University of California
Agriculture and Natural Resources

Entomology & Biologicals

Microbial Control and IPM: What, why, where, when, and how?

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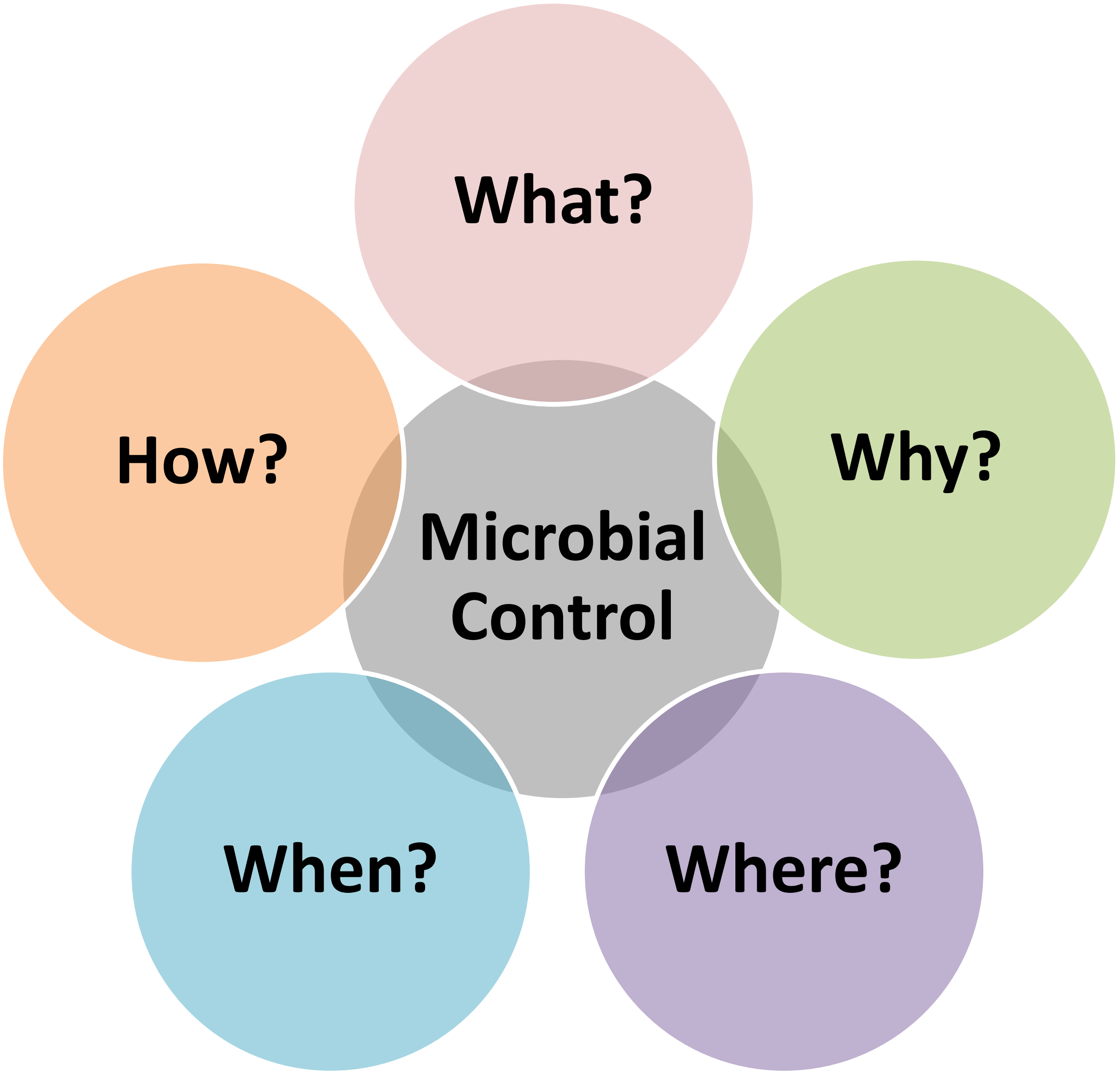
SBCo Nursery & Flower Growers Association, 15 January, 2019

Microbial control and IPM



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What? Microbial control

- Microbial control refers to the control of pests with microorganisms or microbe-derived byproducts.
- Microbial control agents: bacteria, fungi, microsporidia, nematodes, and viruses.
  - Bacteria: *Bacillus thuringiensis* and *Panenibacillus popilliae*
  - Fungi: *Beauveria bassiana, Entomophaga maimaiga, Entomophthora muscae, Hirsutella thompsonii, Isaria fumosorosea, Metarhizium brunneum, Lecanicillium lecanii, Neozygites* spp., and *Pandora neoaphidis*
  - Microsporidia: *Nosema* spp., *Paranosema locustae,* and *Vairimorpha necatrix*
  - Nematodes: *Heterorhabditis* spp. and *Steinernema* spp.
  - Viruses: Granuloviruses and nucleopolyhedroviruses
- Commercial formulations
  - Microorganism-based products
  - Those based on toxins or toxic metabolites
- Natural infections vs. inundative applications.

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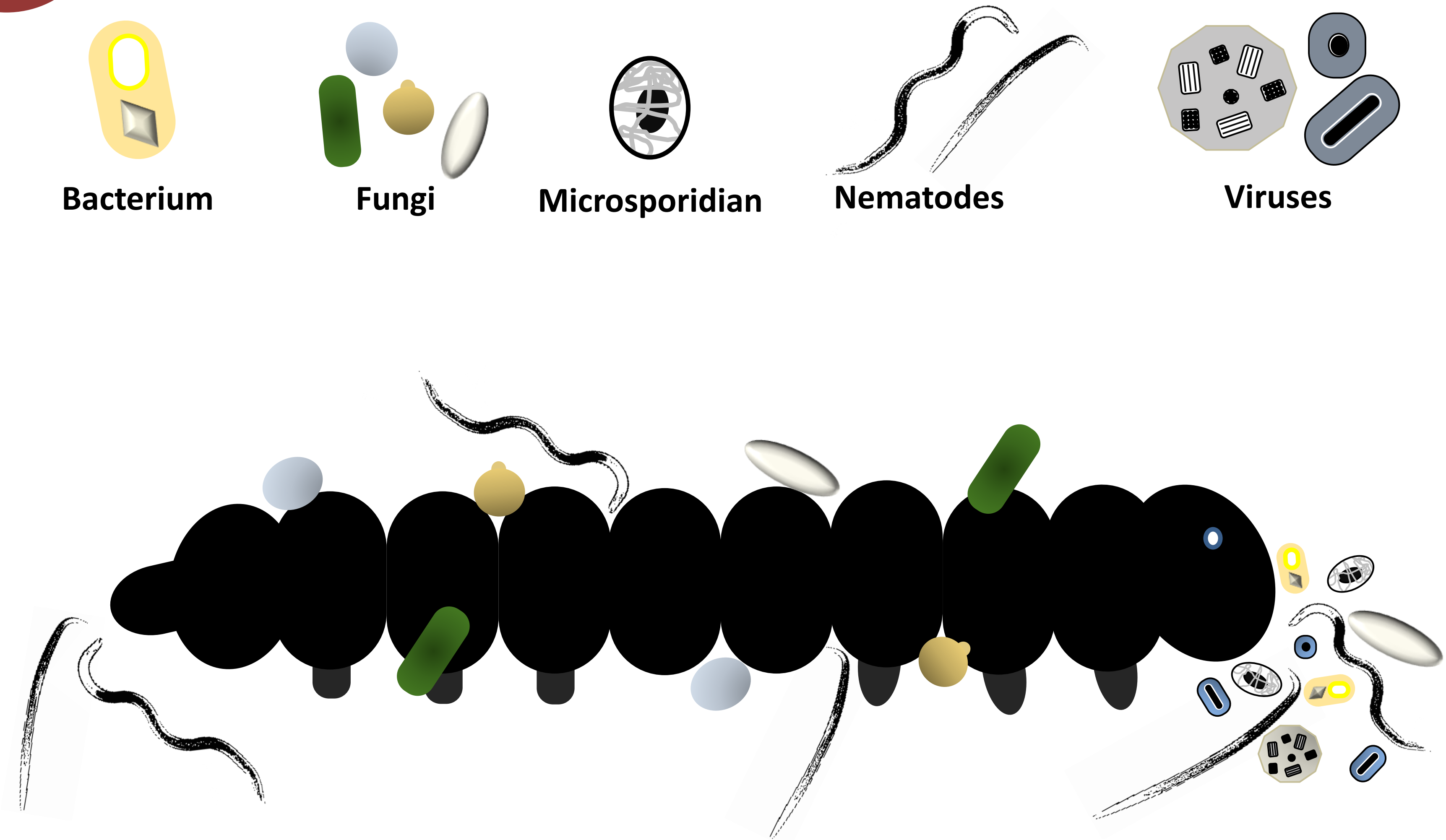
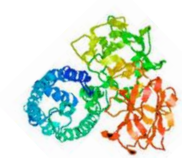
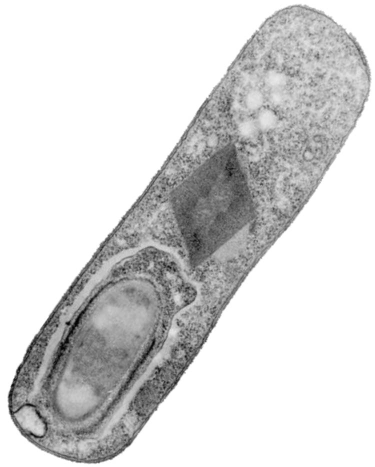
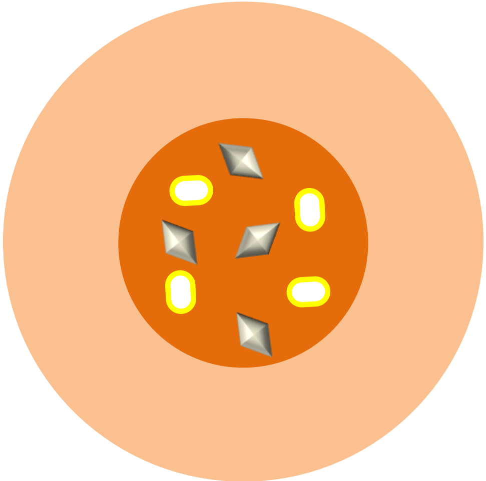
What? Entomopathogen infection routes

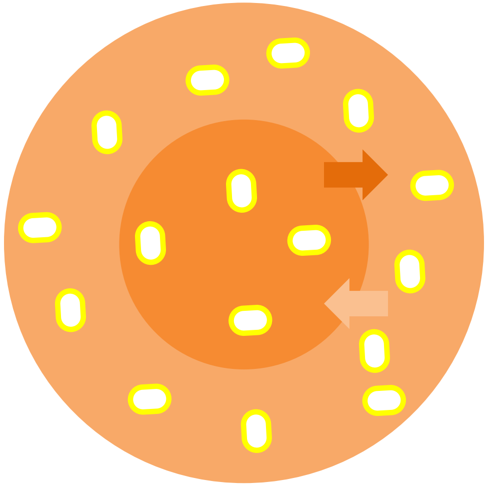


What? Bacterial infections

- High pH in the insect gut activates δ-endotoxin 
- Toxin attaches to the receptor sites and creates pores in the midgut cells leading to the loss of osmoregulation, midgut paralysis, and cell lysis
- Contents of the gut leak into the hemocoel and bacteria causes septicemia
- Blood enters into the gut disrupting the pH balance







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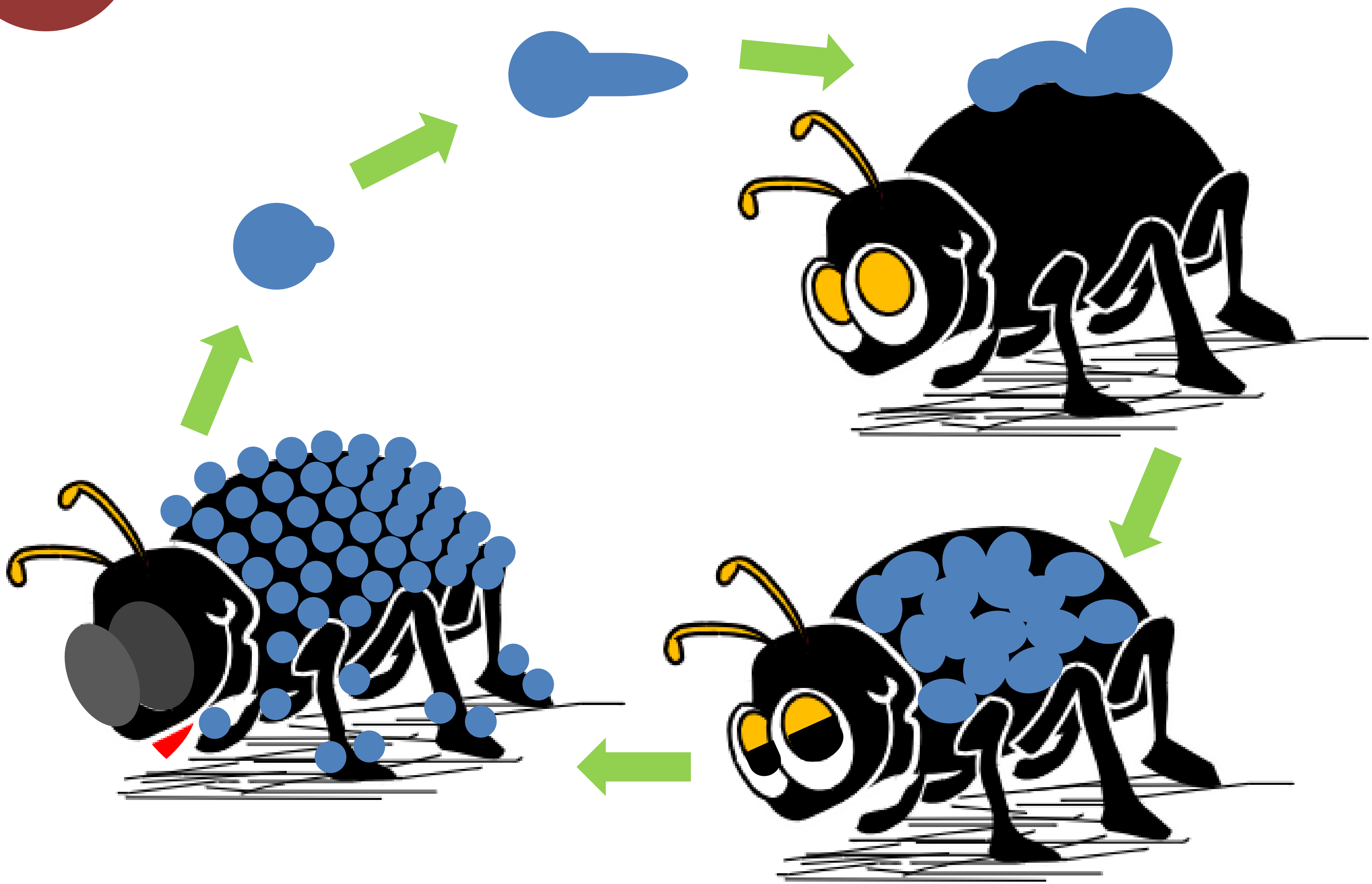
What? **Fungal infections**



What? Fungal infections-Hypocreales

Isaria fumosorosea-Bagrada bug

Beauveria bassiana-Bagrada bug

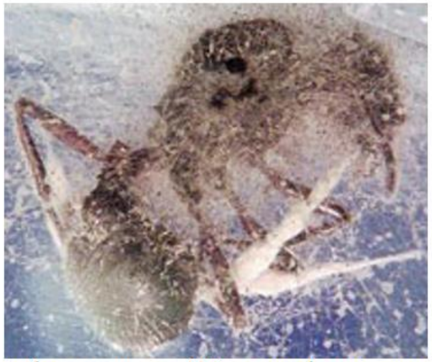
Metarhizium brunneum-Bagrada bug

Beauveria bassiana-Lygus bug

Beauveria bassiana-GWSS

Metarhizium brunneum-GWSS

Photo: Surendra Dara



Paecilomyces sp.-Western harvester ant

Beauveria bassiana-Western harvester ant

What? Fungal infections-Entomophthorales

Entomophthora planchoniana-Strawberry aphid

Source: Surendra Dara

Pandora neoaphidis-Green peach aphid

Source: Unknown

Entomophthora muscae-Spotted-wing drosophila

Source: Tom Mann

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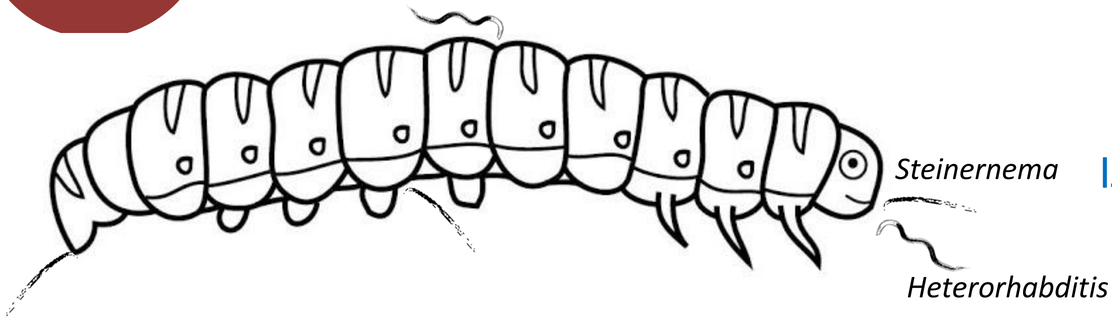
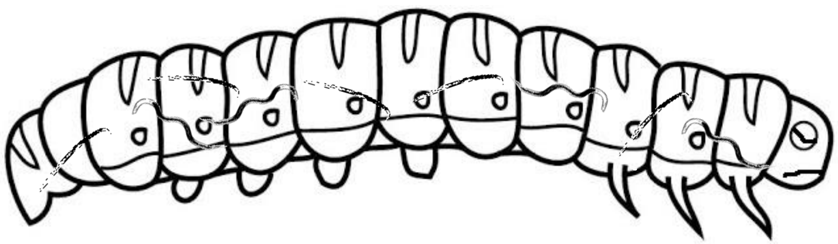
What? Nematode infections

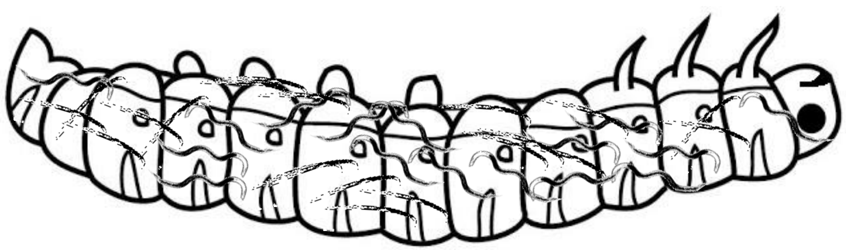


IJ search for the host and enter

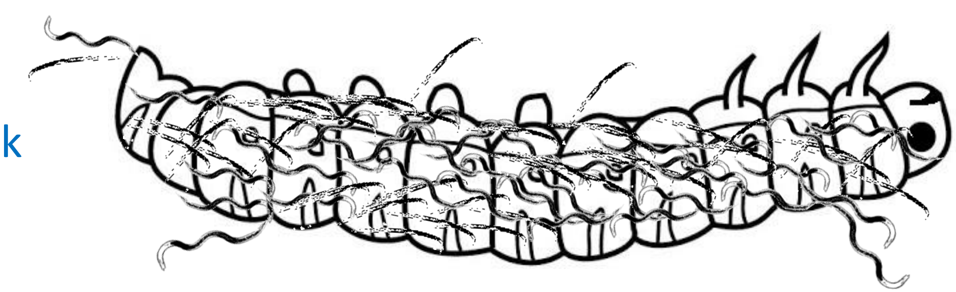


Release bacteria
Kill the host
Develop in the host

Multiply in the host
for 1-3 generations

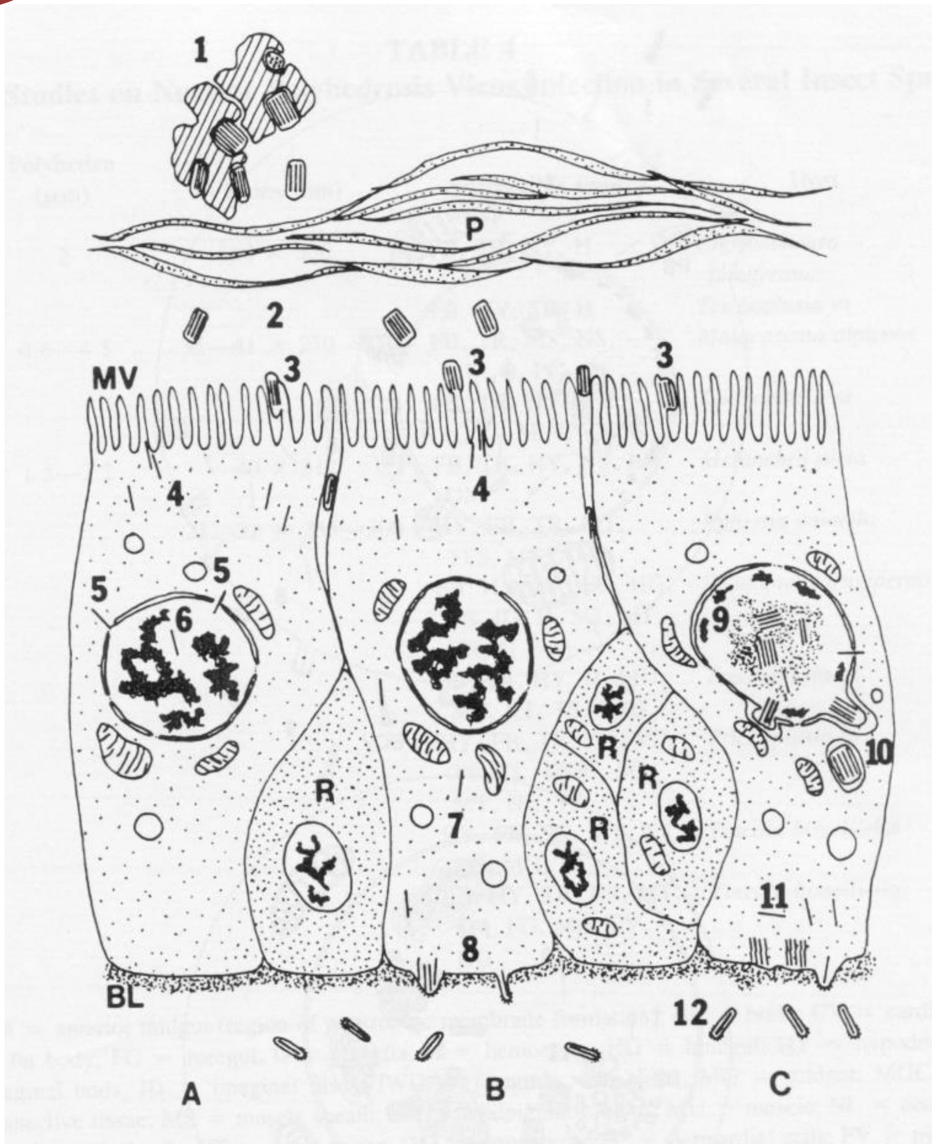


IJ emerge and seek
other hosts



Caterpillar clipart from http://www.idibujosparacolorear.com

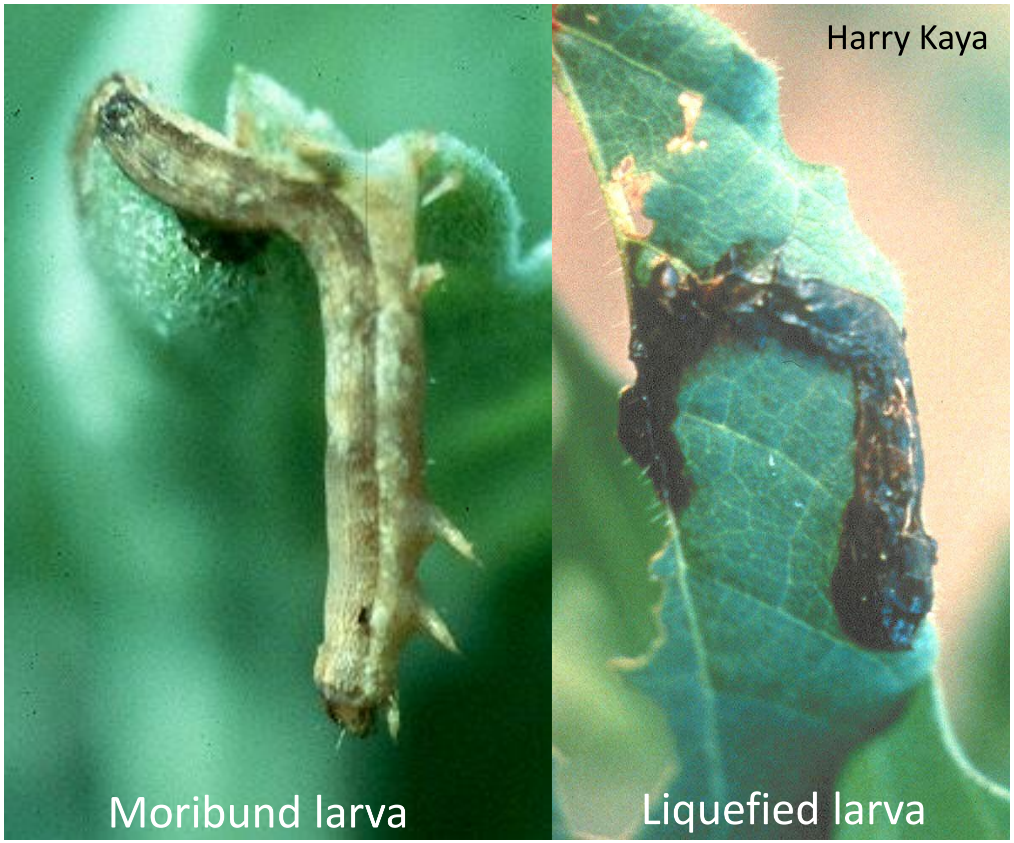
What? Nucleopolyhedrovirus infection



1. Dissolution
2. Pass PM
3. Attachment to columnar cells
4. Cytoplasm
5. Nuclear pore
6. Nucleus
7. Passage through
8. Envelope
9. Viral replication
10. Viral progeny
11. Envelope
12. Hemocoel

What?

Viral infections



NPV-killed beet armyworm

GV-killed geometrid larva

What? **Commercial products of MCAs**

Microbial control agent	Tradenames of biopesticides	Target pests
Bacteria		
Bacillus thuringiensis subsp. *aizawai*	Agree WG and XenTari DF	Lepidoptera
B. thuringiensis subsp. *israelensis*	Mosquito Beater WSP	Diptera
B. thuringiensis subsp. *kurstaki*	CoStar, DiPel ES, Monterey B.t., and Thuricide	Lepidoptera
B. thuringiensis subsp. *tenebrionis*	Novodor FC	Coleoptera
Paenibacillus popilliae	Milky Spore Powder	Japanese beetle, *Popillia japonica*
Fungi		
Beauveria bassiana	BotaniGard ES, Mycotrol-ESO, Myco-Jaal, and Naturalis-L	One or more pests of Acarina, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Orthoptera, Thysanoptera, and others
Hirsutella thompsonii	ABTEC Hirsutella	
Isaria fumosorosea	NoFly WP and Pfr-97 WDG	
Lecanicillium lecanii	Phule Bugicide	
L. longisporum	Vertalec	
Metarhizium anisopliae	BioCane, Metarril and Ory-X	
M. brunneum	Met52 EC	
Paecilomyces lilacinus	MeloCon WG	Plant-parasitic nematodes
Nematodes		
Heterorhabditis bacteriophora	Nemasys and Terranem	Several orders of soilborne pests
Steinernema carpocapsae	Ecomask and NemAttack	
S. feltiae	Entonem, Fungus Gnat & Rootknot Exterminator, and Scanmask	
H. heliothidis and *S. carpocapsae*	Double-Death	
Viruses		
Granulovirus (GV)		Lepidoptera
Cydia pomonella GV	CYD-X and MADEX HP	
Nucelopolyhedrovirus (NPV)		
Helicoverpa zea NPV	Gemstar LC	
Spodoptera exigua NPV	Spod-X LC	

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Why?

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

Why? Microbial control in IPM

- A powerful tool for pest management
- Can be very specific or effective against a broad range of pests through multiple modes of action
- Sustainable control option
- Helps reduce insecticide resistance
- Grower-friendly and consumer-friendly
- Some entomopathogens can also play other roles

Where? Microbial control agents and others

Pest control

Bacillus thuringiensis

Burkholderia rinojensis
Chromobacterium subtsugae

Beauveria bassiana
Isaria fumosorosea
Metarhizium brunneum

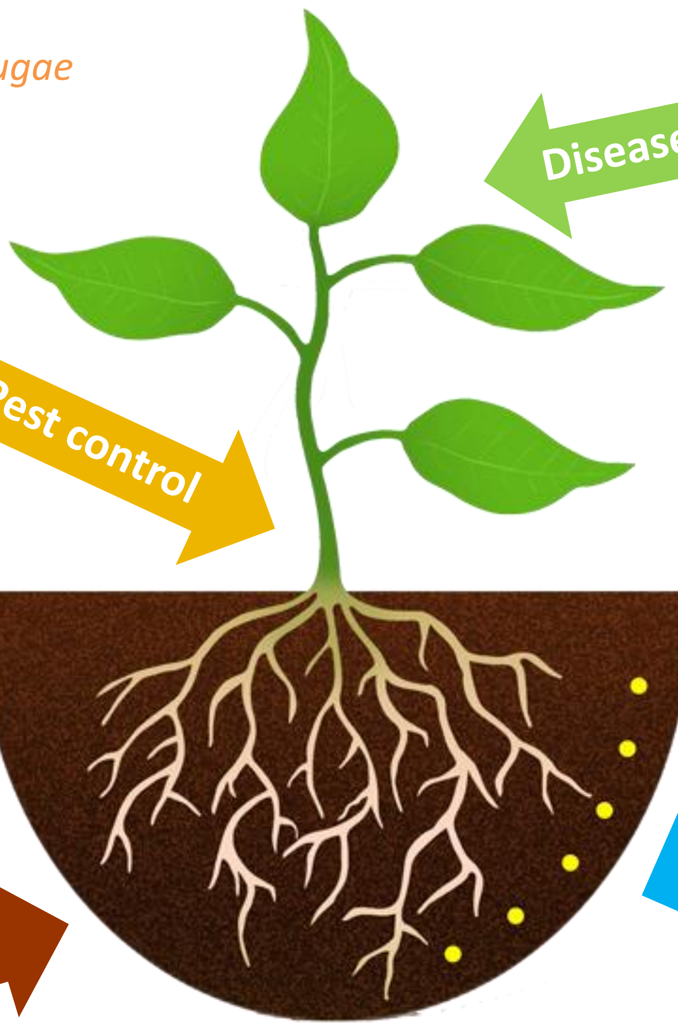
Steinernema spp.
Heterorhabditis spp.

NPV, GV

Disease control

Aureobasidium spp.
Trichoderma spp.
Ulocladium spp.

Bacillus spp.
Pseudomonas spp.
Streptomyces spp.



Soil health

Azorhizobium spp.
Azospirellum spp.
Azotobacter spp.
Bacillus spp.
Pseudomonas spp.
Rhizobium spp.

Trichoderma spp.
Rhizophagus spp.

Biostimulation

Bacillus spp.
Comamonas spp.
Citrobacter spp.
Enterobacter spp.
Pseudomonas spp.

Beauveria bassiana

Saccharomyces cerevisiae

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When? **Opportunities for using MCAs**

- For controlling several endemic and invasive pests
- Throughout the crop production - inoculate transplants or apply as curative treatments
- When there is a risk of pesticide resistance or pest management is not effective with existing options
- For controlling certain pests where chemical pesticides are less effective or cannot be used
- Under certain environmental conditions that are favorable to MCAs

How?

Using microbial control agents

- Understand different modes of action and suitability for various pest and crop situations
- Store them according to the manufacturer guidelines
- Avoid exposure to excessive heat and solar radiation
- Consider applying in the evenings
- Avoid incompatible tank-mix partners
- Use before pest populations are out of control

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How? Using microbial control agents

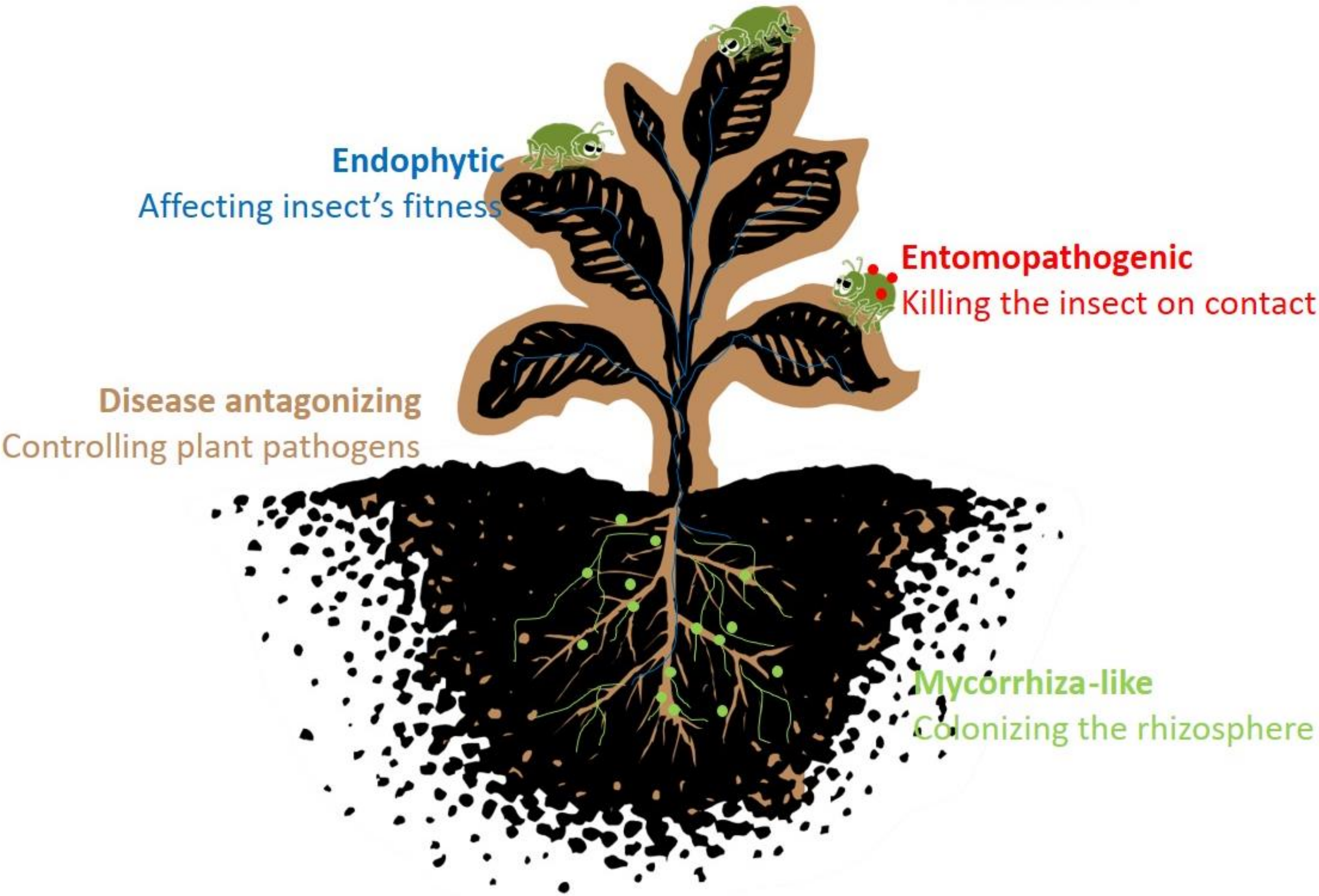
- Combine with a low label rate of a chemical pesticide (reduction in chemical pesticide use)

- Combine with botanical pesticides (improved efficacy)

- Rotate with chemical pesticides (reduced risk of insecticide resistance)

- Combine multiple microbial control agents (improved efficacy and control of multiple pests)

How? Multiple roles of entomopathogenic fungi



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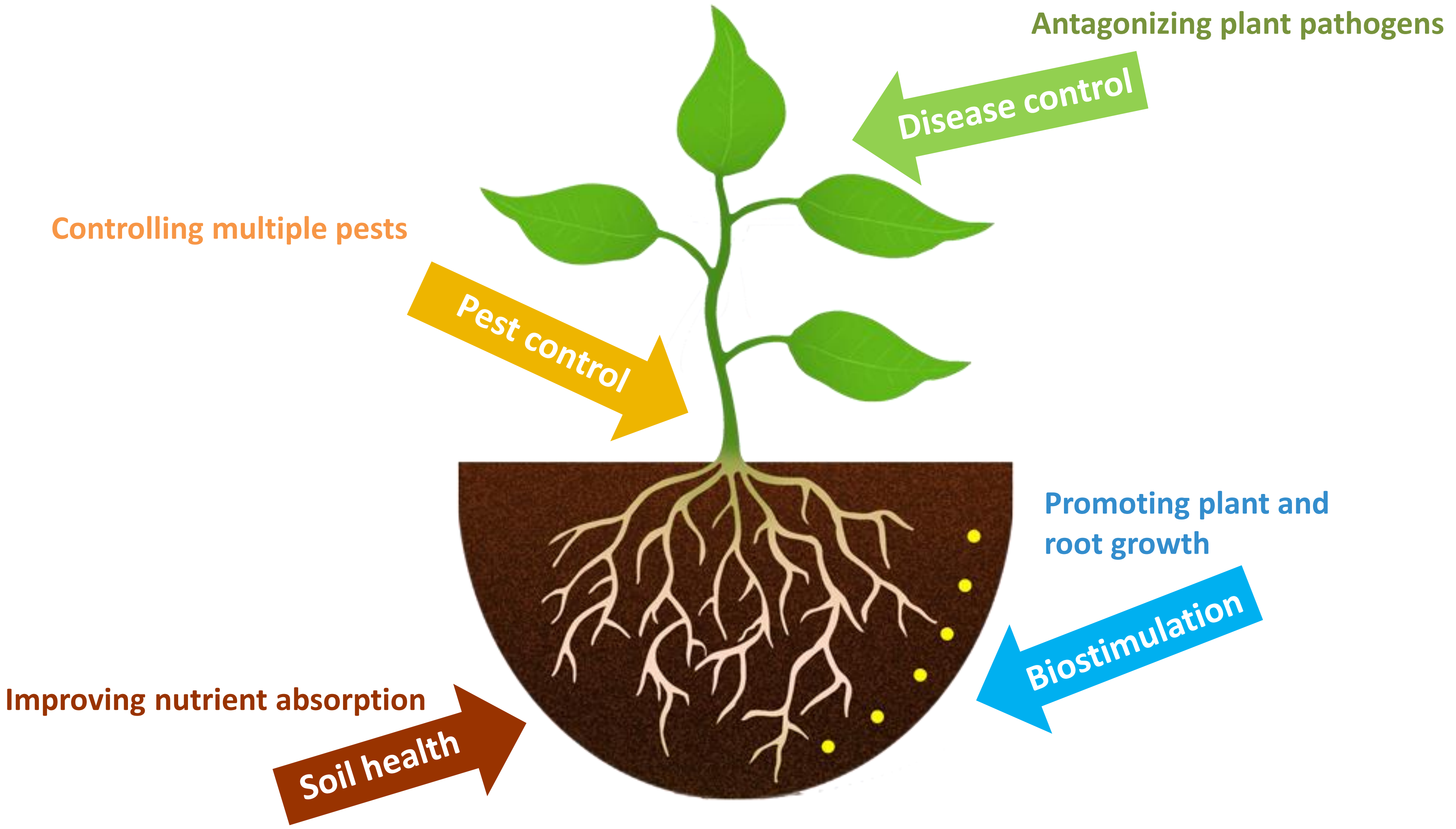
How? Multiple roles of entomopathogenic fungi



How? Greenhouse strawberry pest control

Treatments

1. Untreated control
2. BotaniGard 22 WP *(Beauveria bassiana*)
3. Conserv (Spinosad)
4. AzaSol (Azadirachtin)
5. Conserv + AzaSol

Plot size 15' long X 4 rows, replicated 4 times

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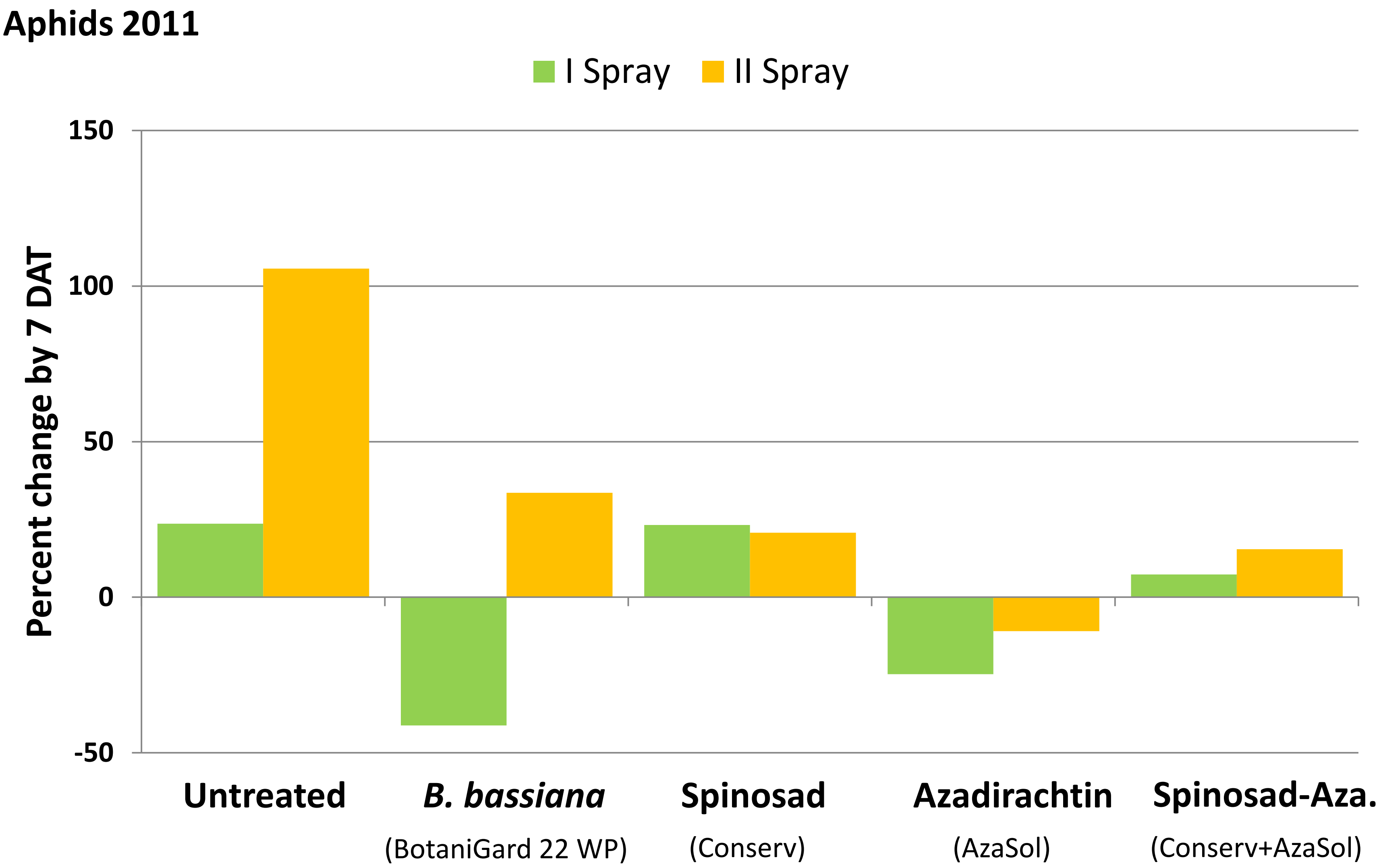
How? Greenhouse strawberry pest control



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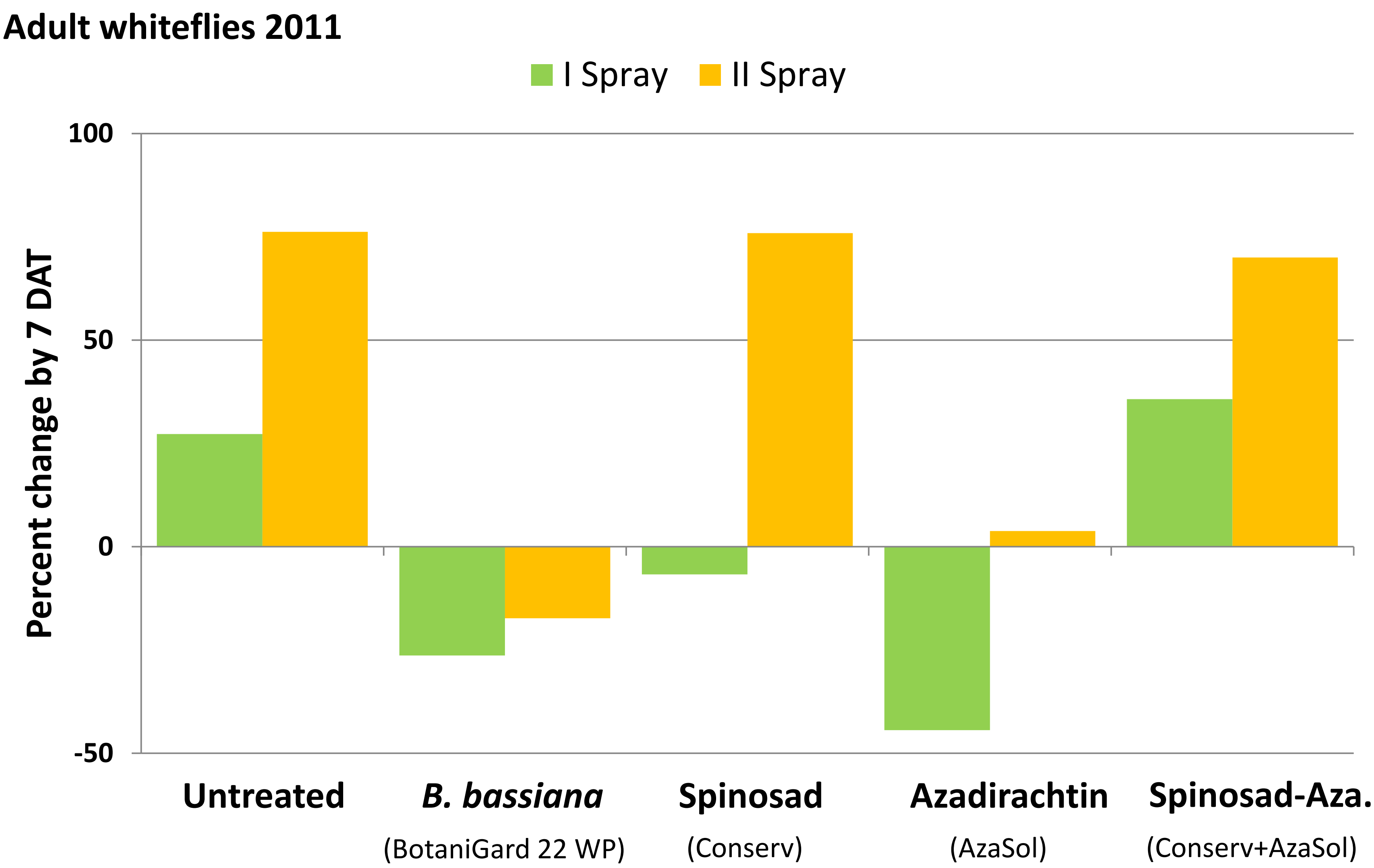
How? Greenhouse strawberry pest control



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How? **Greenhouse strawberry pest control**

Conclusion

- *B. bassiana* and azadirachtin showed a good potential for managing some strawberry pests

Dara, S. K., S. R. Dara, and S. S. Dara. 2013. Endophytic colonization and pest management potential of *Beauveria bassiana* in strawberries. J. Berry Res. 3: 203-211. https://content.iospress.com/articles/journal-of-berry-research/jbr058

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How? Lygus bug control in field strawberry

	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	XPULSE *B. bassiana*+neem (1qrt)	XCEDE *B. bassiana*+pyrethrum **3A**+neem (1qrt)	XPECTRO *B. bassiana*+pyrethrum **3A** (1qrt)
11	XPECTRO *B. bassiana*+pyrethrum **3A** (1qrt)	XPULSE *B. bassiana*+neem (1qrt)	Beleaf 50 SG (2.8 oz) **9C**
12	XPECTRO *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

9C Flonicamid – Modulators of chordotonal organs

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

15 Benzoylureas - Inhibitors of chitin biosynthesis

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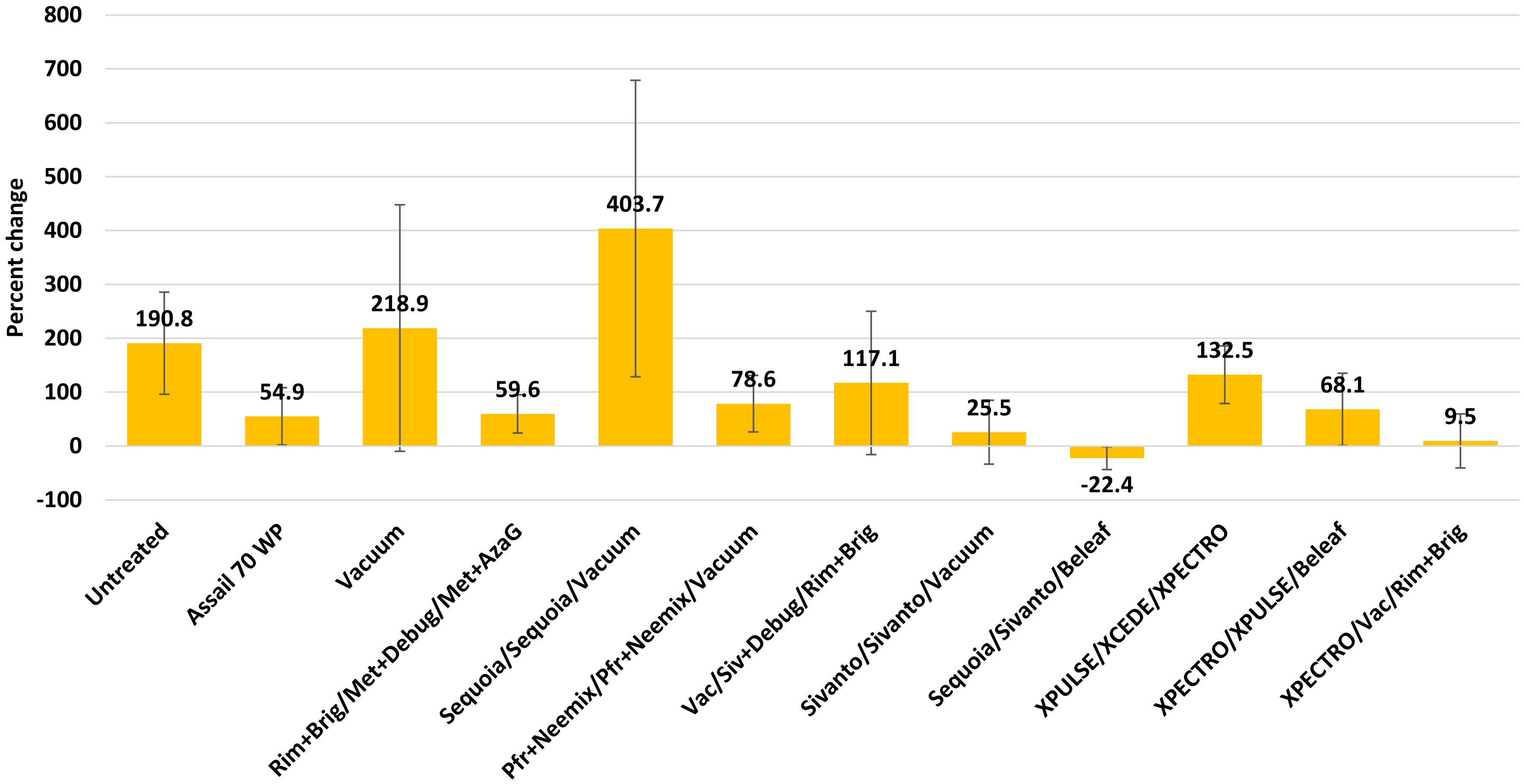
How? Lygus bug control in field strawberry



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How? **Lygus bug control in field strawberry**

Conclusion

- Microbial and botanical control options were very effective as a combination and rotation tools

Dara, S. K. 2016. Managing strawberry pests with chemical pesticides and non-chemical alternatives. Int. J. Fruit Sci. http://www.tandfonline.com/doi/pdf/10.1080/15538362.2016.1195311

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How? Arthropod management in zucchini

1 Untreated control
2 Sivanto 200 SL (flupyradifurone) 14 fl oz
3 Sequoia (sulfoxaflor) 2.5 fl oz
4 Venerate XC (*Burkholderia rinojensis* strain A396) 4 qrt
5 PFR-97 20% WDG *(Isaria fumosorosea* Apopka strain 97*)* 2 lb
6 I1800A 10.3 fl oz
7 I1800A 12.7 fl oz
8 I1800A 17.1 fl oz
9 I1800A 20.5 fl oz
10 Spear-T (spider venom peptide-VST-00634LC) 25%

- Spray volume 50 gpa (25 gpa for treatment 10)
- Treatments were applied on 8/28 and 9/4/17 Using a tractor-mounted sprayer with 3 Teejet 8003vs flat spray nozzles
- Pest counts were made on 8/28, 9/1, and 9/8/17 from a 2 square inch disc from each of 5 leaves/plot

IV	5	9	1	2	8	10	3	7	6	4	75'
III	2	10	1	3	5	4	7	6	8	9	75'
II	4	8	7	9	6	3	10	2	5	1	75'
I	9	4	10	6	8	5	1	7	2	3	75'
	2 beds	2 beds	2 beds	2 beds	2 beds	2 beds	2 beds	2 beds	2 beds	2 beds	

How? Arthropod management in zucchini

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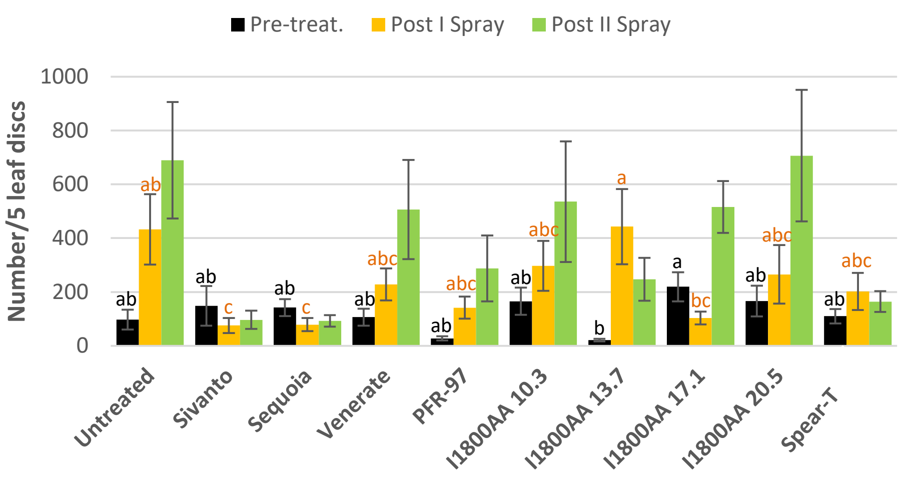
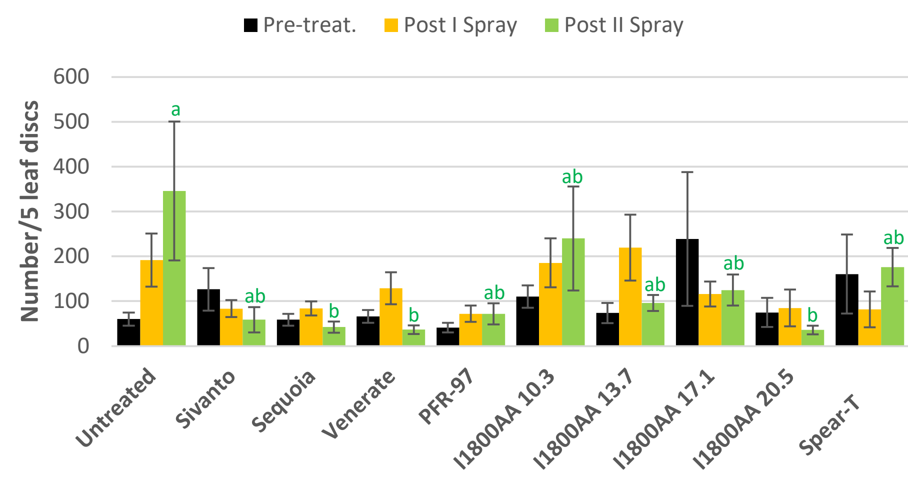
How? Arthropod management in zucchini

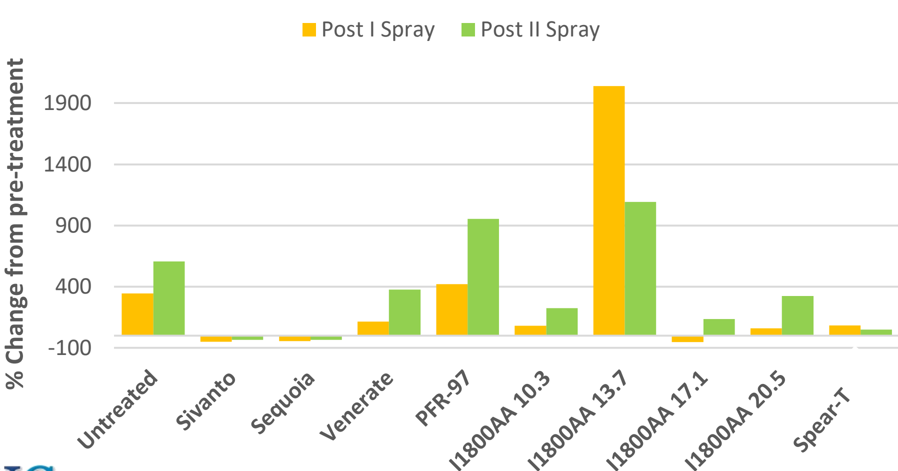
Silverleaf whitefly eggs



Silverleaf whitefly nymphs



Silverleaf whitefly eggs



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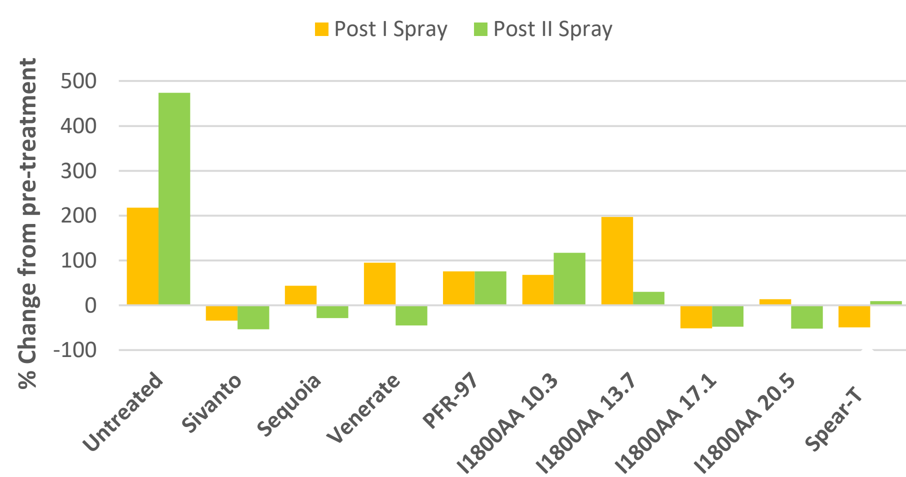

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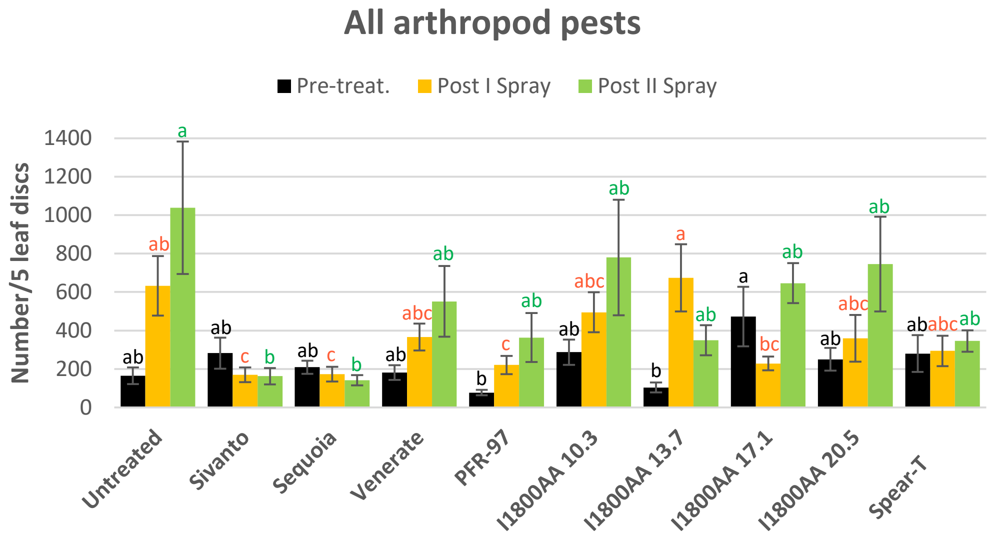
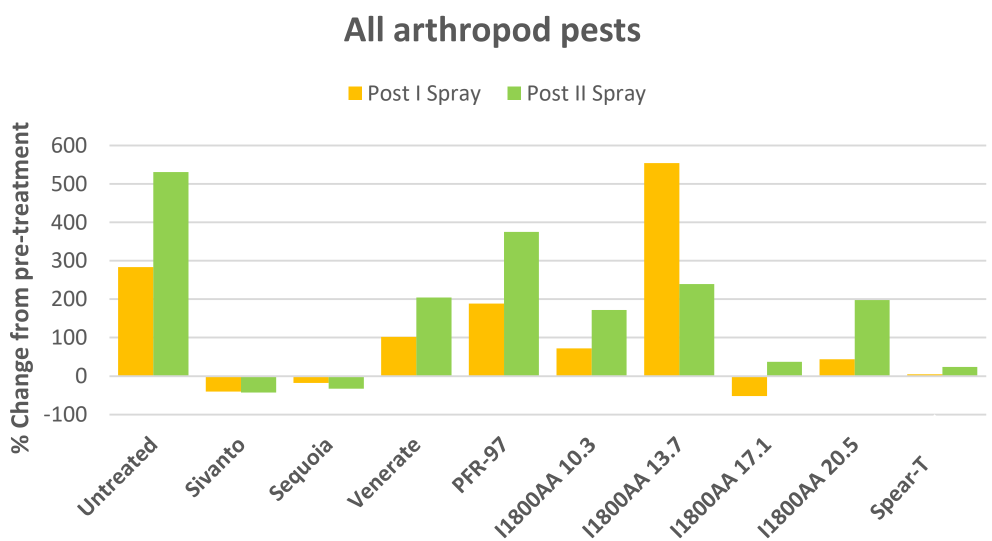
Tukey's HSD $P \leq 0.05$

How? Arthropod management in zucchini





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Tukey's HSD $P \leq 0.05$

How? # Arthropod management in zucchini

Conclusions

- Control efficacy varied among pesticides
  - Chemical Very good
  - Microbial Moderate
  - Botanical Moderate to good
  - Biological Good
- All pesticides can play an important role in IPM

Dara, S. K., S.S.R. Dara, S.S. Dara, and E. Lewis. 2017. Efficacy of chemical, botanical, and microbial pesticides against mite and insect pests on zucchini. Strawberries and Vegetables, 22 December, 2017. https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=25967

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How? Fusarium management in cotton

Treatments

1. Healthy potting mix (negative control)
2. Potting mix with *Fusarium oxyspofurm* f.sp. *vasinfectum* Race 4 (positive control)
3. Potting mix with FOV Race 4 + BotaniGard ES (*B. bassiana* Strain GHA) 2 qrt/ac
4. Potting mix with FOV Race 4 + Met 52EC (*M. brunneum* Strain F52) 2 (foliar rate) and 2.5 (soil rate) qrt/ac
5. Potting mix with FOV Race 4 + Pfr-97 20% WDG (*I. fumosorosea* Apopka Strain 97) 2 lb/ac
6. Potting mix with FOV Race 4 + Actinovate AG (*Streptomyces lydicus* WYEC 108) 54 oz/ac
7. Potting mix with FOV Race 4 + Regalia (Extract of *Reynoutria sachalinensis*) 4 qrt/ac
8. Potting mix with FOV Race 4 + Stargus (*Bacillus amyloliquefaciens* strain F727) 4 qrt/ac

Regimen A - 10 ml of water or treatment liquid at soil application rate administered right after planting cotton seed.

Regimen B - 10 ml of water or treatment liquid at soil application rate administered right after and 1 and 2 weeks after planting.

Regimen C – 10 ml of water or treatment liquid at foliar application rate administered right after planting.

How? Fusarium management in cotton

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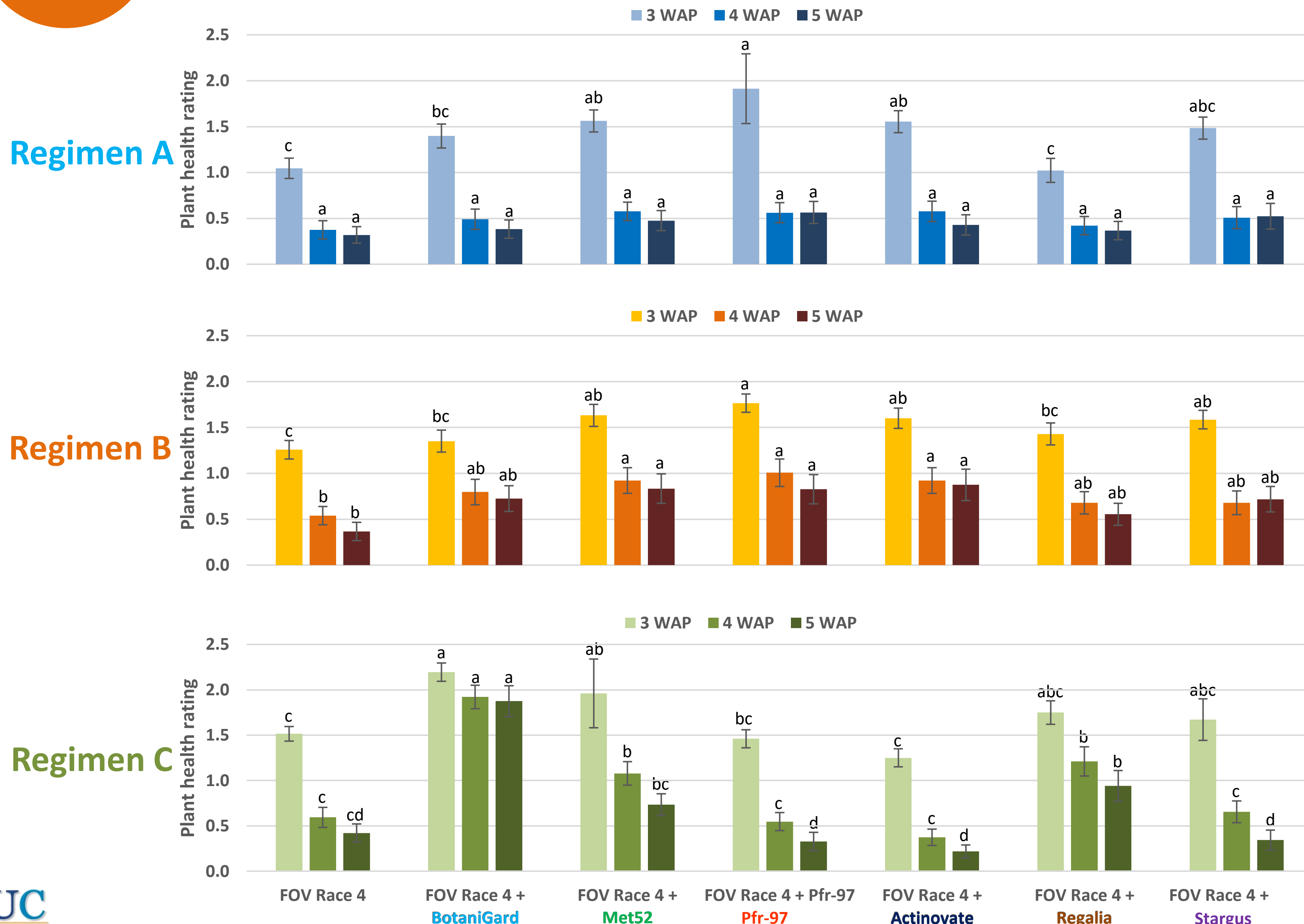
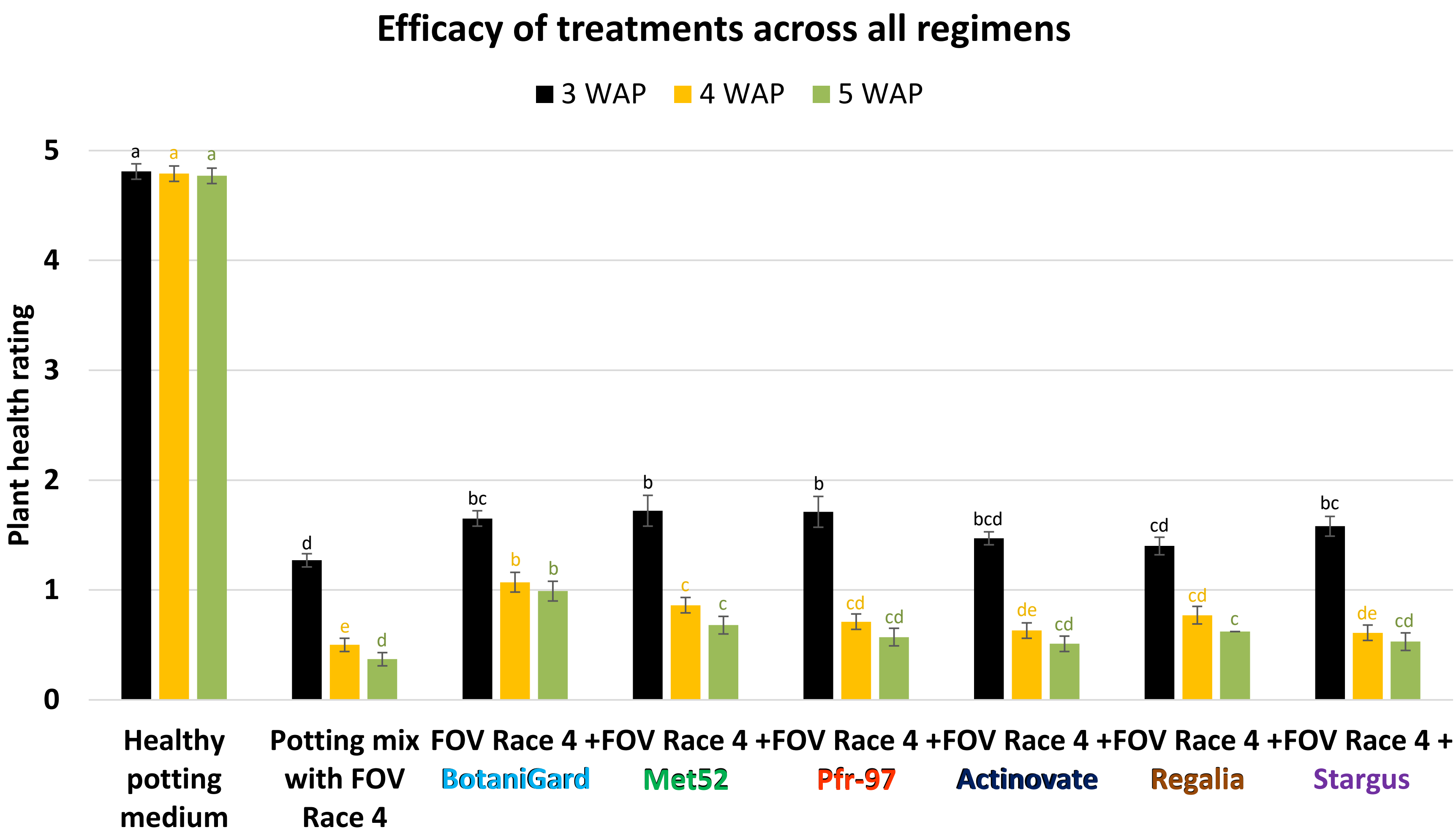
How? Fusarium management in cotton

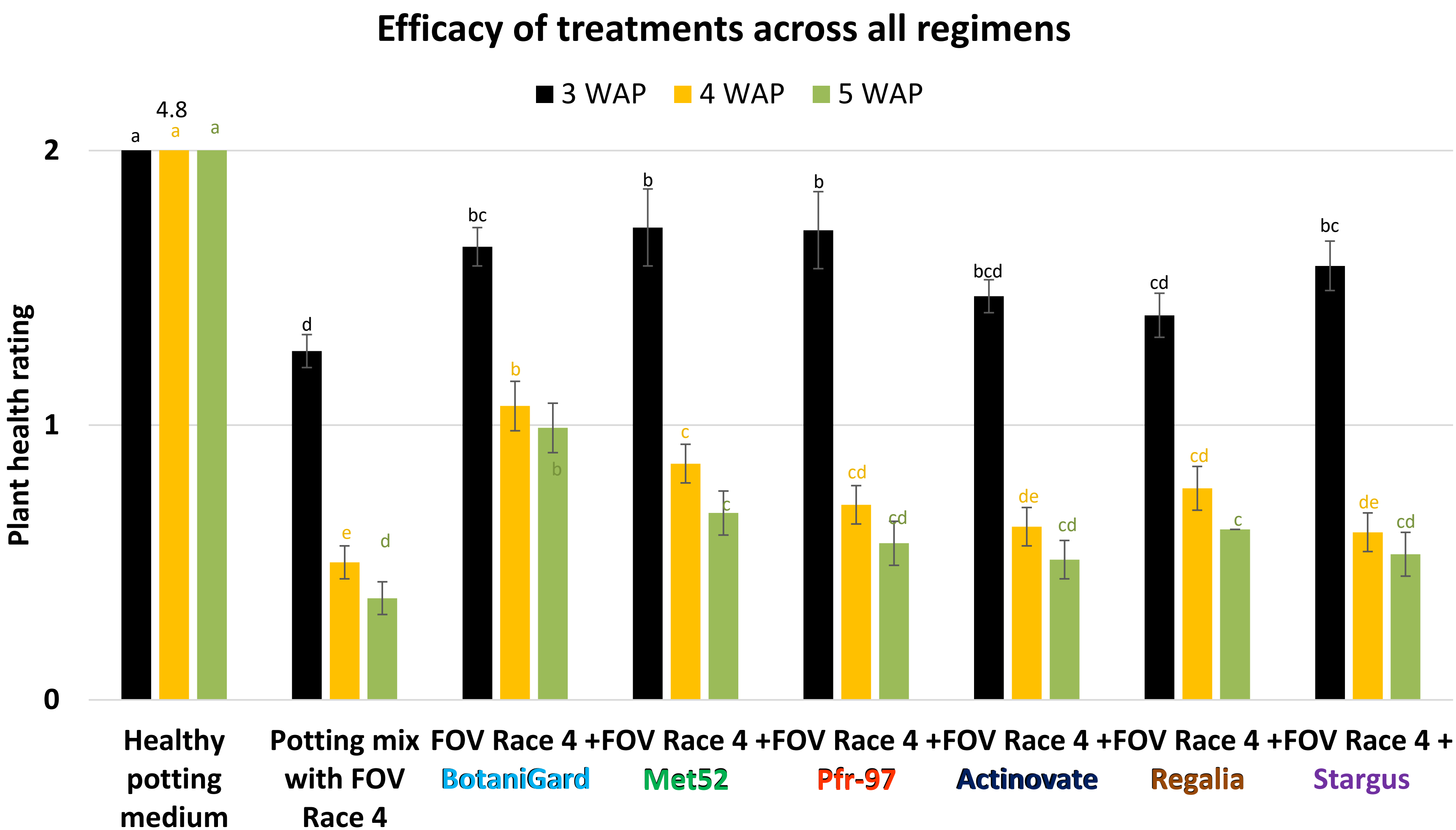


Fusarium management in cotton



Tukey's HSD $P < 0.05$

How? Fusarium management in cotton



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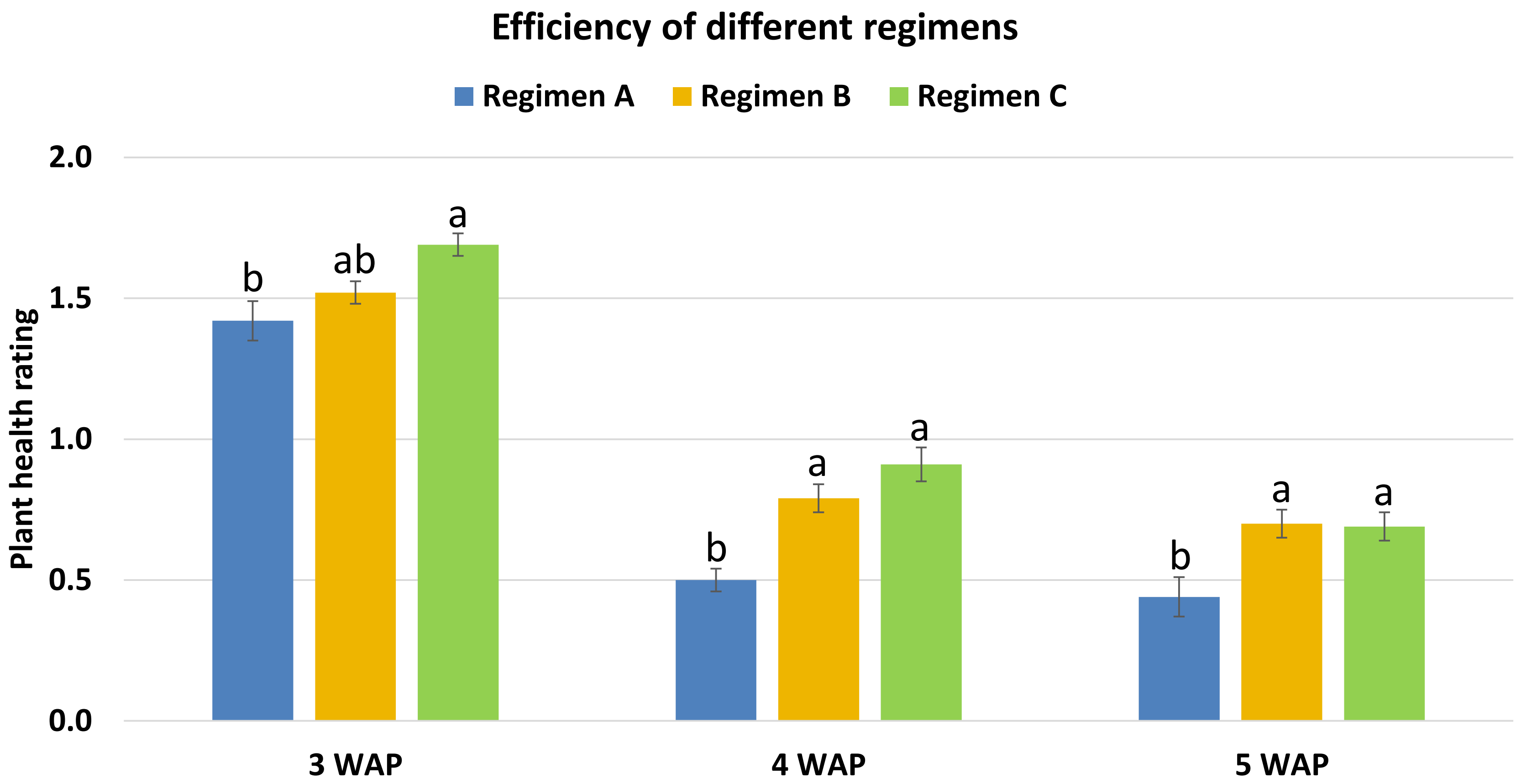
Tukey's HSD $P < 0.05$

How? Fusarium management in cotton



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Tukey's HSD $P < 0.05$

How? **Fusarium management in cotton**

Conclusions

- Entomopathogenic fungi *B. bassiana*, *I. fumosorosea*, and *M. brunneum* antagonized *F. oxysporum* f.sp. *vasinfectum* Race 4
- Multiple applications or higher rates are more effective

Dara, S. K., S. S. Dara, S.S.R. Dara, and T. Anderson. 2016. First report of three entomopathogenic fungi offering protection against the plant pathogen, *Fusarium oxysporum* f.sp. *vasinfectum*. https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=22199

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How? Botrytis management in strawberry

1 Untreated control
2 Captan 2 qrt (captan) alternated with Switch 625WG 14 oz (cyprodinil+fludioxonil)
3 Thiram 2.6 qrt (thiram) alternated with Elevate 50 WDG 1.5 lb (fenhexamid)
4 Aleo 3 fl oz (78% Garlic oil)
5 Aleo 6 fl oz
6 Aleo 12 fl oz
7 Botector 10 oz (*Aureobasidium pullulans* DSM 14940 and 14941)
8 BotryStop 4 lb (*Ulocladium oudemansii* strain U3)
9 BotaniGard ES 2 qrt (*Beauveria bassiana* strain GHA)
10 PFR-97 WDG 2 lb (*Isaria fumosorosea* Apopka strain 97)

- Dyne-Amic was used at 0.125% for all except Aleo treatments that had 719 Spreader (trisiloxane alkoxylate) at 1 pint/100 gal
- Spray volume 100 gpa applied at 40 PSI using flat fan nozzles
- Weekly spray application (on 5, 12, 19, 26 April, 3 and 11 May, 2018) followed by harvesting and postharvest disease (Botrytis and others) rating at 3 and 5 days of storage

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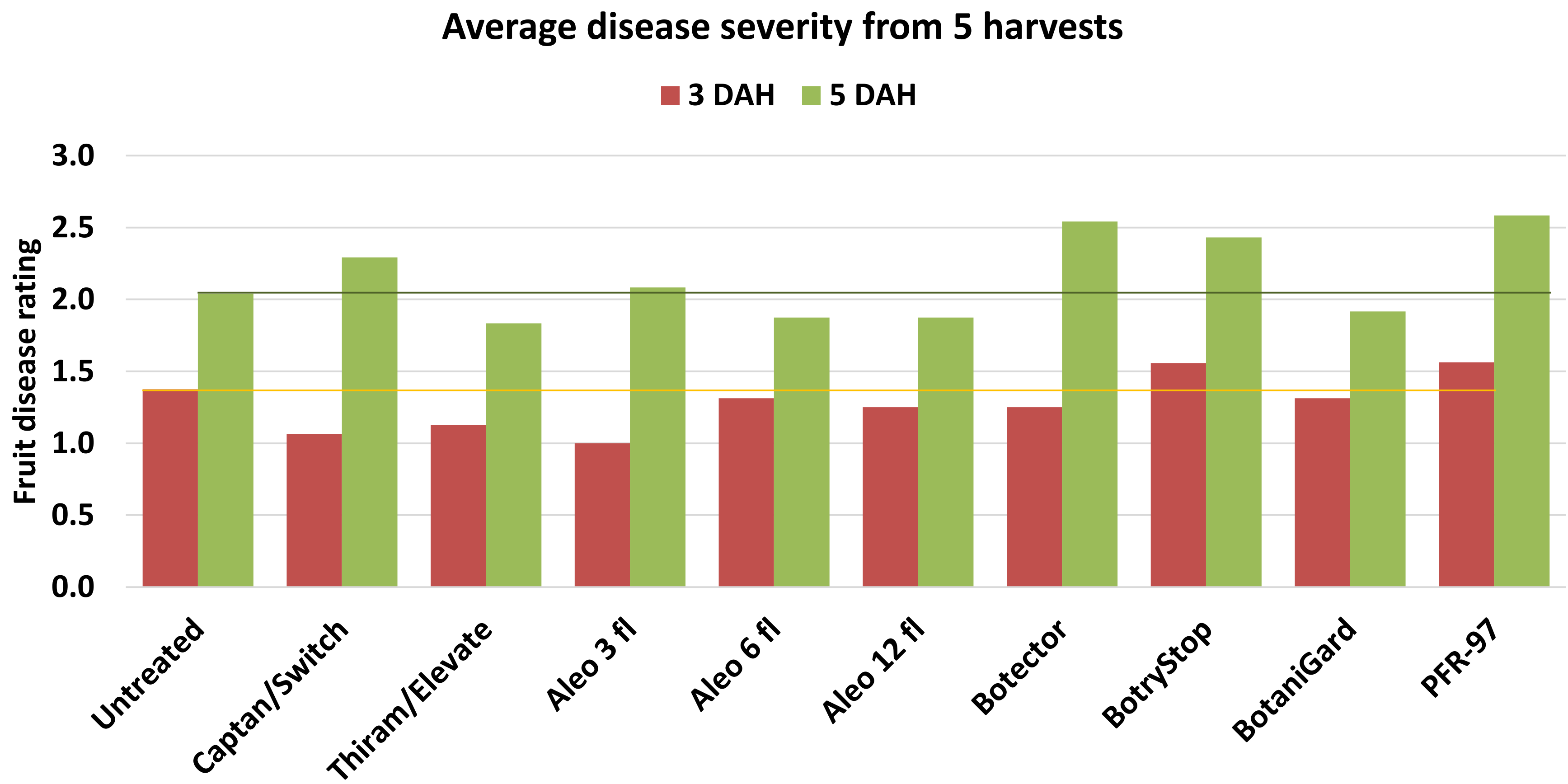
How? Botrytis management in strawberry



0=No disease
1=1-25%
2=26-50%
3=51-75
4=76-100%

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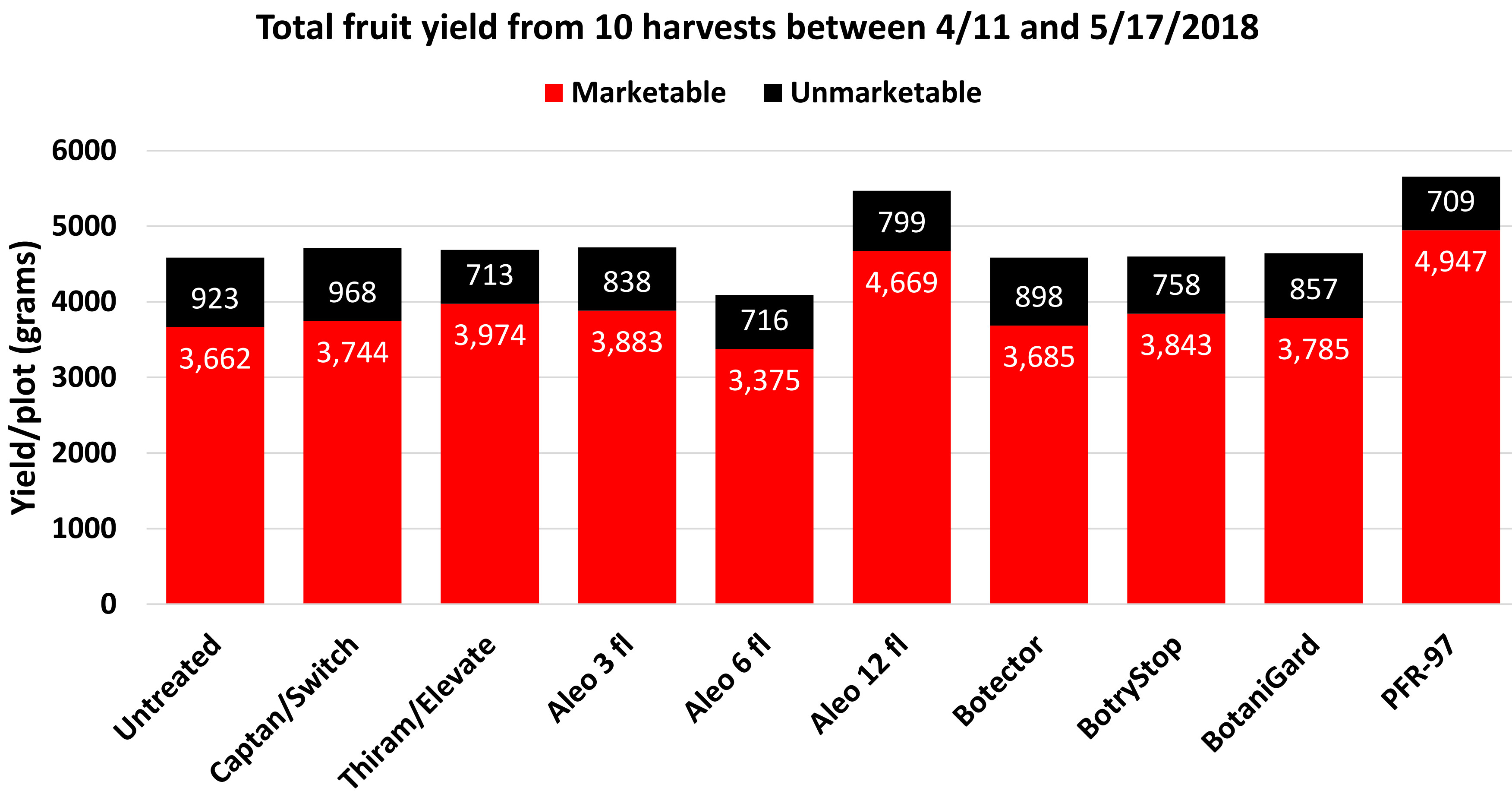
How? Botrytis management in strawberry



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How? Botrytis management in strawberry

Conclusions

- Microbial and botanical fungicides have a potential in botrytis control, and entomopathogenic fungi also seem to have a positive impact. Additional studies are necessary to further investigate their efficacy.

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How? *Macrophomina* vs. entomopathogenic fungi

1 Untreated control

2 Soil inoculated with *Macrophomina phaseolina*

3 Soil inoculated with *Beauveria bassiana* 1 week prior to *Macrophomina phaseolina* inoculation

4 Soil inoculated with *Metarhizium anisopliae* s.l. 1 week prior to *Macrophomina phaseolina* inoculation

5 Soil inoculated with *Beauveria bassiana* at the time of *Macrophomina phaseolina* inoculation

6 Soil inoculated with *Metarhizium anisopliae* s.l. at the time of *Macrophomina phaseolina* inoculation

7 Soil inoculated with *Beauveria bassiana* 1 week after *Macrophomina phaseolina* inoculation

8 Soil inoculated with *Metarhizium anisopliae* s.l. 1 week after *Macrophomina phaseolina* inoculation

- Weekly observations were taken starting from 1 week after the final application
- Plant health was rate on a scale of 0 to 5 where 0=dead, 5=very healthy, and the rest in between.

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How? *Macrophomina* vs. entomopathogenic fungi

How? *Macrophomina* vs. entomopathogenic fungi

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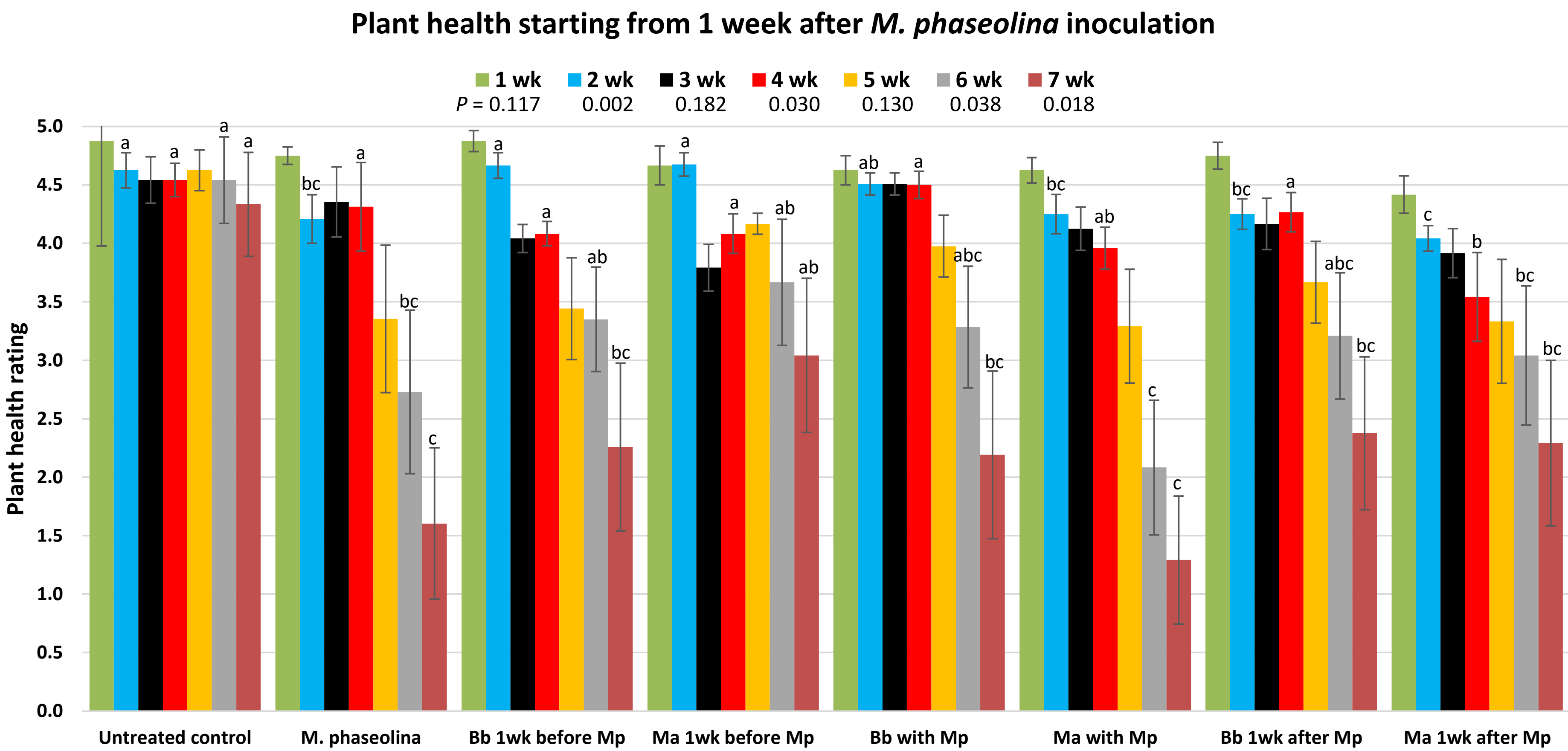
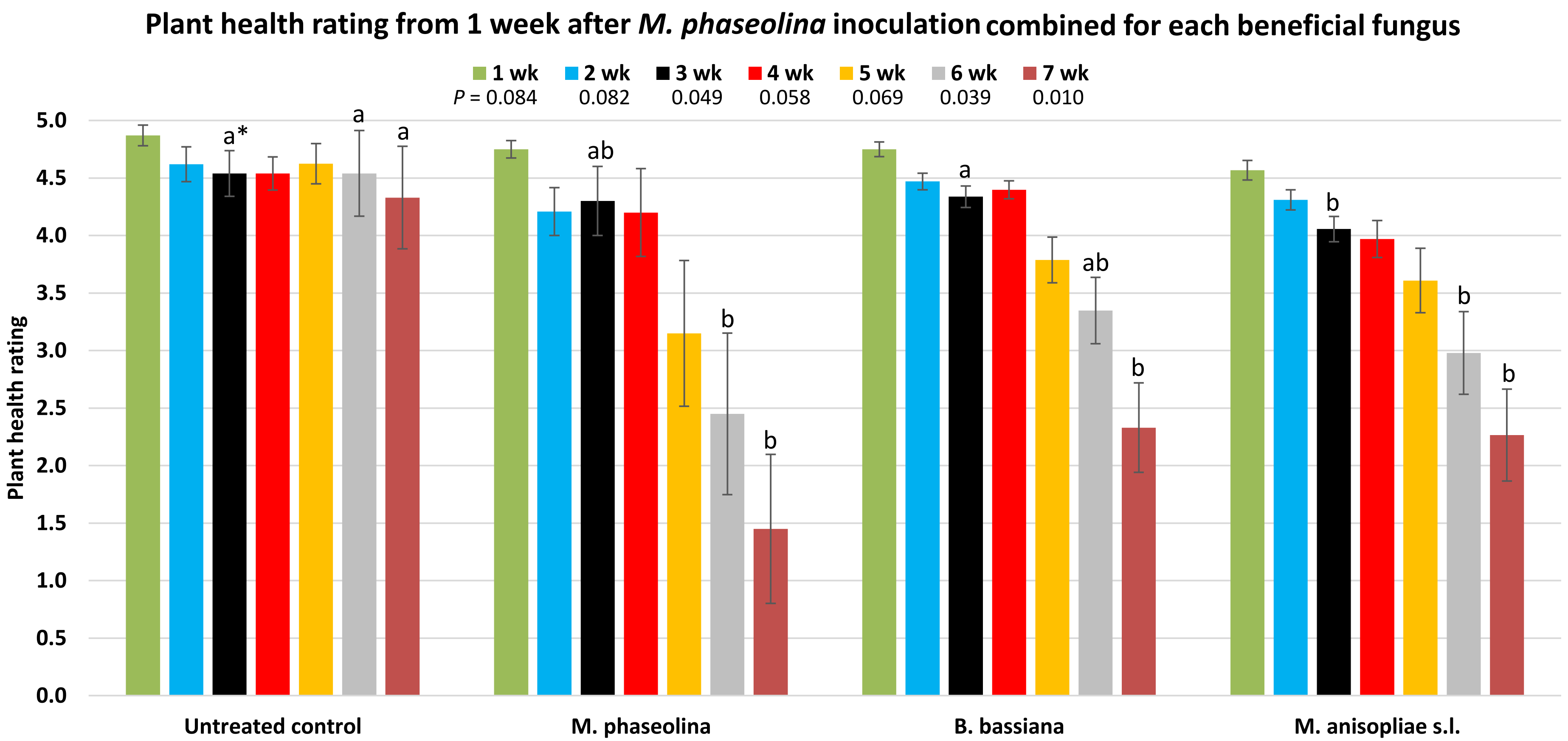
How? *Macrophomina* vs. entomopathogenic fungi



How? *Macrophomina* vs. entomopathogenic fungi



*Bars with no or same letter within each week are not significantly different (LSD test)

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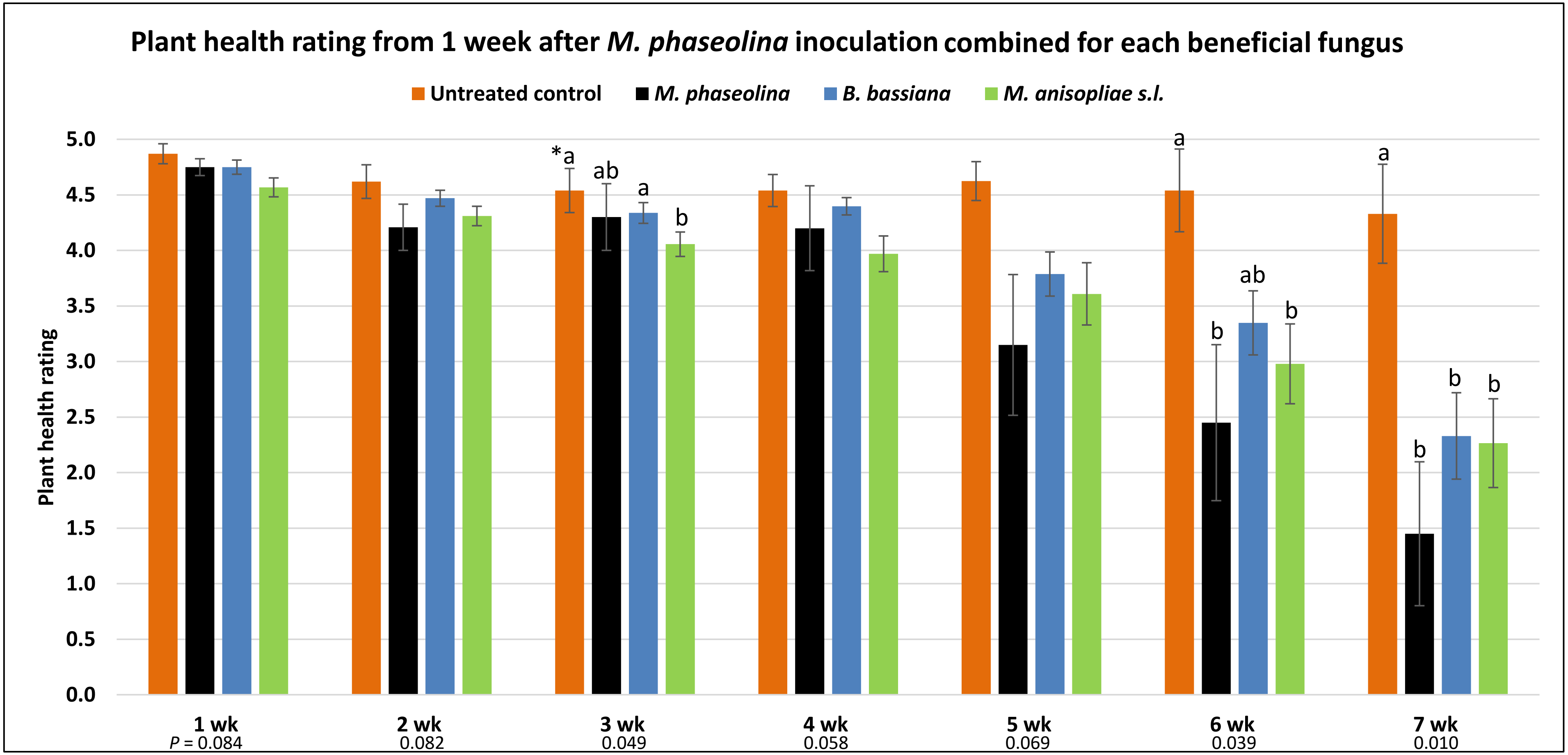
How? *Macrophomina* vs. entomopathogenic fungi



*Bars with no or same letter within each week are not significantly different (LSD test)

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How? *Macrophomina* vs. entomopathogenic fungi

Conclusions

- Entomopathogenic fungi offered some level of protection again the charcoal rot fungus. Additional studies are necessary to optimize application rates and frequency.

Dara, S. K., S. S. Dara, and S.S.R. Dara. 2018. Preliminary report on the potential of *Beauveria bassiana* and *Metarhizium anisopliae* s.l. in antagonizing the charcoal rot causing fungus *Macrophomina phaseolina* in strawberry. https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=28274

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Conclusions

- Microbial control agents play a critical role in crop protection
- Entomopathogenic fungi can play multiple roles in crop production and protection
- There is a growing interest in their use for sustainable agriculture
- The more we understand the better we can explore their potential

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Thank you!

- Growers, collaborators, and technicians
- Santa Barbara County Nursery and Flower Growers Association

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eJournals:	http://ucanr.edu/strawberries-vegetables
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