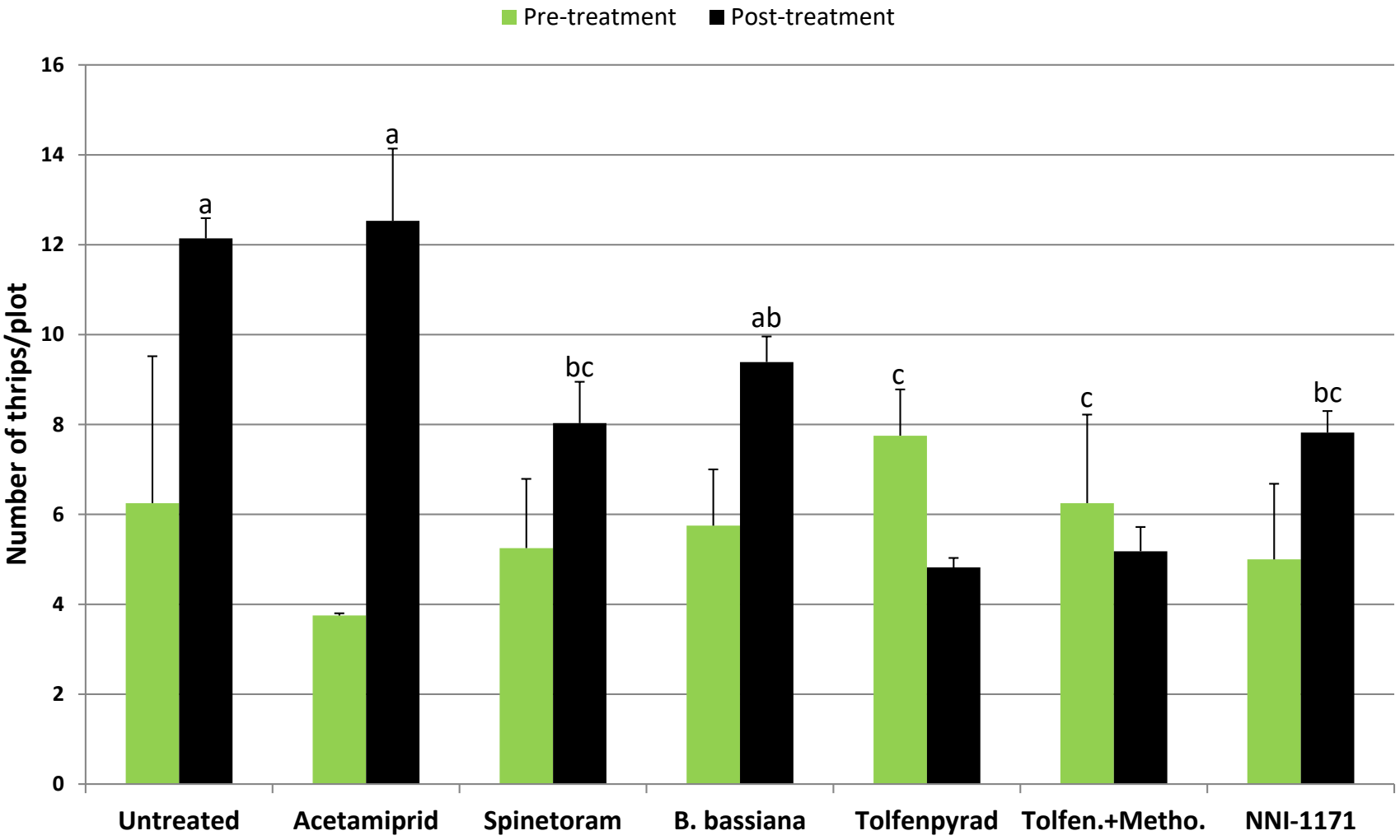
Thrips before and after the spray applications



Tukey's HSD $P = 0.02$

Green peach and cabbage aphids on broccoli

Cabbage aphid, *Brevicoryne brassicae*

Green peach aphid, *Myzus persicae*

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Green peach and cabbage aphids on broccoli

Treatments

1. Untreated control
2. Assail 30 SC (acetamiprid) 4 oz
   + DyneAmic (NIS) 0.1% v/v
3. BotaniGard 22 WP (*Beauveria bassiana*) 2 lb
   + DyneAmic 0.125%
4. Torac 15 EC (tolfenpyrad) 21 fl oz
   + DyneAmic 0.25%
5. Pyrifluquinazon 3.2 fl oz + DyneAmic 0.25%
6. NNI-1171 21 fl oz (new ai) + DyneAmic 0.25%
7. Sequoia (sulfoxaflor) 1.5 fl oz + DyneAmic 0.25%
8. Sequoia 2.0 fl oz + DyneAmic 0.25%

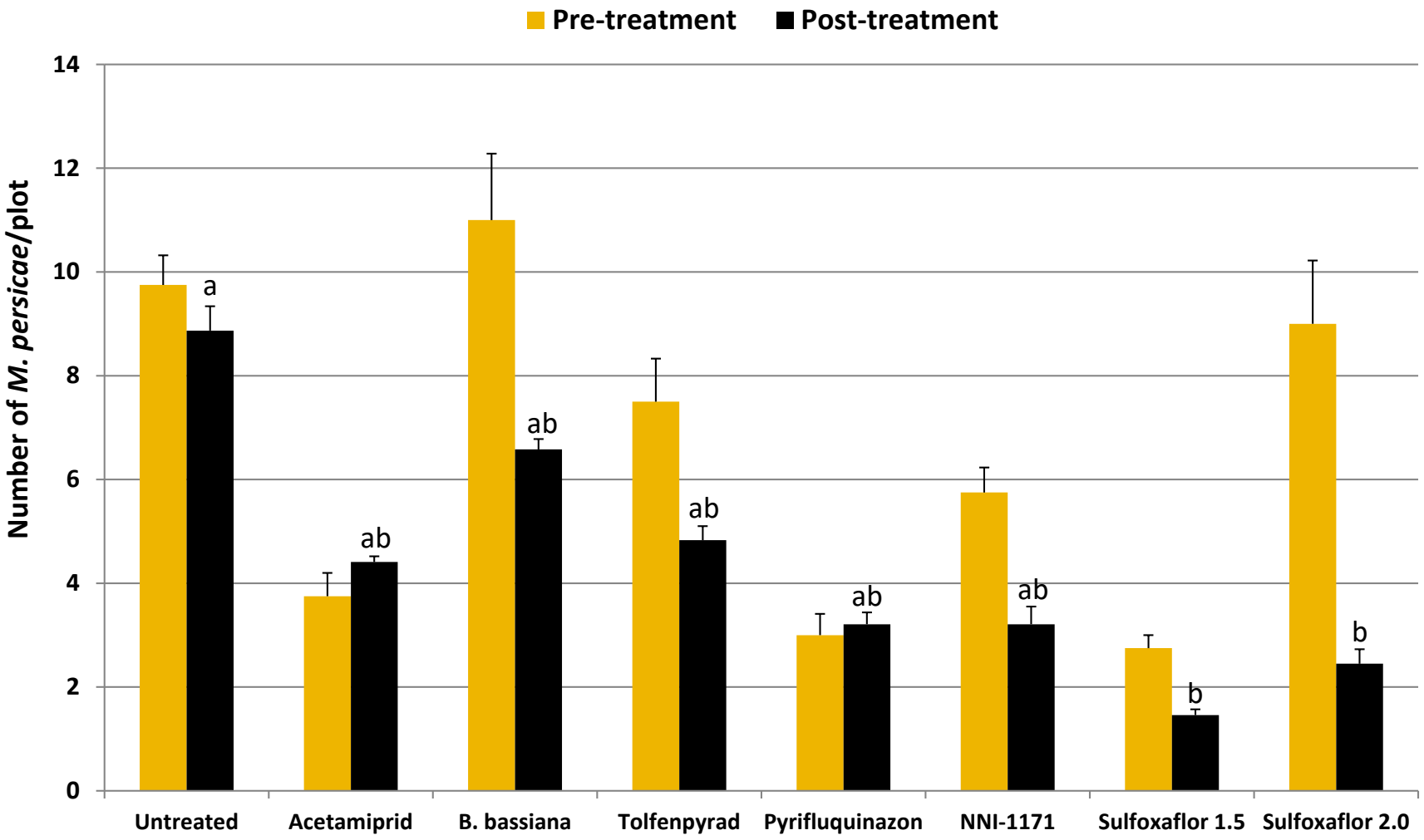
Spraying 50* gal/acre at 70 psi with flat fan nozzle (*100 gpa for BotaniGard)

Plot size 5 rows, 5.33’ wide 20’ long bed replicated 4 times

Planted on July 31, 2012

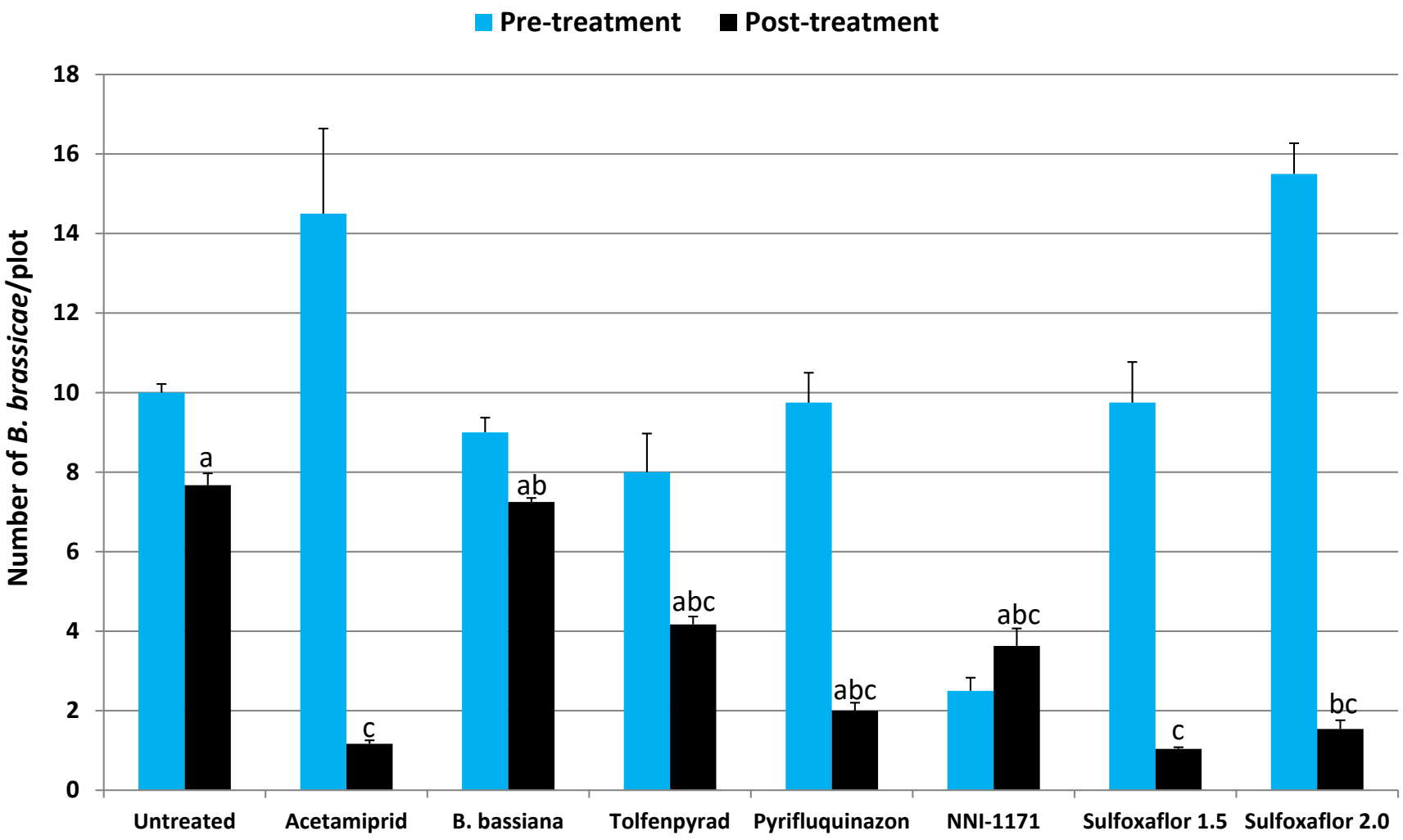
Treated on September 5 and 25, 2012

GPA before and after spray applications



Tukey's HSD $P = 0.01$

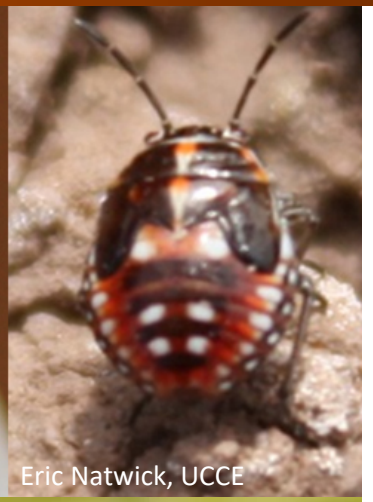
CA before and after spray applications



Tukey's HSD $P = 0.01$

Bagrada bug

Ta-I Huang,
Univ Arizona

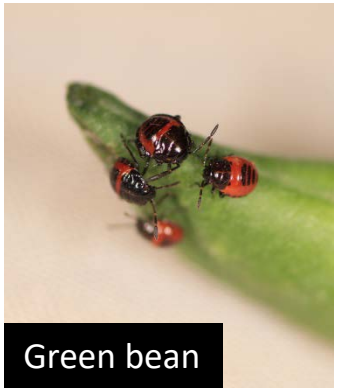


Eric Natwick, UCCE

Bagrada hilaris

Bagrada bug damage


Tomato


Green bean


Broccoli


Radish


Chiko burdock


Asparagus


Carrot


Sunflower


Corn

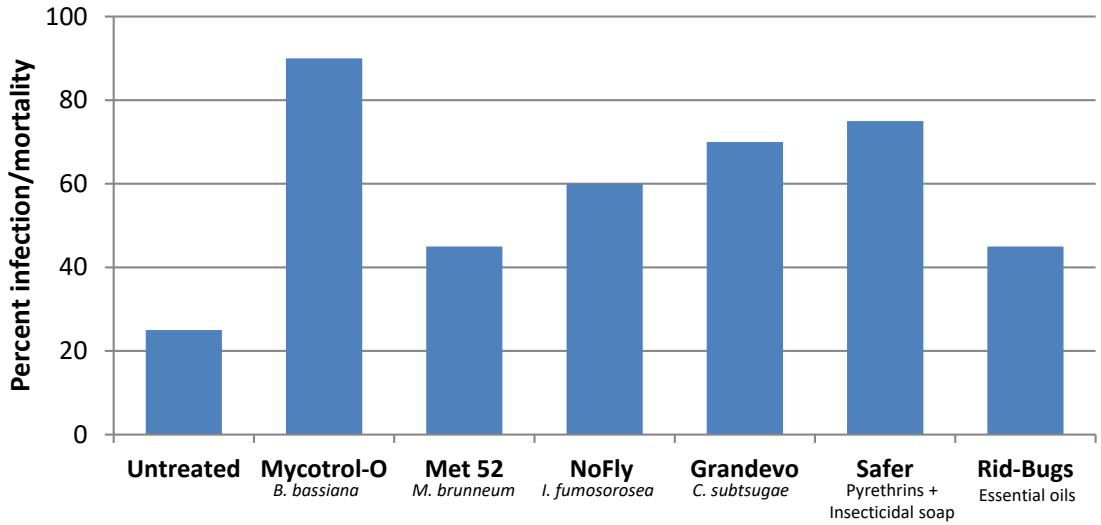

Pepper


Potato


Kale

Bagrada bug control

- Laboratory assays



- Field studies in carrots and broccoli and grower feedback
  - Mycotrol+Debug Turbo/Molt-X
  - Venerate+OroBoost/Grandevo+OroBoost
  - Mycotrol-O/BotaniGard+azadirachtin+OroBoost

Bagrada bug control

B. hilaris killed by *B. bassiana*

B. hilaris killed by *M. brunneum*

B. hilaris killed by *I. fumosorosea*

Root aphids in organic celery

Rice root aphid, *Rhopalosiphum rufiabdominale*

Photo by Brian Cabrera, SB Ag Commissioner's Office

Honeysuckle aphid, *Hyadaphis foeniculi*

Photo by A. Jensen, aphid.aphidnet.org

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Root aphids in organic celery

Root aphids in organic celery

Treatments

1. Untreated control
2. Ecotec (rosemary oil 10% and peppermint oil 2%) 19.2 fl oz + Kinetic (silicone and non-ionic surfactants) 12 fl oz
3. AzaGuard (azadirachtin) 6.3 fl oz + OroBoost (alcohol ethoxylate) 20 fl oz
4. Mycotrol-O (*Beauveria bassiana*) 1.5 qrt
5. Mycotrol-O 1.5 qrt + AzaGuard 6.3 fl oz
6. Venerate (*Burkholderia* spp.) 2 gal
7. Grandevo *(Chromobacterium subtsugae)* 2 lb

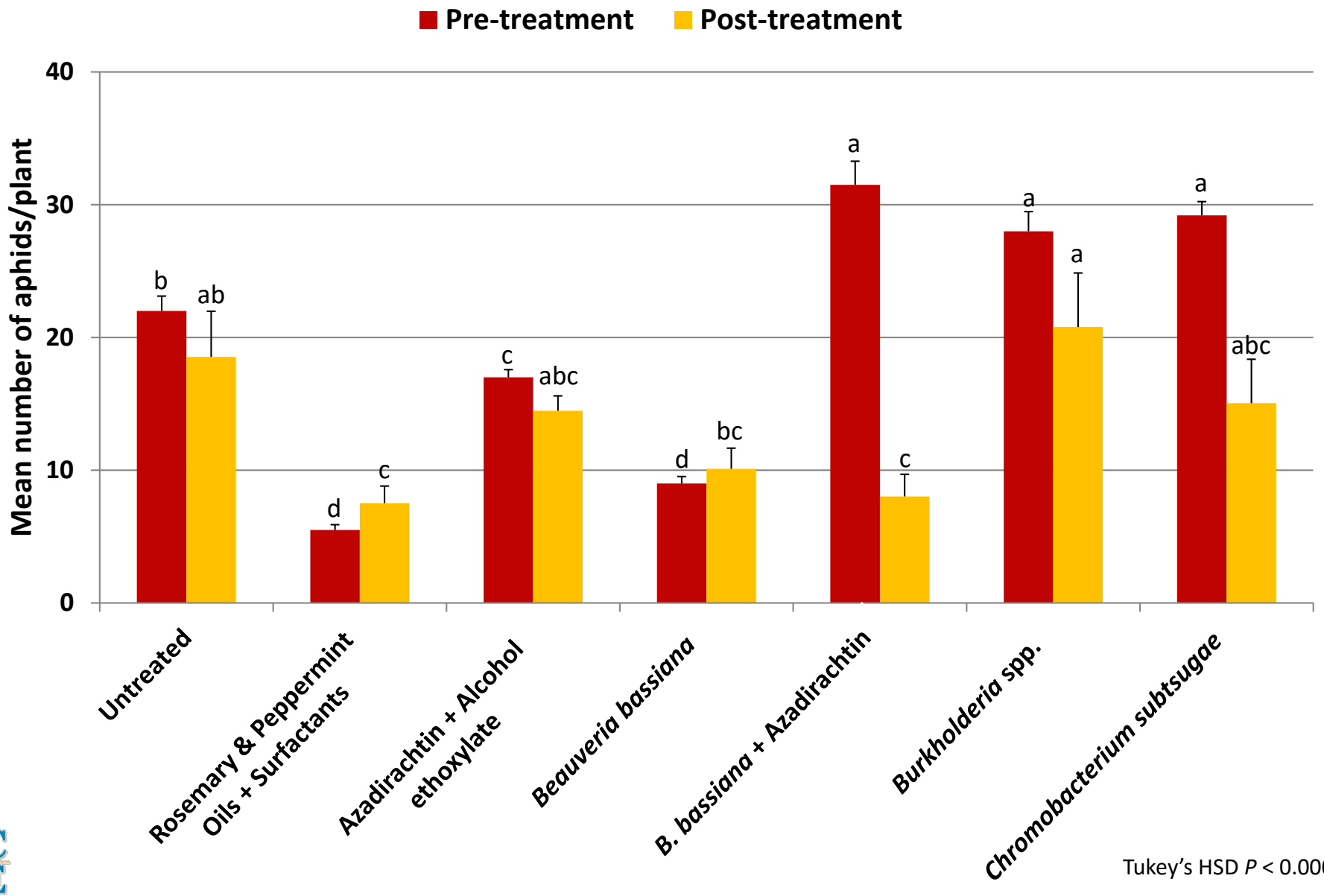
Application Through drip (250 gal for 40-45 min)

Plot size 4 beds (0.3 acre)

Sampling 10 plants from 4 parts of each plot

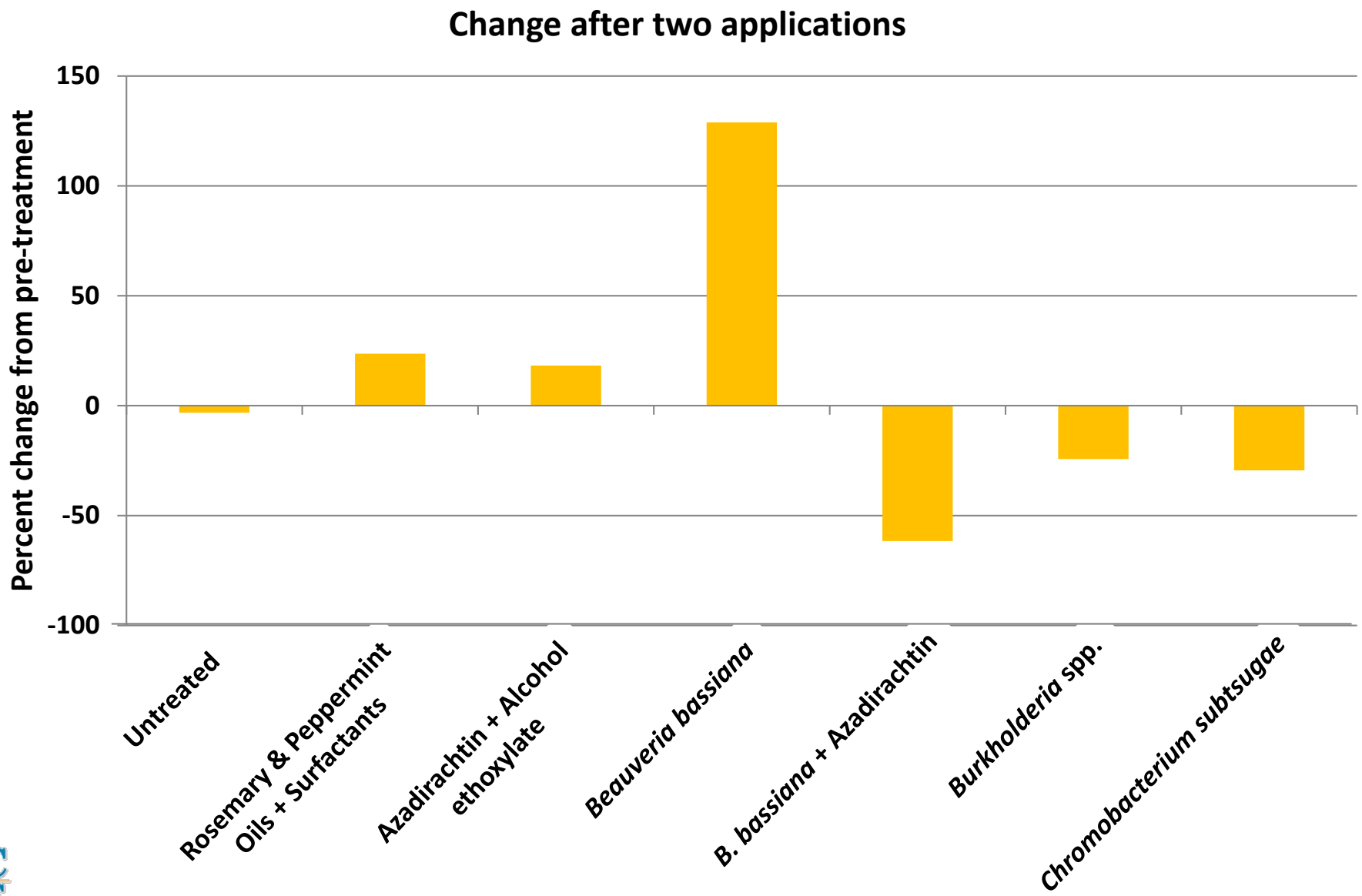
Treated on December 9 and 23, 2014

Root aphids before and after treatments



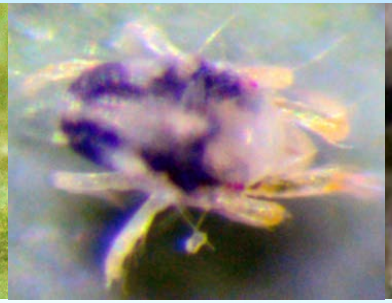
Tukey's HSD $P < 0.0001$

Percent change in root aphid numbers



Strawberry pests

Twospotted spider mite



Strawberry spider mite

Carmine spider mite

Lewis spider mite

Western tarnished plant bug

Twospotted spider mite in strawberry

Treatments

1. Untreated
2. Acramite 50 WS (bifenazate) 1 lb
3. Agri-Mek SC (abamectin) 4.29 fl oz
4. BotaniGard ES (*B. bassiana*) 1qrt + Acramite 0.75 lb
5. Eco-Mite 1% (rosemary and cotton seed oils)
6. Fujimite 5 EC (fenpyroximate) 2 pt
7. Fujimite XLO 2 pt
8. Grandevo *(C. subtsugae)* 2 lb
9. Venerate (*Burkholderia* spp.) 2 gal
10. Nealta (cyflumetofen) 13.7 fl oz

Spraying 150 gal/acre at 70 psi with hollow cone nozzle

Plot size 14’ longX44” wide bed replicated 4 times

Treated on May 16 and 25, 2013

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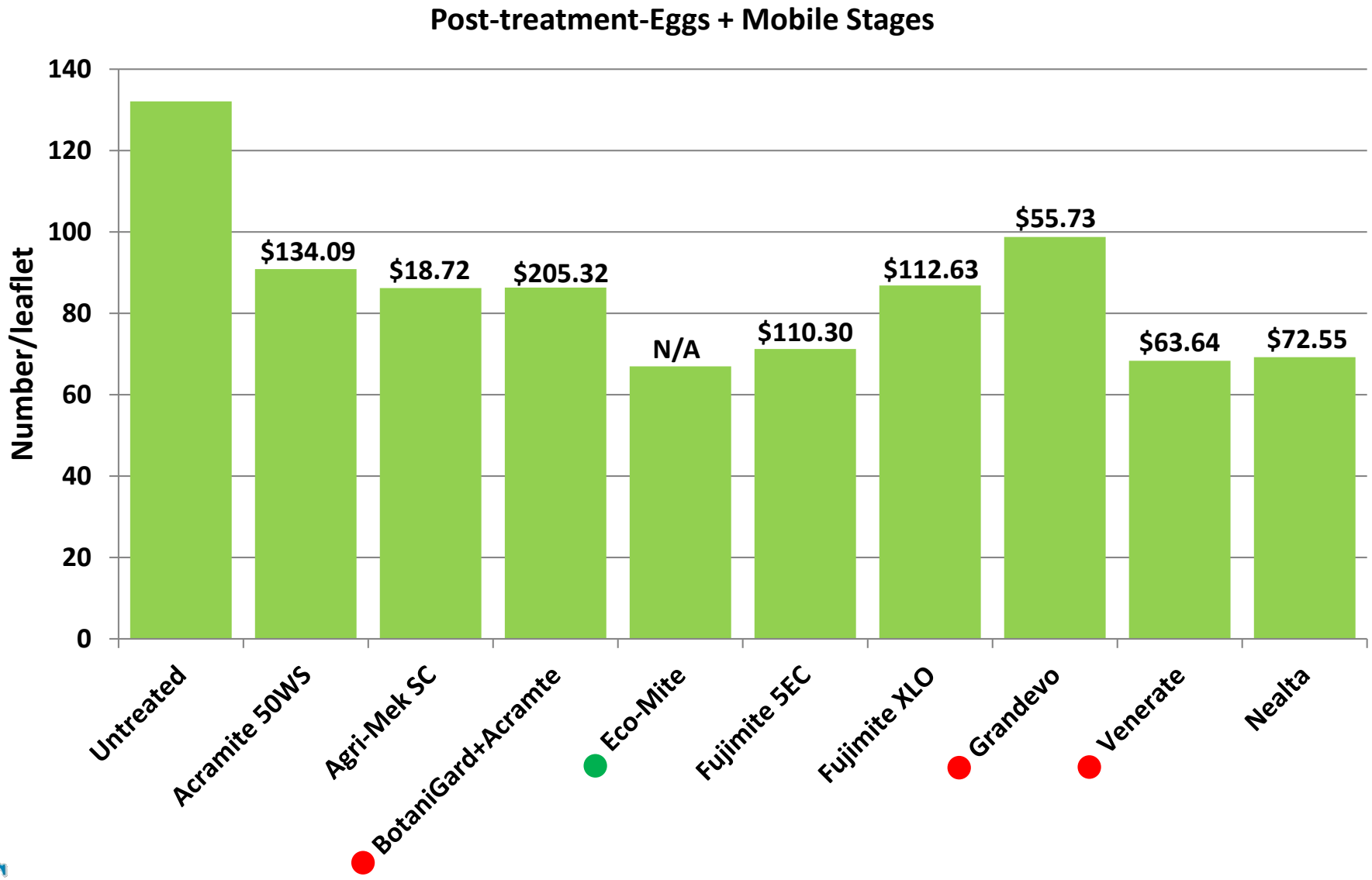
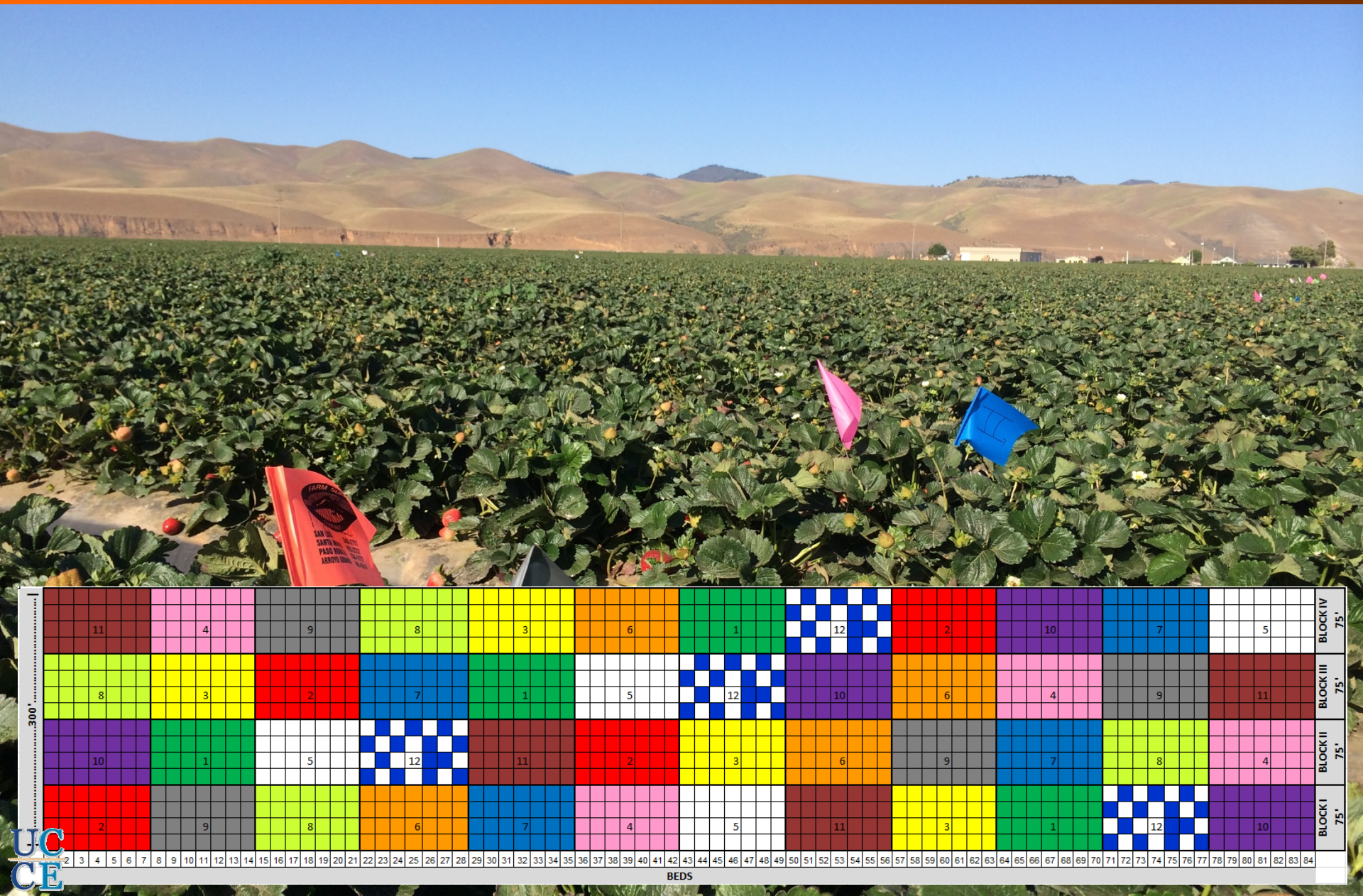
Twospotted spider mite in strawberry



Western tarnished plant bug studies



Western tarnished plant bug-2014 study

	1st application (Rate/acre)	2nd application (Rate/acre)	3rd application (Rate/acre)
1	Untreated	Untreated	Untreated
2	Assail 70 WP (3 oz) **4A***	Assail 70 WP (3 oz) **4A**	Assail 70 WP (3 oz) **4A**
3	Rimon 0.83 EC (12 fl oz) **15** + Assail 30SG (6.9 oz) **4A**	Rimon 0.83 EC (12 fl oz) **15** + Sequoia SC (4.5 fl oz) **4C**	Rimon 0.83 EC (12 fl oz) **15** + Assail 30SG (6.9 oz) **4A**
4	Rimon 0.83 EC (12 fl oz) **15** + Brigade (16 oz) **3A**	BotaniGard ES (2 qrt) + Molt-X (8 fl oz)	BotaniGard ES (2 qrt) + Molt-X (8 fl oz)
5	Rimon 0.83 EC (12 fl oz) **15** + Assail 30SG (6.9 oz) **4A**	Rimon 0.83 EC (12 fl oz) **15** + Beleaf 50 SG (2.8 oz) **9C**	Rimon 0.83 EC (12 fl oz) **15** + Assail 30SG (6.9 oz) **4A**
6	BotaniGard ES (2 qrt) + Molt-X (8 fl oz)	BotaniGard ES (2 qrt) + Low Beleaf 50 SG (1.4 oz) **9C**	Low BotaniGard ES (1 qrt) + Low Sequoia (3 oz) **4C**
7	Actara (4 oz) **4A**	Actara (4 oz) **4A** + Agri-Mek SC (3.5 fl oz) **6**	BotaniGard ES (2 qrt) + Molt-X (8 fl oz)
8	High Sequoia (4.5 oz) **4C**	High Sequoia (4.5 oz) **4C**	High Sequoia (4.5 oz) **4C**
9	Low Sequoia (3 oz) **4C**	Low Sequoia (3 oz) **4C**	Low Sequoia (3 oz) **4C**
10	High Diafil 610 Slurry (70 lb)	Low BotaniGard ES (1 qrt) + Low Sequoia (3 oz) **4C**	Met52 EC(16 fl oz) + Assail 70 WP (3 oz) **4A**
11	Low Diafil 610 Slurry (35 lb)	Low Sequoia (3 oz) **4C** + Molt-X (8 fl oz)	Met52 EC(16 fl oz)
12	High Diafil 610 Dust (70 lb)	Low BotaniGard ES (1 qrt) + Assail 70 WP (3 oz) **4A**	Met52 EC (16 fl oz) + Molt-X (8 fl oz)

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4A Neonicotinoids
4C Sulfoximines
6 Chloride channel activators
9C Selective homopteran feeding blockers
3A Sodium channel modulators
15 Inhibitors of chitin biosynthesis

Western tarnished plant bug-2014 study

Rank	%Change	I Spray	II Spray	III Spray
I	14	Sequoia High	Sequoia High	Sequoia High
II	17	Diafil Dust High	BotaniGard Low + Assail 70WP	Met52 + Molt-X
III	48	Rimon + Assail 30SG	Rimon + Beleaf 50SG	Rimon + Assail 30SG
IV	54	Rimon + Brigade	BotaniGard ES + Molt-X	BotaniGard ES + Molt-X
V	81	Sequoia Low	Sequoia Low	Sequoia Low
VI	143	Diafil Slurry High	Sequoia Low + BotaniGard ES Low	Met52 + Assail 70WP
VII	167	Rimon + Assail 30SG	Rimon + Sequoia High	Rimon + Assail 30SG
VIII	280	Actara	Actara + Agri-Mek	BotaniGard ES + Molt-X
IX	307	BotaniGard ES + Molt-X	BotaniGard ES + Beleaf 50SG Low	BotaniGard ES Low + Sequoia Low
X	367	Diafil Slurry Low	Sequoia Low	Met52 + Molt-X
XI	383	Untreated	Untreated	Untreated
XII	1083	Assail 70WP	Assail 70WP	Assail 70WP

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Western tarnished plant bug-2014 study

Rank	%Change	I Spray	II Spray	III Spray	Cost/ac
I	14	Sequoia High	Sequoia High	Sequoia High	$143.82
II	17	~~Diafil Dust High~~ Sequoia High	BotaniGard Low + Assail 70WP	Met52 + Molt-X	~~$385.74~~ $216.16
III	48	Rimon + Assail 30SG	Rimon + Beleaf 50SG	Rimon + Assail 30SG	$178.42
IV	54	Rimon + Brigade	BotaniGard ES + Molt-X	BotaniGard ES + Molt-X	$333.39
V	81	Sequoia Low	Sequoia Low	Sequoia Low	$95.88
VI	143	Diafil Slurry High	Sequoia Low + BotaniGard ES Low	Met52 + Assail 70WP	$378.22
VII	167	Rimon + Assail 30SG	Rimon + Sequoia High	Rimon + Assail 30SG	$195.43
VIII	280	Actara	Actara + Agri-Mek	BotaniGard ES + Molt-X	$180.60
IX	307	BotaniGard ES + Molt-X	BotaniGard ES + Beleaf 50SG Low	BotaniGard ES Low + Sequoia Low	$178.42
X	367	Diafil Slurry Low	Sequoia Low	Met52 + Molt-X	$218.12
XI	383	Untreated	Untreated	Untreated	0
XII	1083	Assail 70WP	Assail 70WP	Assail 70WP	$126.63

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Western tarnished plant bug-2015 study

	1st application (Rate/acre)	2nd application (Rate/acre)	3rd application (Rate/acre)
1	Untreated	Untreated	Untreated
2	Assail 70 WP (3 oz) **4A***	Assail 70 WP (3 oz) **4A**	Assail 70 WP (3 oz) **4A**
3	Vacuum	Vacuum	Vacuum
4	Rimon 0.83 EC (12 fl oz) **15** + Brigade (16 oz) **3A**	Met52 EC(16 fl oz) + Debug Turbo (104 fl oz)	Met52 EC (16 fl oz) + AzaGuard (16 fl oz)
5	Sequoia (4.5 oz) **4C**	Sequoia (4.5 oz) **4C**	Vacuum
6	Pfr-97 (2 lb) + Neemix (9 fl oz)	Pfr-97 (2 lb) + Neemix (9 fl oz)	Vacuum
7	Vacuum	Sivanto (14 fl oz) **4D** + Debug Turbo (104 fl oz)	Rimon 0.83 EC (12 fl oz) **15** + Brigade (16 oz) **3A**
8	Sivanto (14 fl oz) **4D**	Sivanto (14 fl oz) **4D**	Vacuum
9	Sequoia (4.5 oz) **4C**	Sivanto (14 fl oz) **4D**	Beleaf 50 SG (2.8 oz) **9C**
10	*B. bassiana*+neem (1qrt)	*B. bassiana*+pyrethrum **3A**+neem (1qrt)	*B. bassiana*+pyrethrum **3A** (1qrt)
11	*B. bassiana*+pyrethrum **3A** (1qrt)	*B. bassiana*+neem (1qrt)	Beleaf 50 SG (2.8 oz) **9C**
12	*B. bassiana*+pyrethrum **3A** (1qrt)	Vacuum	Rimon 0.83 EC (12 fl oz) **15** + Brigade (16 oz) **3A**

*MoA group

3A Pyrethrins-Sodium channel modulators

4A Neonicotinoids
4C Sulfoximines
4D Butenolides
} Nicotinic acetylcholine receptor competitive modulators

9C Flonicamid – Modulators of chordotonal organs

15 Benzoylureas - Inhibitors of chitin biosynthesis

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Western tarnished plant bug-2015 study

Rank	% Change	I Spray	II Spray	III Spray
I	-28.9	Sequoia (4.5 oz) **4C***	Sivanto (14 fl oz) **4D**	Beleaf 50 SG (2.8 oz) **9C**
II	-12.1	Sivanto (14 fl oz) **4D**	Sivanto (14 fl oz) **4D**	Vacuum
III	0.0	*B. bassiana*+pyrethrum **3A** (1qrt)	Vacuum	Rimon 0.83 EC (12 fl oz) **15** + Brigade (16 oz) **3A**
IV	7.8	Rimon 0.83 EC (12 fl oz) **15** + Brigade (16 oz) **3A**	Met52 EC(16 fl oz) + Debug Turbo (104 fl oz)	Met52 EC (16 fl oz) + AzaGuard (16 fl oz)
V	8.0	Assail 70 WP (3 oz) **4A***	Assail 70 WP (3 oz) **4A**	Assail 70 WP (3 oz) **4A**
VI	11.5	Vacuum	Vacuum	Vacuum
VII	27.3	Vacuum	Sivanto (14 fl oz) **4D** + Debug Turbo (104 fl oz)	Rimon 0.83 EC (12 fl oz) **15** + Brigade (16 oz) **3A**
VIII	32.7	Pfr-97 (2 lb) + Neemix (9 fl oz)	Pfr-97 (2 lb) + Neemix (9 fl oz)	Vacuum
IX	46.8	*B. bassiana*+pyrethrum **3A** (1qrt)	*B. bassiana*+neem (1qrt)	Beleaf 50 SG (2.8 oz) **9C**
X	70.8	Sequoia (4.5 oz) **4C**	Sequoia (4.5 oz) **4C**	Vacuum
XI	78.3	Untreated	Untreated	Untreated
XII	85.7	*B. bassiana*+neem (1qrt)	*B. bassiana*+pyrethrum **3A** +neem (1qrt)	*B. bassiana*+pyrethrum **3A** (1qrt)

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*Mode of action group

Take home message

Microbial pesticides do work and we need to know when and how to use them.

Thank you!

Thanks to my strawberry and vegetable growers, technicians, and industry partners for their collaboration, technical assistance, and financial support.

Download free IPMinfo app for iOS and Android devices

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