RUTGERS
School of Environmental and Biological Sciences
DEPARTMENT OF ENTOMOLOGY

NEVF
New England Vegetable and Fruit Conference

NOVEL BEHAVIOR-BASED STRATEGIES FOR SWD

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Entomology

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New England Veg & Fruit Conference
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BLUEBERRY INSECT/MITE PESTS

Growth stage	pre-bloom	bloom	mid-season	pre-harvest	harvest	post-harvest
Scale						
Cranberry weevil						
Leafrollers						
Spanworms						
Gypsy moth						
Thrips						
Gall midge						
Plum curculio						
Cranberry fruitworm						
Aphids						
Leafhoppers						
Leafminers						
Oriental beetle						
Blueberry maggot						
Japanese beetle						
BB bud mite						

Bars show period when scouting and management of the pest is most important.

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BLUEBERRY MAGGOT IPM

Treatment Thresholds

Blueberry Maggot IPM

Monitoring

Reduced-risk Chemical Control

Site-specific Applications

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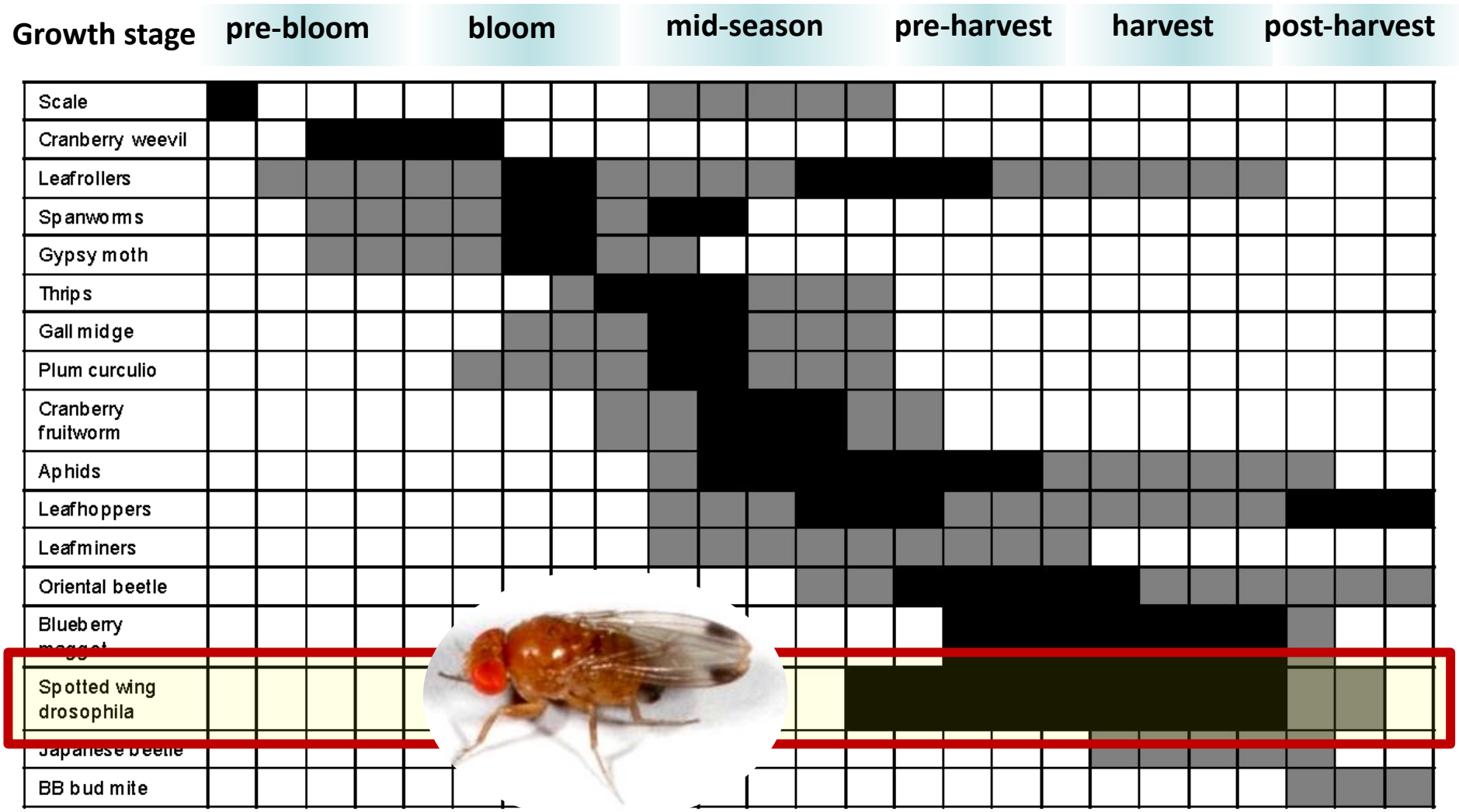
BLUEBERRY INSECT/MITE PESTS



Bars show period when scouting and management of the pest is most important.

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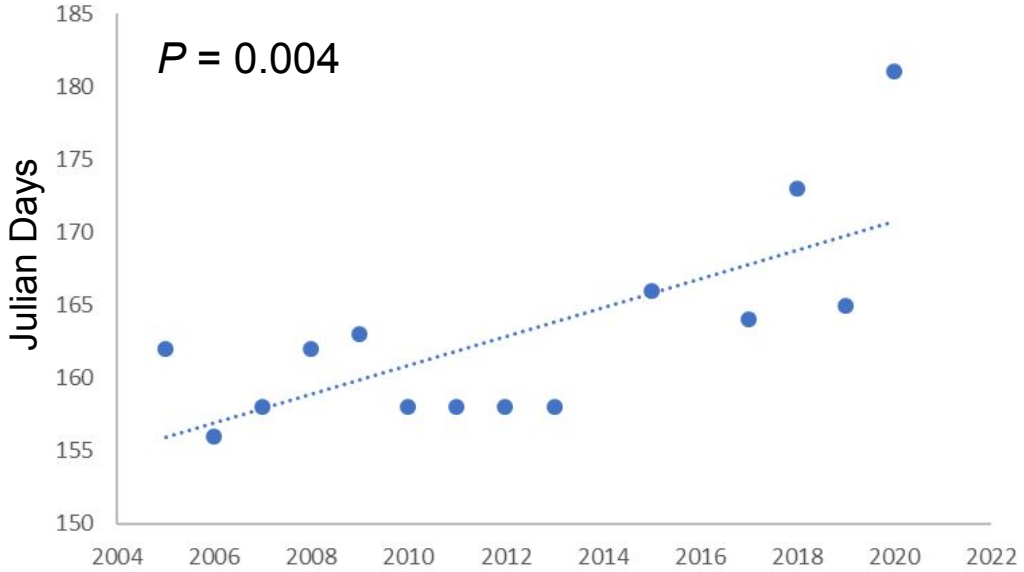
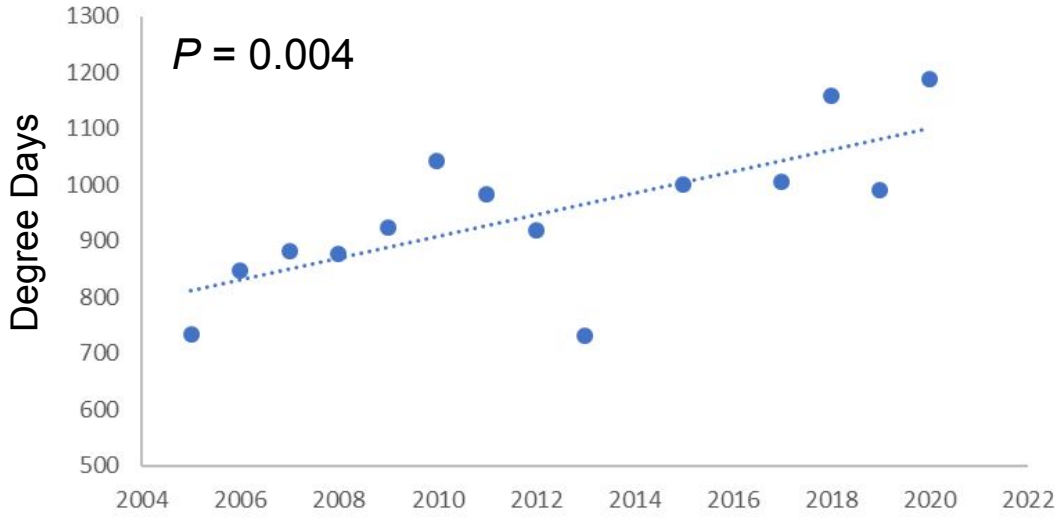
BLUEBERRY MAGGOT FLY





Shope, Rodriguez-Saona et al.

Emergence of blueberry maggot fly later and later each year.

Possibly due to biotic (competition with SWD) factors.

A possible case of **Competitive Exclusion**.

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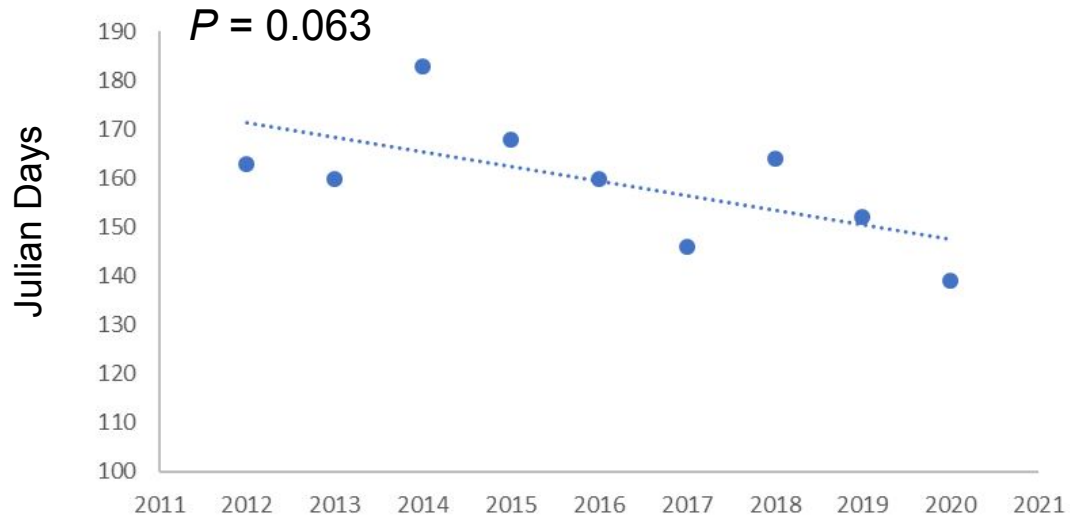
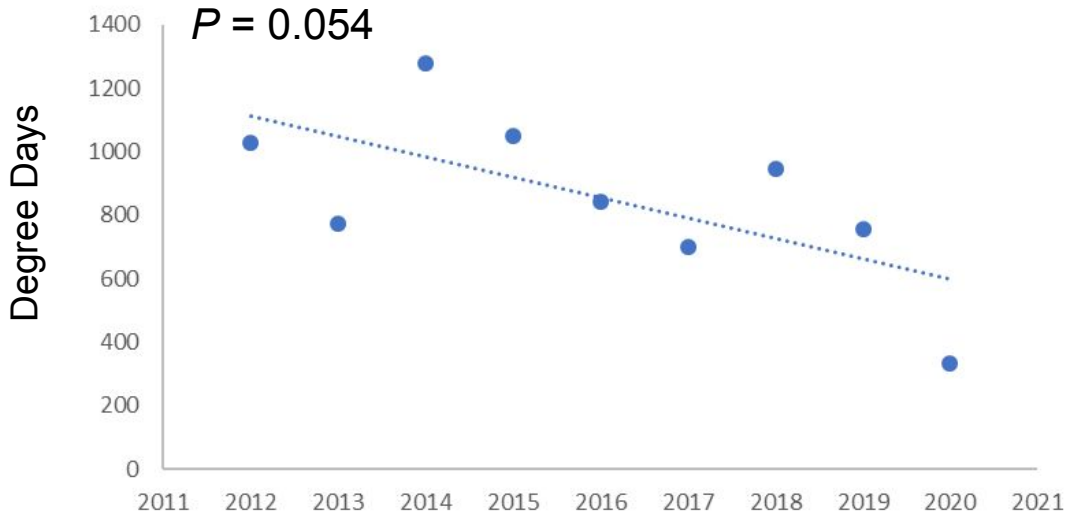
SPOTTED-WING DROSOPHILA





Emergence of SWD earlier and earlier each year.

Possibly due to abiotic (climate change) factors (number of winter freezing days).

Shope, Rodriguez-Saona et al.

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ON-GOING RESEARCH

SWD IPM

Cultural Control

- Sanitation
- Pruning
- Irrigation
- Weed mat/mulches
- Netting
- Surrounding habitats

Behavioral Control

Attractants:

- Fermentation
- Yeast
- Fruit
- Leaves

Chemical Control

New insecticides:

- Exirel
- Delegate
- Danitol
- Organic Options

Biological Control

Ganaspis kimorum

Post-Harvest Management

32ºF for 3-5 d

Monitoring

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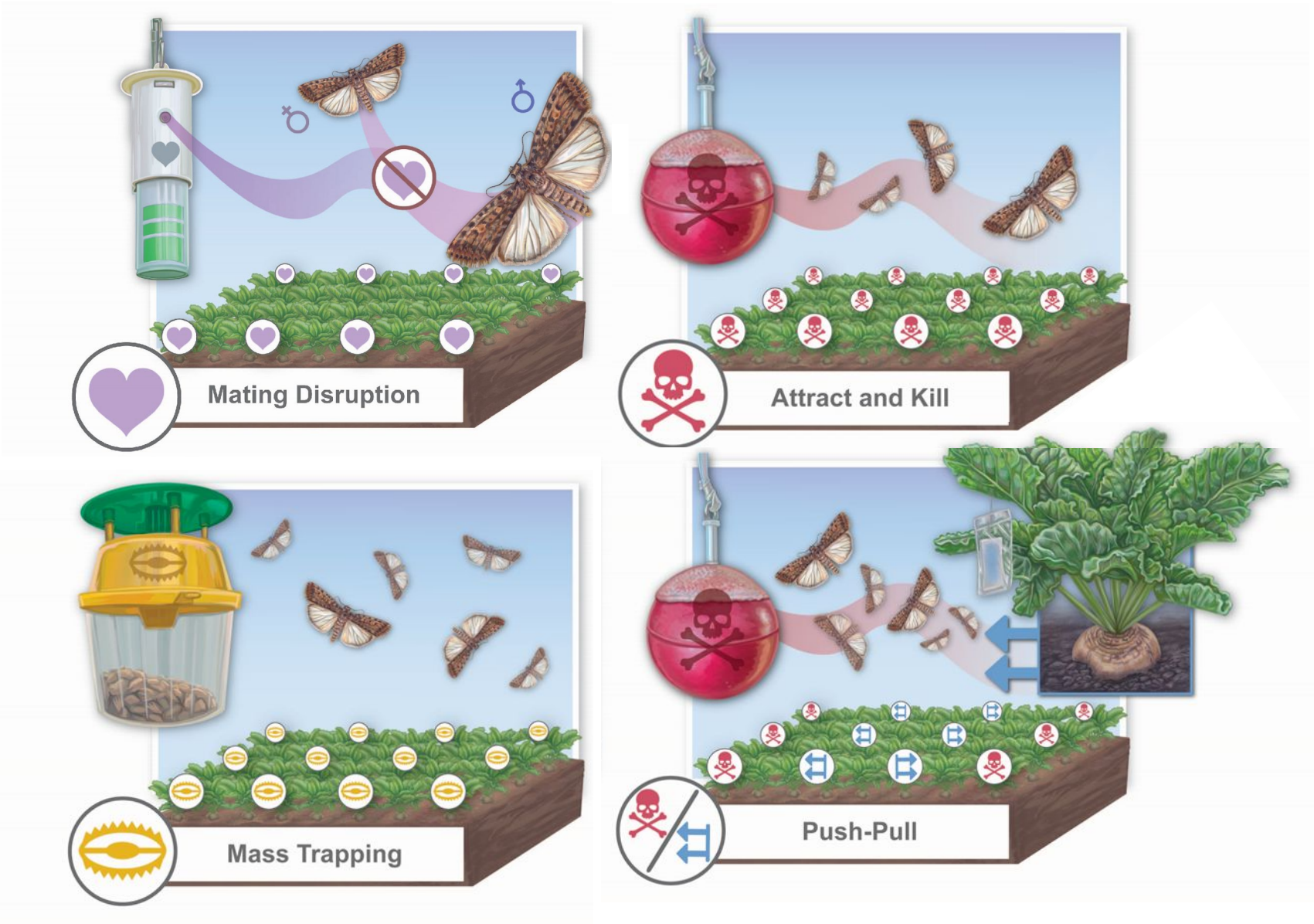
BEHAVIORAL CONTROL



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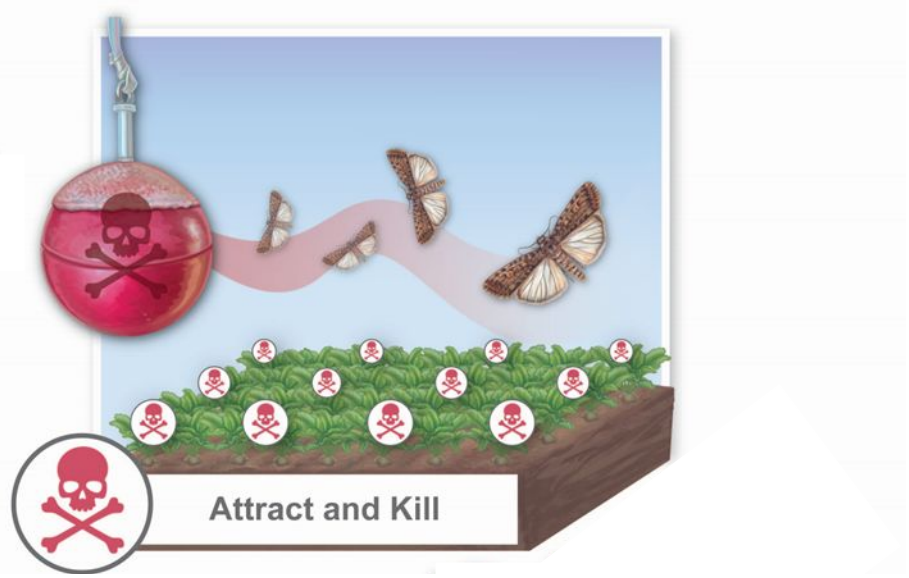
BEHAVIORAL CONTROL



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ATTRACT-AND-KILL

- Attractive cues:
  - Visual
  - Chemical
- Insecticide kills pest
- Reduce injury
- Reduce non-target affects

CAN IT WORK FOR SWD?

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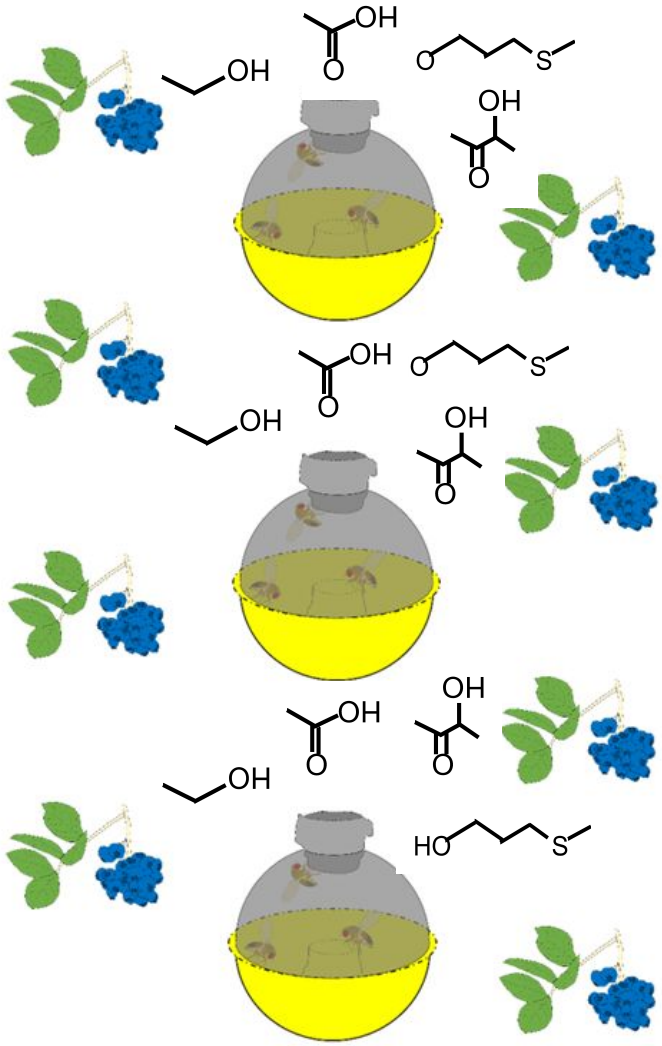
ATTRACT-AND-KILL SWD

Attractants + Phagostimulant + Insecticide

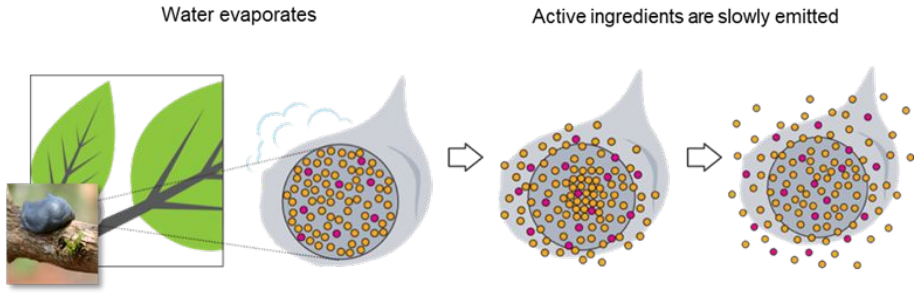


SPLAT SWD A&K (HOOK SWD/ ACTTRA SWD)

Combi-Protec

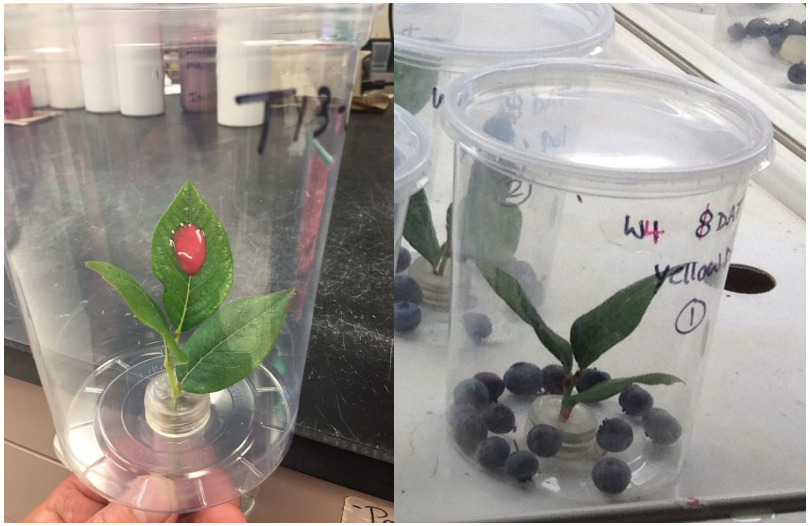
SPLAT SWD A&K

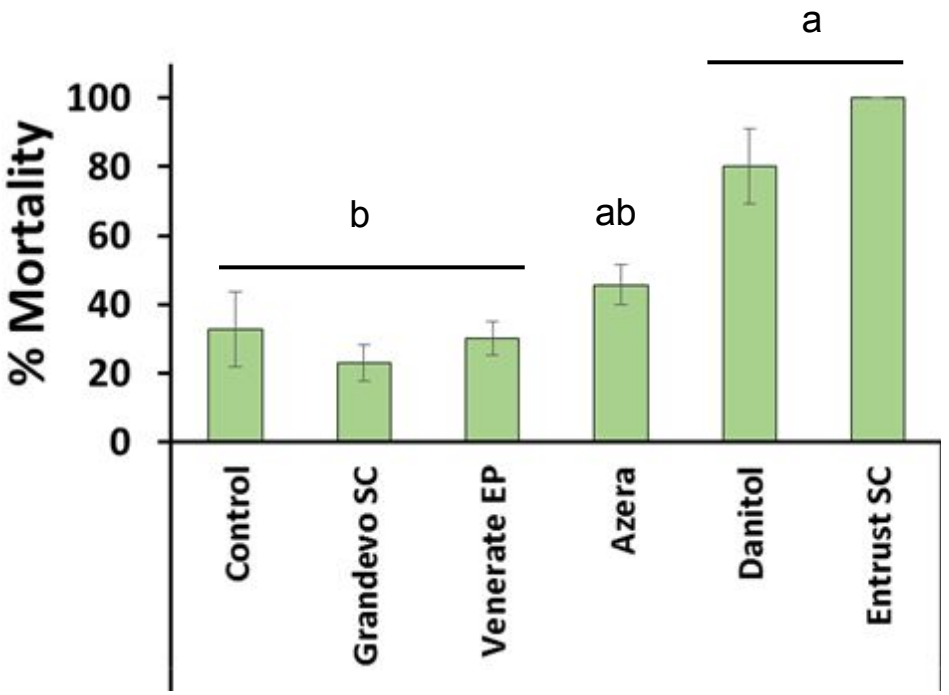
- ISCA Technologies Inc.



Lab Trial

- Four organic insecticides: Grandevo, Venerate, Azera, Entrust
- One conventional insecticide: Danitol
- SWD mortality after 24 h





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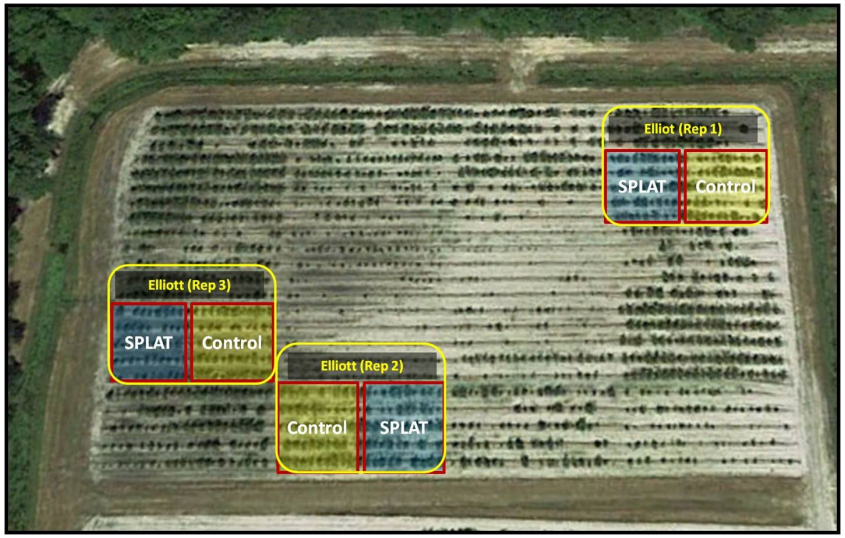
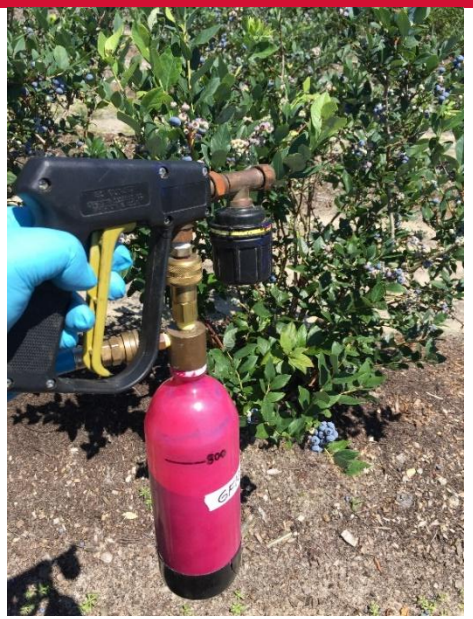
SPLAT SWD A&K

Small Plot Field Trial

- 2-3 SPLAT SWD A&K applications during fruit ripening. Plots = 0.04 ha.
- Fruit samples (~150 berries/plot) taken 1 or 2 weeks after.
- Checked SWD emergence in the laboratory.





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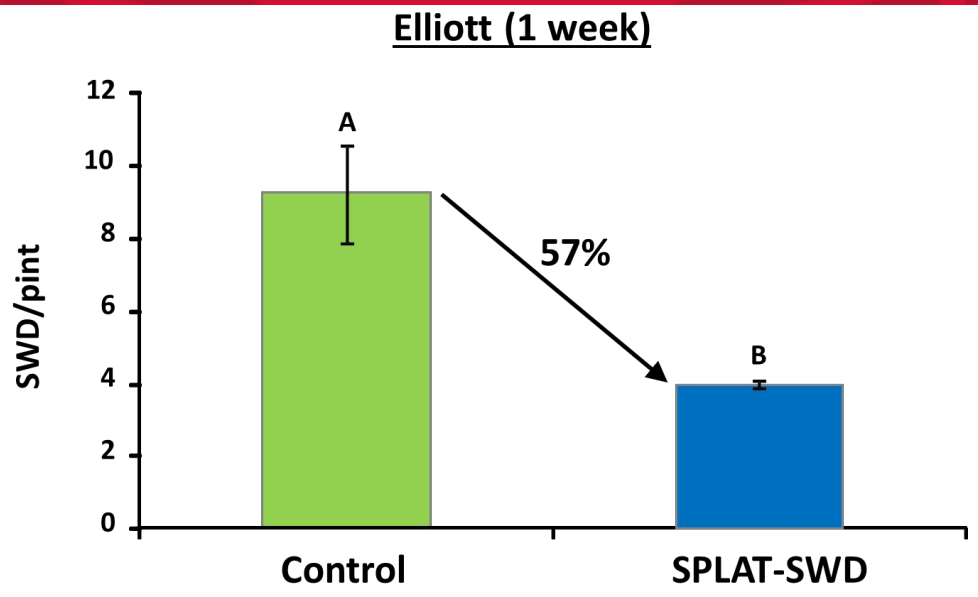
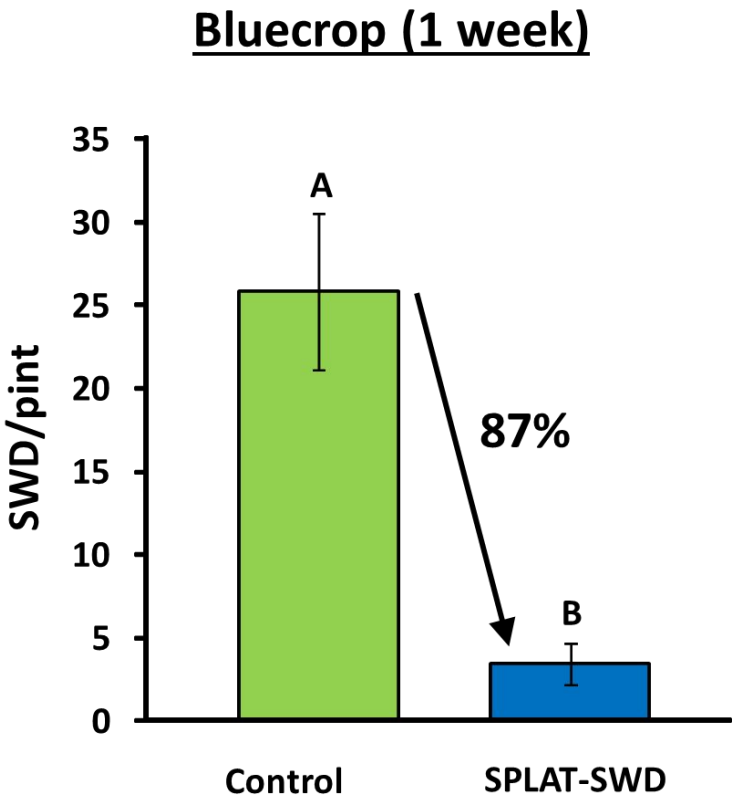
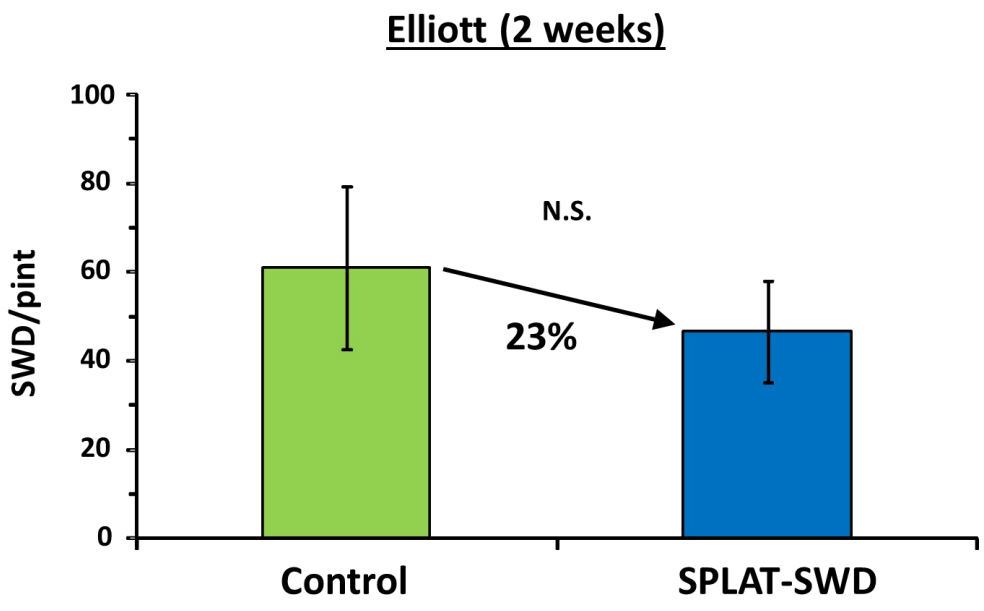
SPLAT SWD A&K





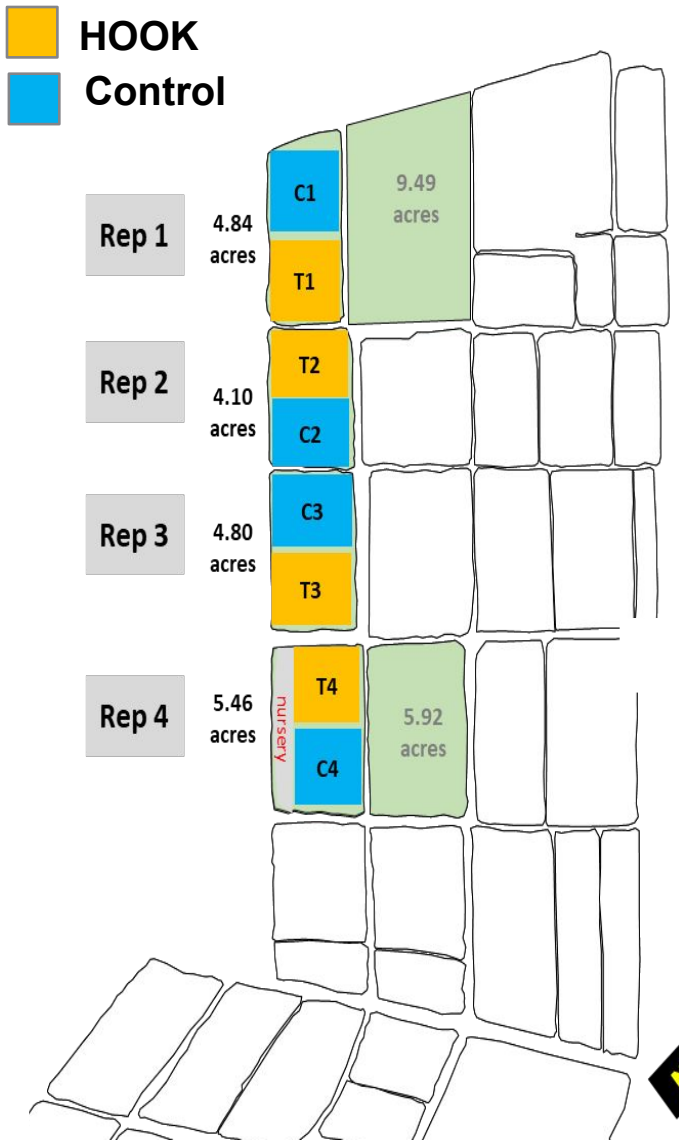


Klick, Rodriguez-Saona et al. 2019

SPLAT SWD A&K

Large Plot Field Trial

- Commercial blueberry farms.
- Treatments: SPLAT SWD A&K vs Control.
- Applications every week or every other week.



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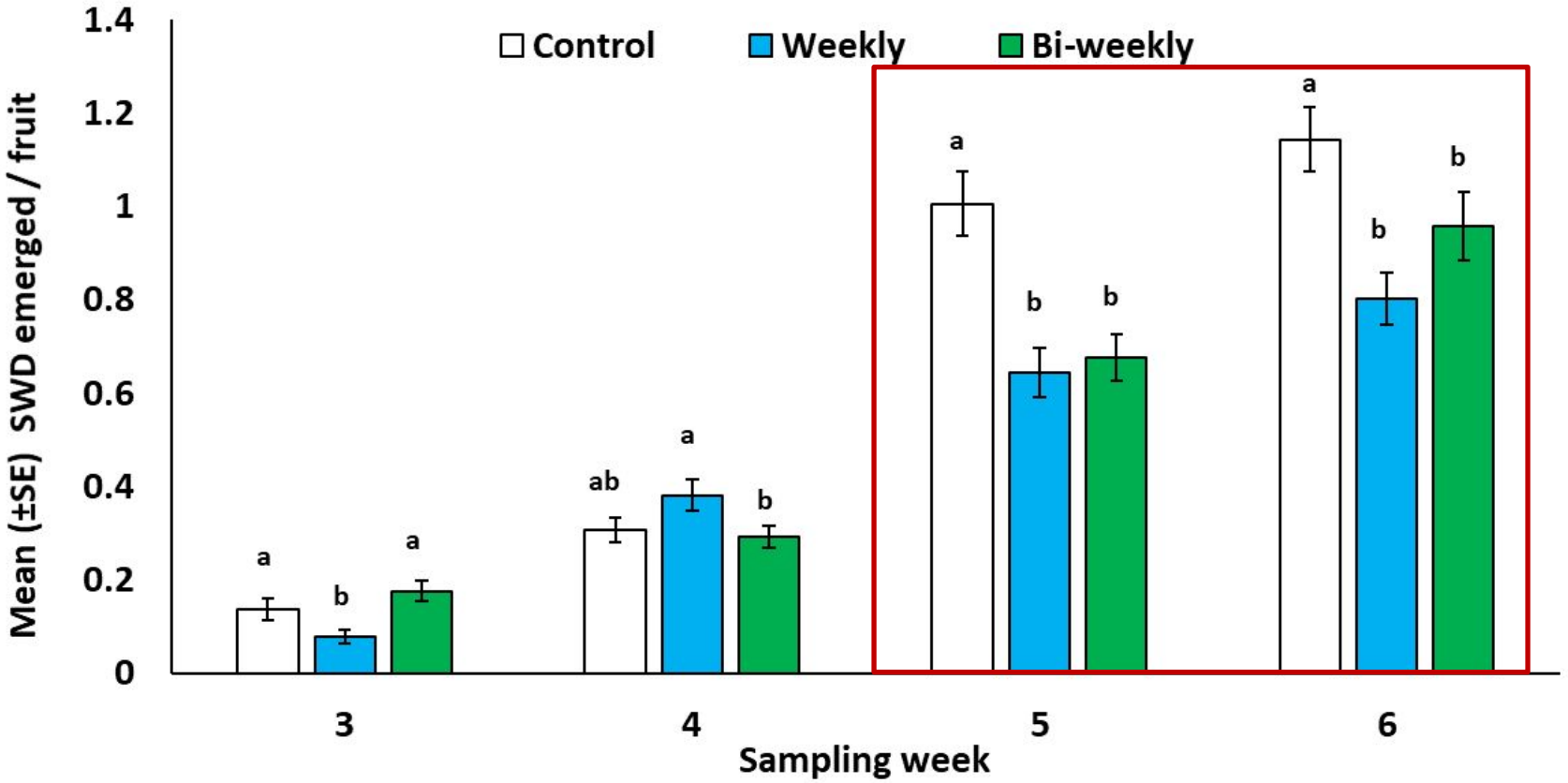
SPLAT SWD A&K



SPLAT SWD A&K REDUCES FRUIT INFESTATION

Urbaneja-Bernat, Rodriguez-Saona et al. 2022

SPLAT SWD A&K

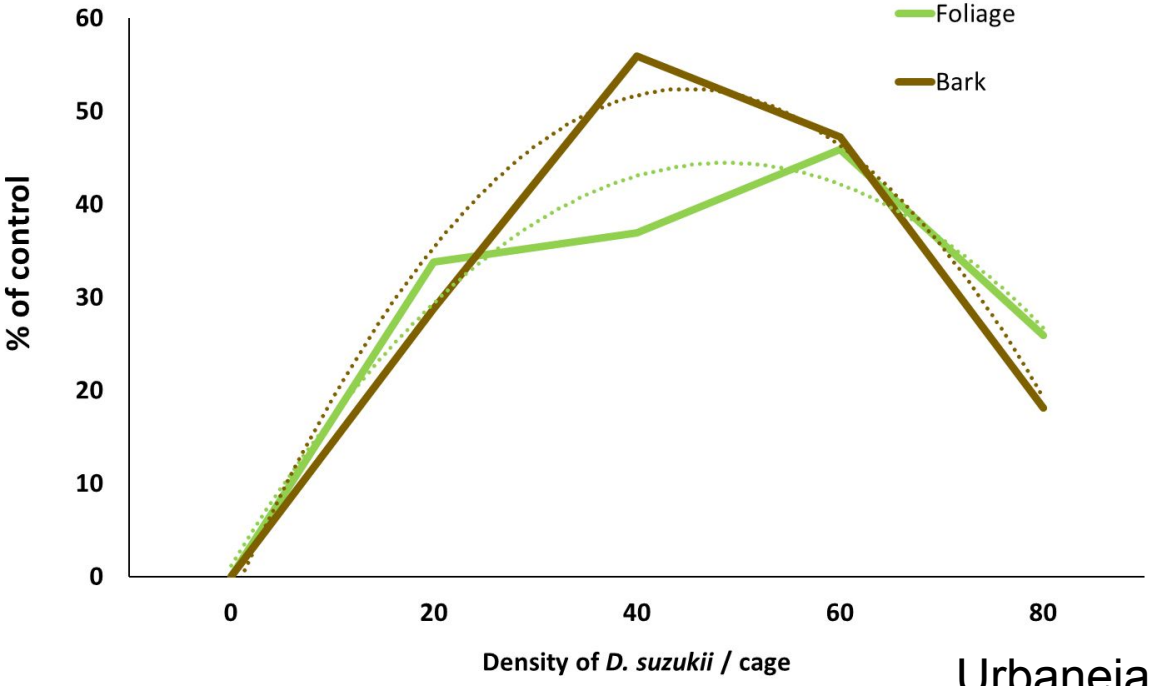
Cage Field Trial

- Five SWD densities: 0, 20, 40, 60, and 80.
- <u>Treatments</u>

  No = No SPLAT SWD A&K

  Foliage = SPLAT SWD A&K applied to a leaf

  Bark = SPLAT SWD A&K applied to the bark



Urbaneja-Bernat, Rodriguez-Saona et al.

SPLAT SWD A&K

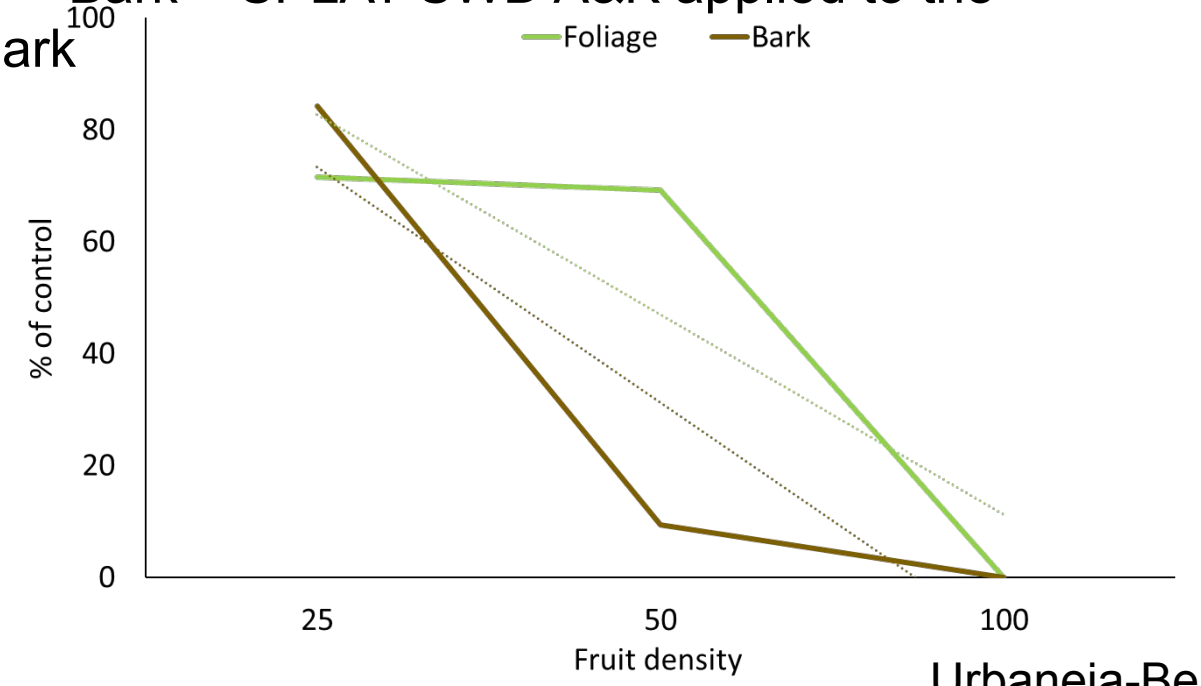
Cage Field Trial

- Three fruit densities: 25, 50, and 100.
- <u>Treatments</u>

  No = No SPLAT SWD A&K

  Foliage = SPLAT SWD A&K applied to a leaf

  Bark = SPLAT SWD A&K applied to the bark



Urbaneja-Bernat, Rodriguez-Saona et al.

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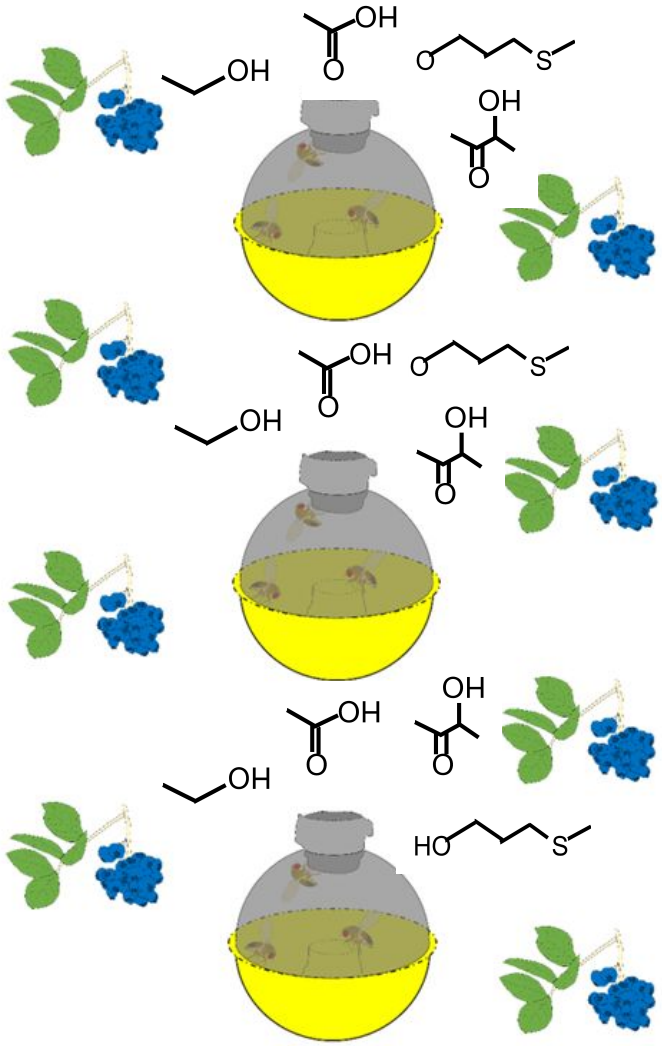
ATTRACT-AND-KILL SWD

Attractants + Phagostimulant + Insecticide



SPLAT SWD A&K (HOOK SWD/ ACTTRA SWD)

Combi-Protec

COMBI-PROTEC

- Insect bait (Andermatt USA Corporation).
- Feeding stimulant.
- Adjuvant – tank mix with any insecticide.
- Treatments:

1) UTC

2) Spinetoram (Delegate) or Spinosad (Entrust) 6 oz

3) Delegate/Entrust (6 oz) + Combi-protec

4) Delegate/Entrust (3 oz) + Combi-protec

COMBI-PROTEC

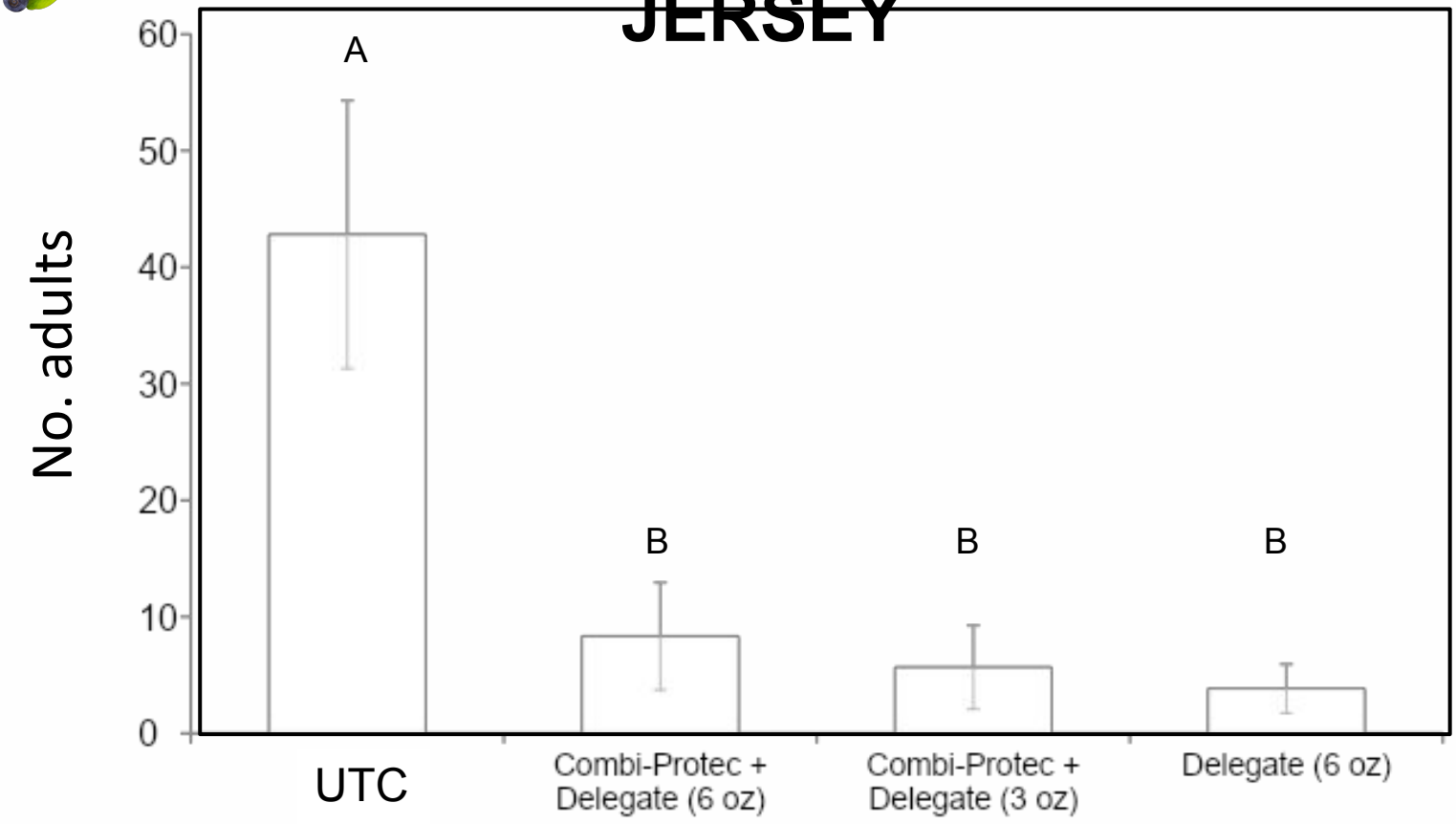



Cage Field Trial

- Highbush and lowbush blueberries and raspberries.
- OR, NJ, ME, NY.
- SWD flies (100) were released in each cage.
- Fruit were sampled and evaluated for number of eggs laid, larvae, and adult emergence.

COMBI-PROTEC

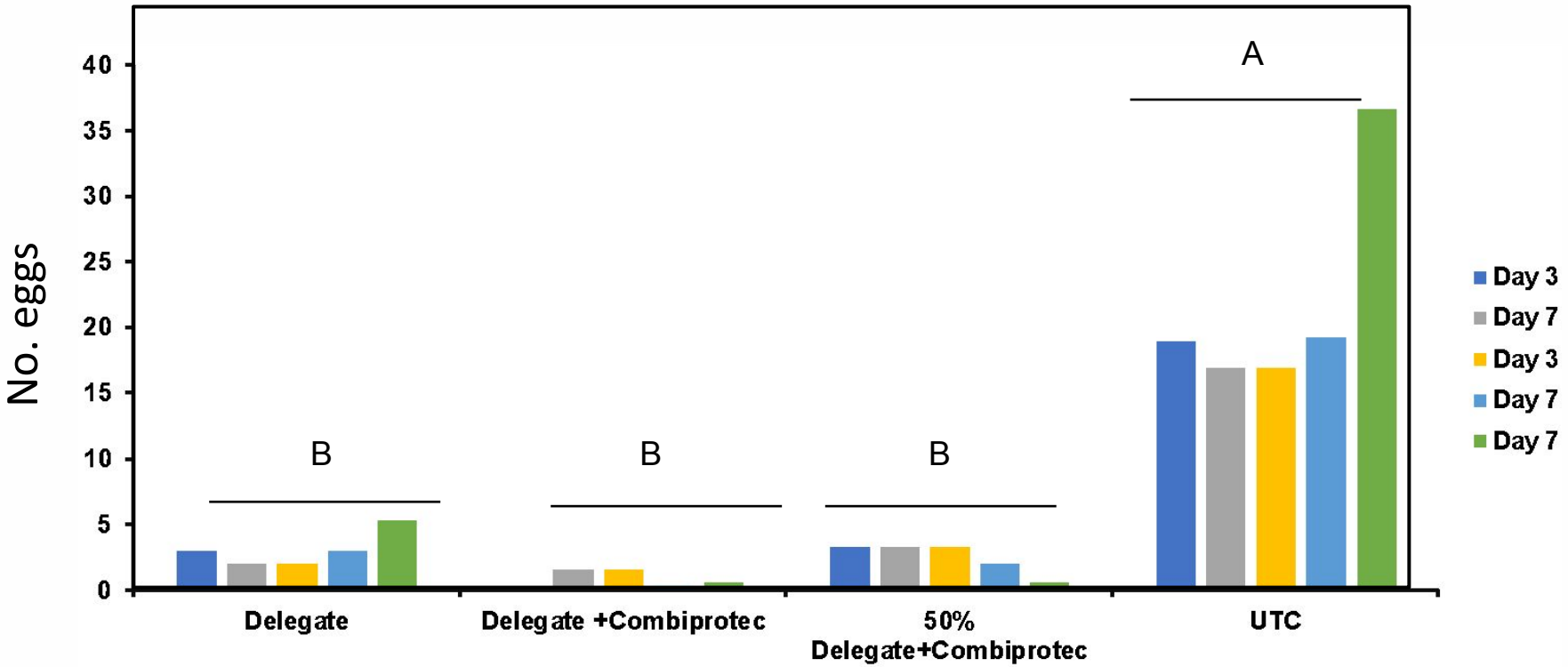
NEW JERSEY



Unpublished data

COMBI-PROTEC

OREGON



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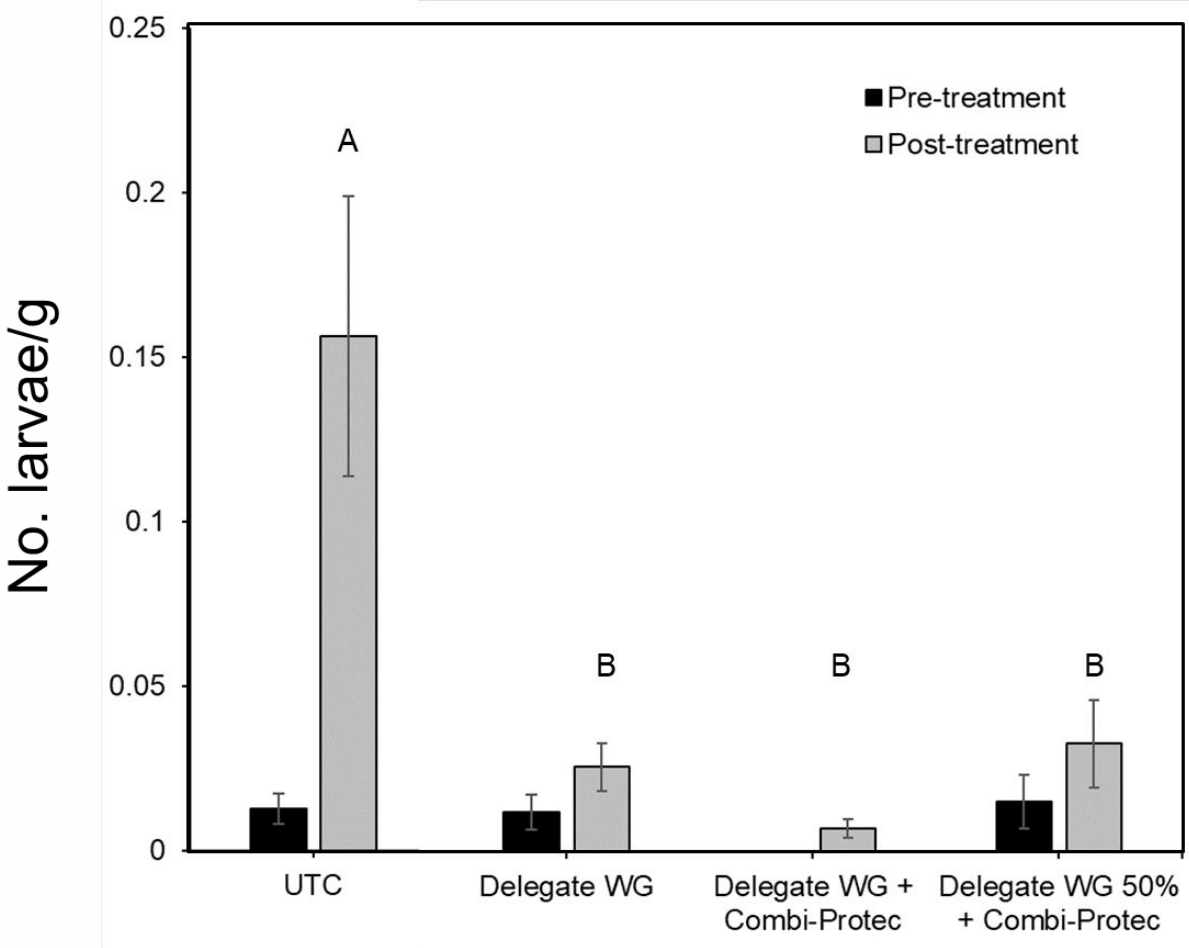
COMBI-PROTEC

MAINE



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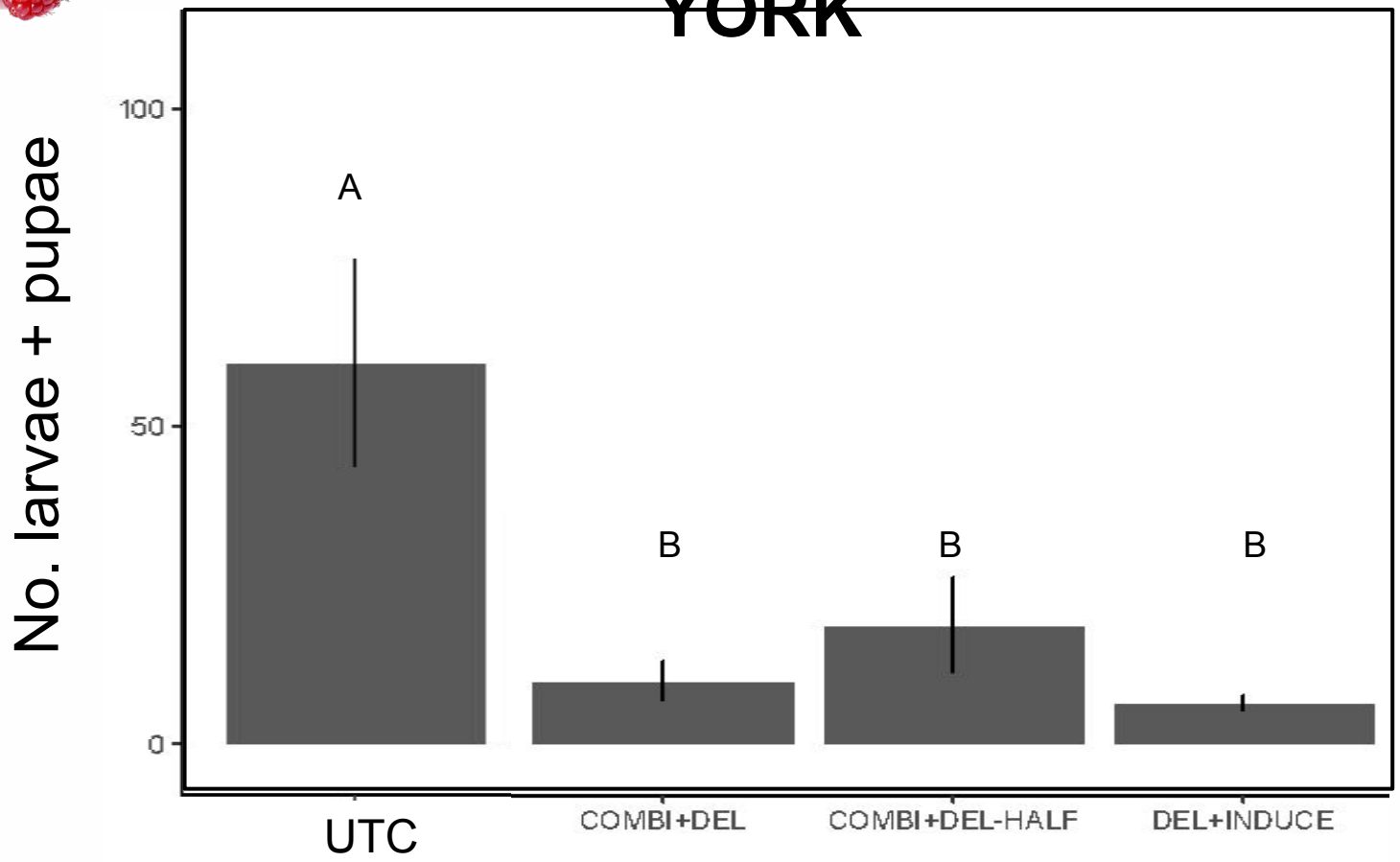
COMBI-PROTEC

NEW YORK



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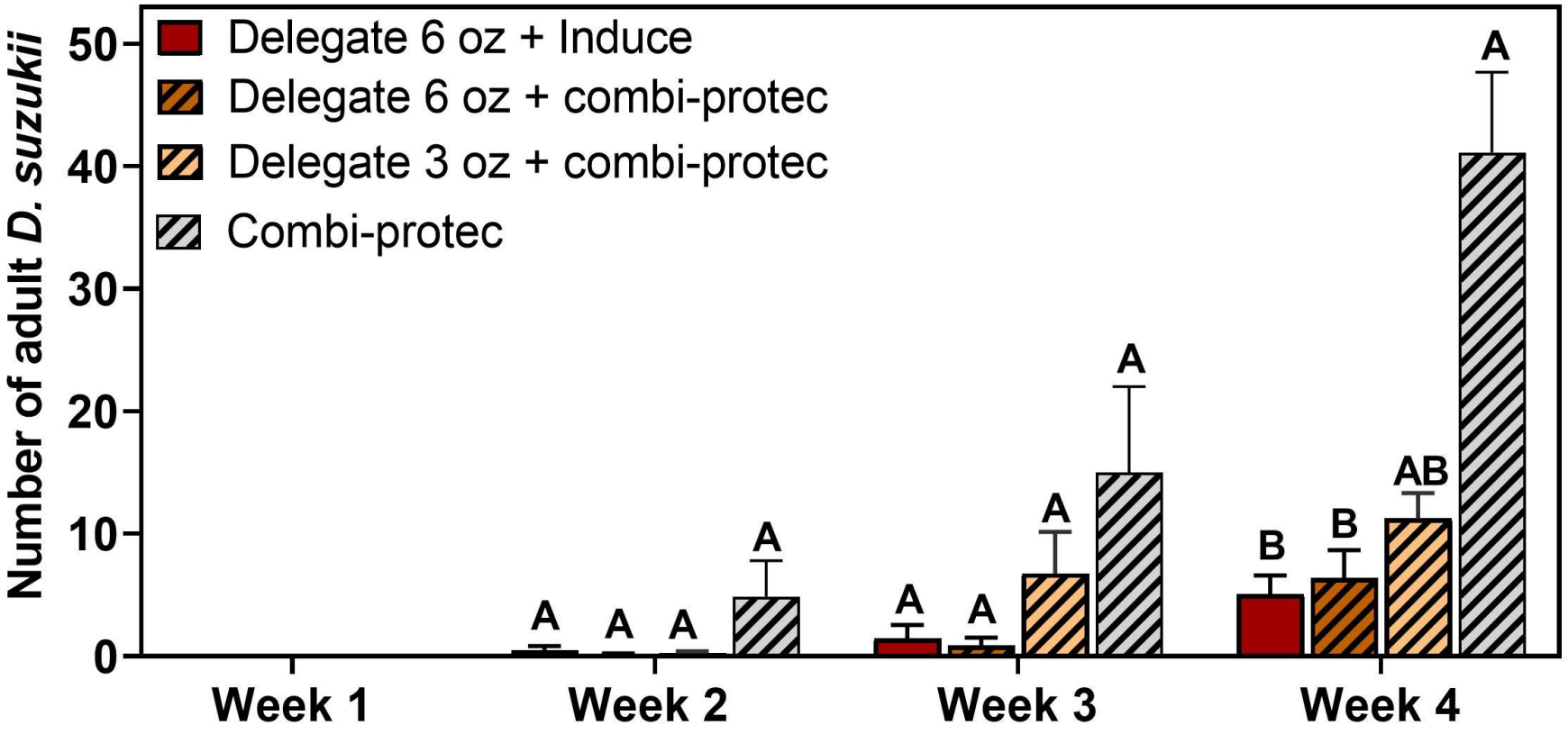
COMBI-PROTEC

Small-Plot Field Trial

- Small-plot field studies.
- Highbush and lowbush blueberries.
- GA, ME, MI.
- Applications once a week.
- Collected ripe fruit samples from bushes, assessed for SWD larvae and adult emergence.

COMBI-PROTEC

GEORG IA



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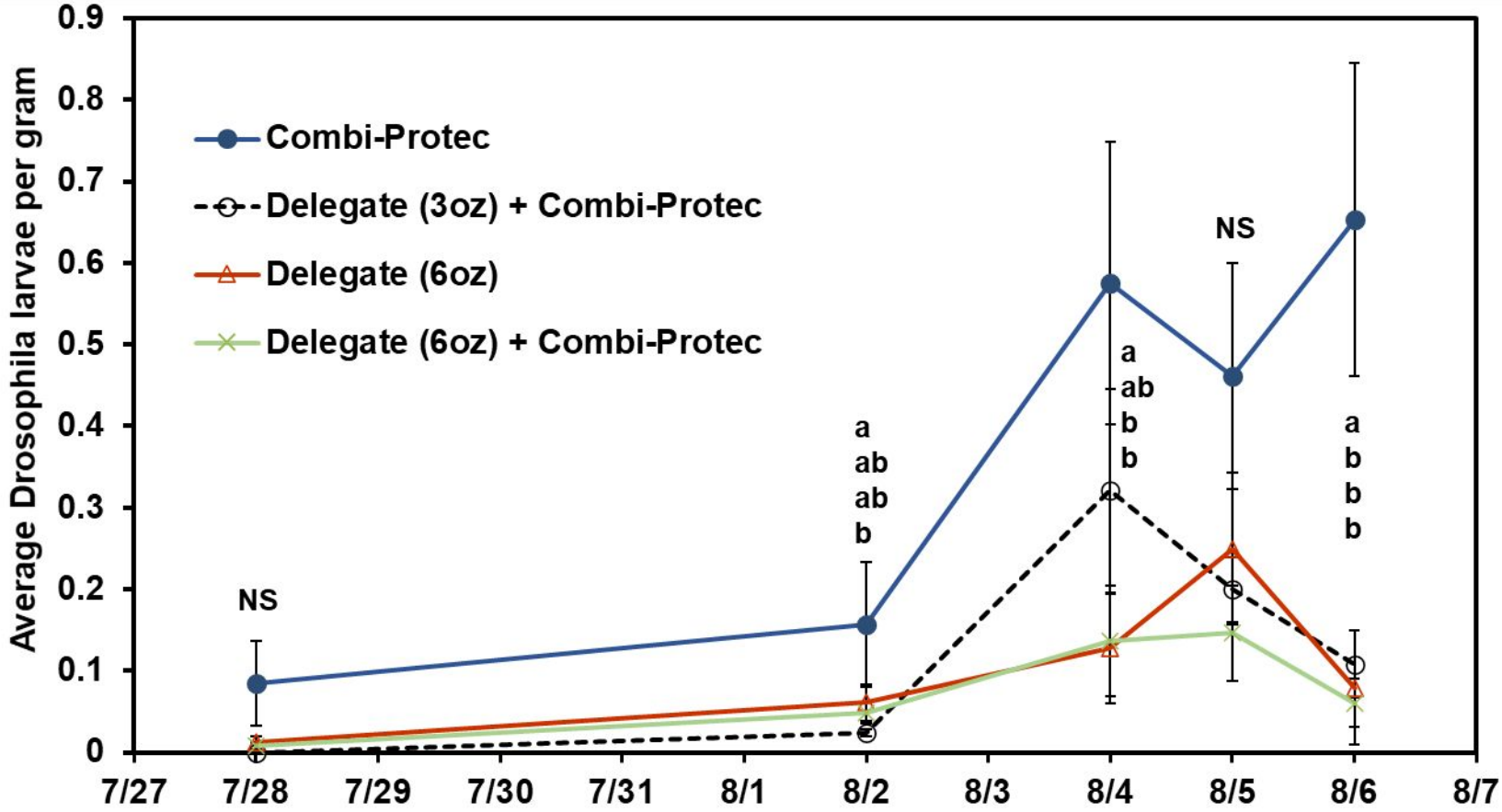
COMBI-PROTEC

MICHIGAN



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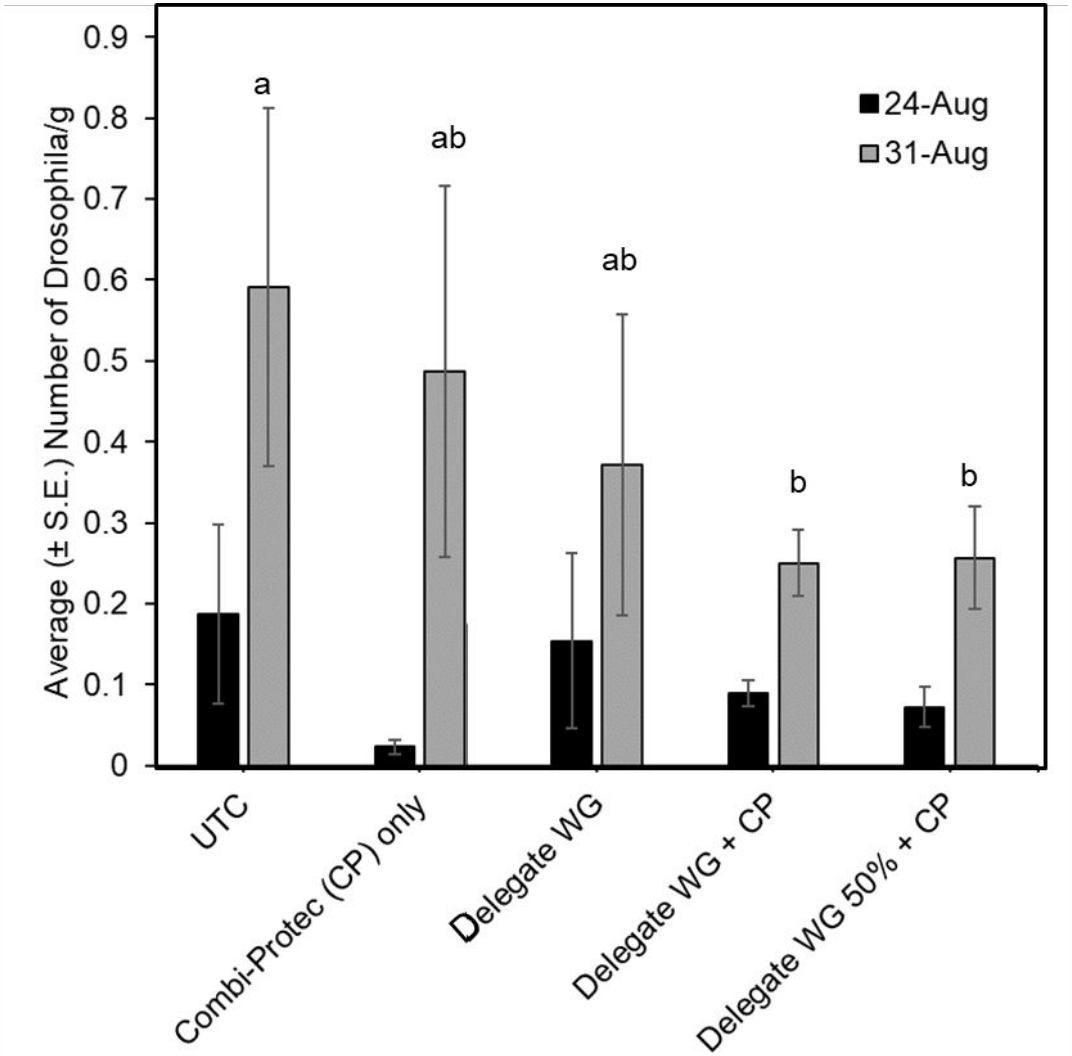
COMBI-PROTEC

MAIN



Unpublished data

COMBI-PROTEC

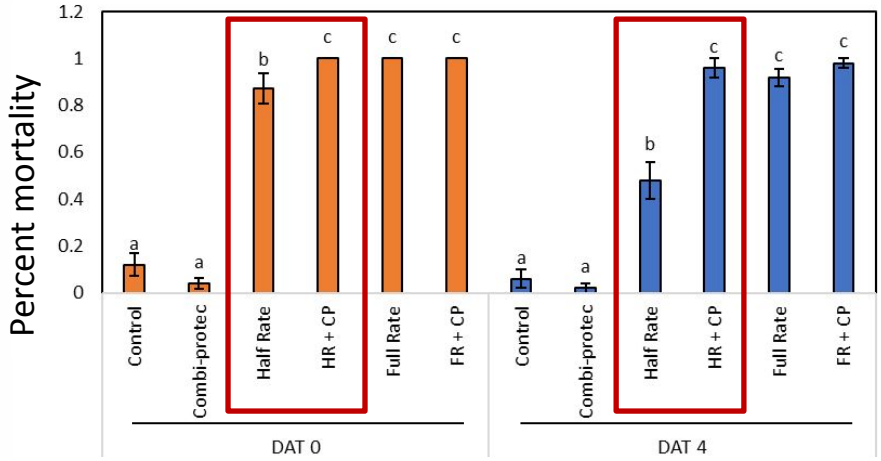
Semi-Field Trial

- Treatments:
  - UTC = untreated control
  - Insecticide program half rate
  - Insecticide program half rate + combi-protec
  - Insecticide program full rate
  - Insecticide program full rate + combi-protec
- Weekly rotation of insecticides (e.g., Imidan, Mustang Maxx, Malathion, Delegate)
- Collected fruit and foliage from bushes.
- Assessed adult mortality, egg count, and adult progeny emergence.

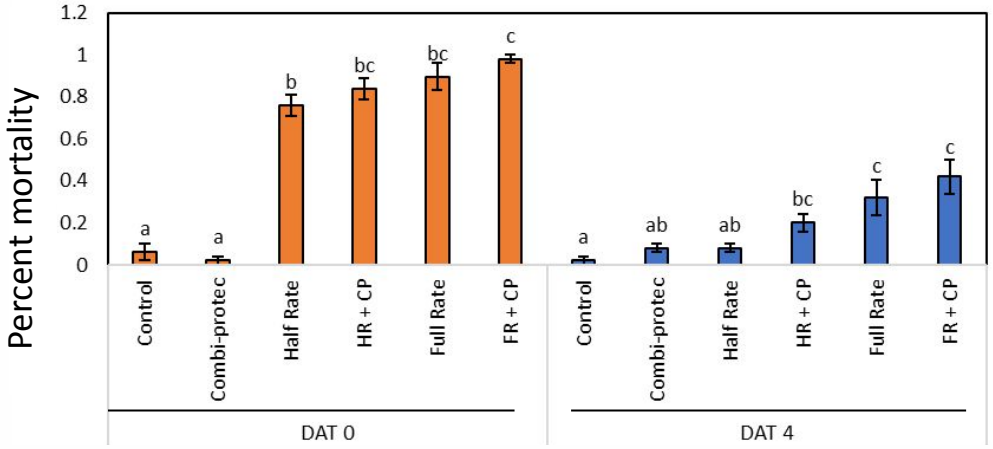
COMBI-PROTEC

Adult Mortality

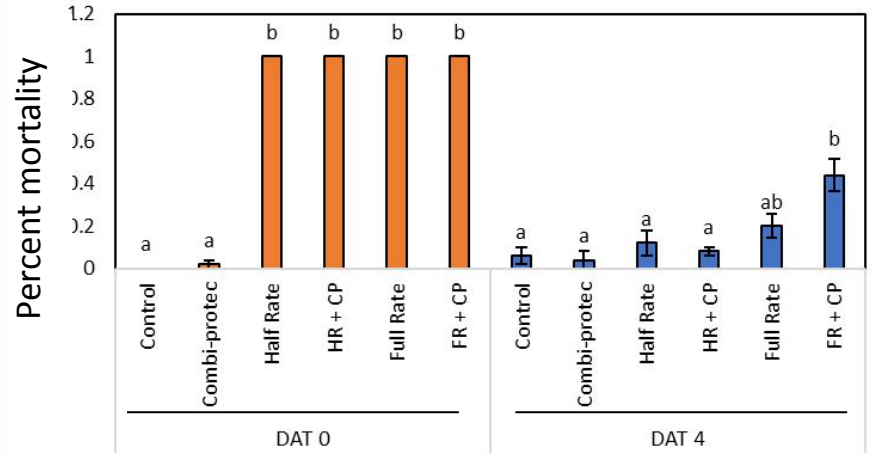
Week 1 – Imidan (Phosmet)



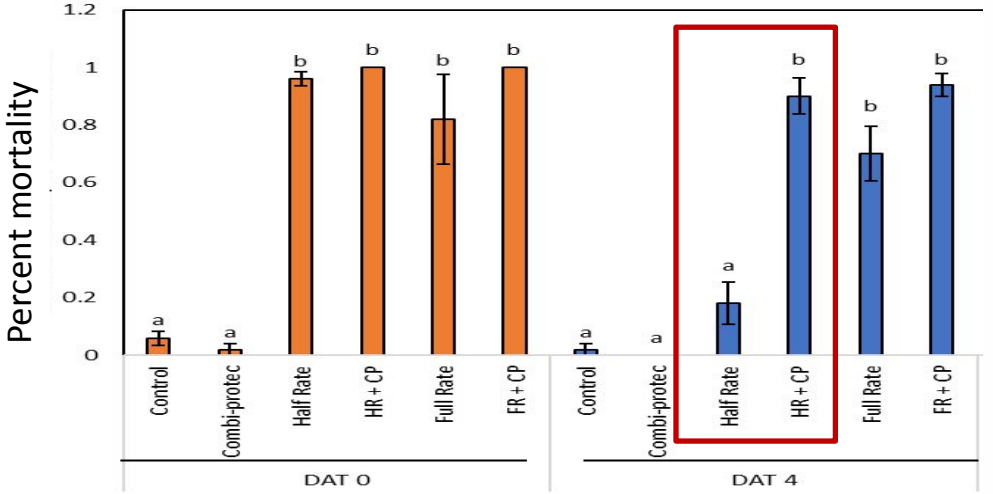
Week 2 – Mustang Maxx (Zeta-Cypermethrin)



Week 3 – Malathion



Week 4 – Delegate (Spinetoram)



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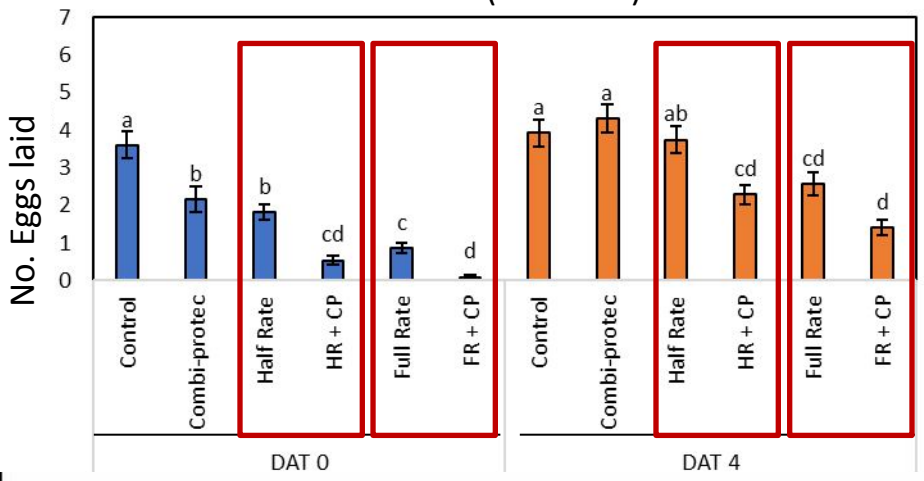
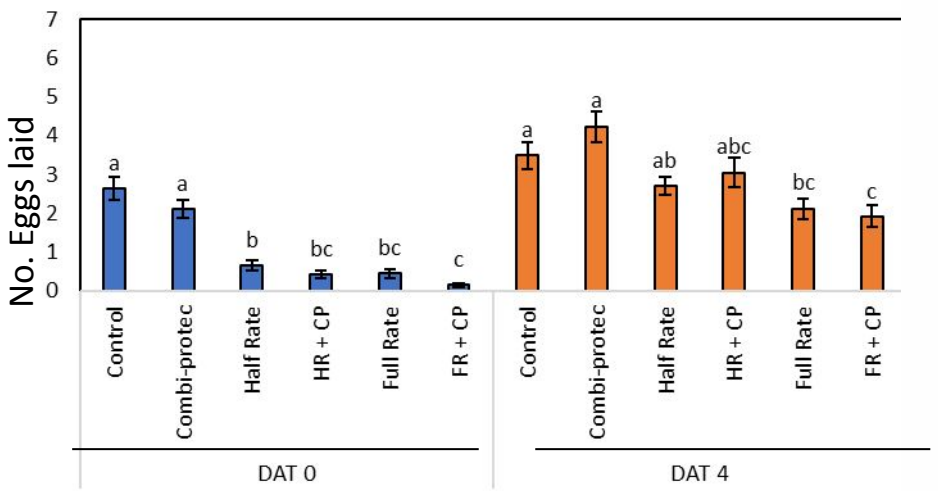
COMBI-PROTEC

Oviposition

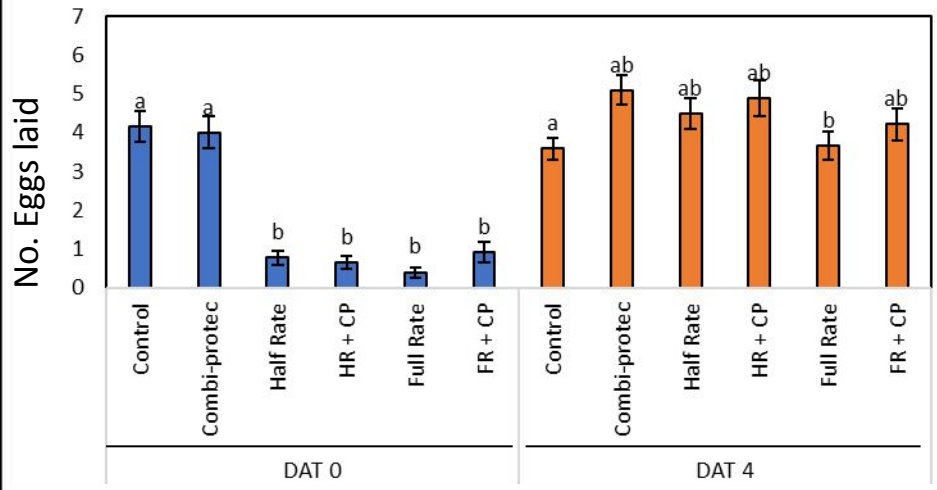
Week 1 – Imidan (Phosmet)



Week 2 – Mustang Maxx (Zeta-Cypermethrin)



Week 3 – Malathion



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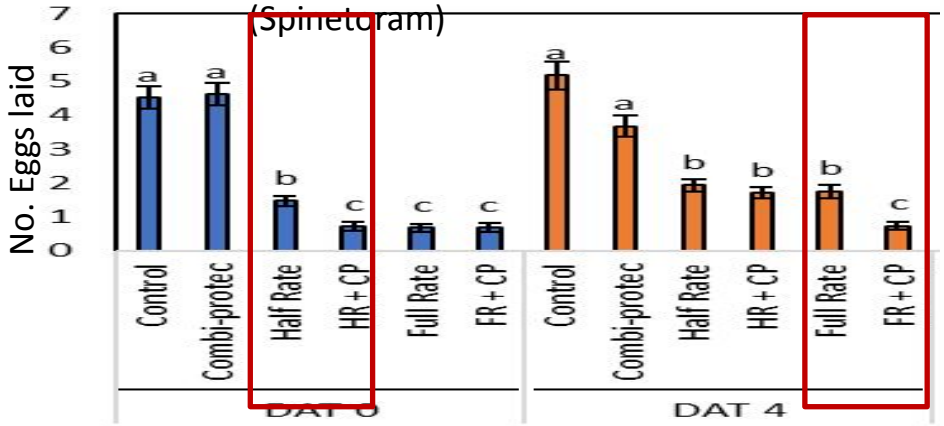

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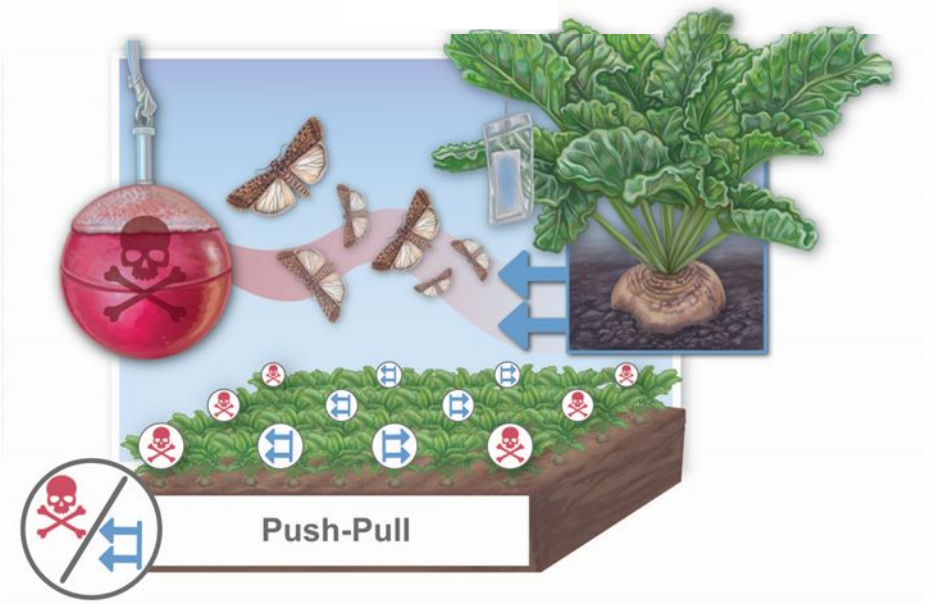
ATTRACT-AND-KILL SWD

- Effective
- Lower insecticide use
- Lower insecticide residues
- Compatible with IPM

- Not 100% control – Low tolerance
- Density dependent (SWD + fruit)
- $$$

ARE MULTIPLE STRATEGIES BETTER THAN ONE?

BEHAVIORAL CONTROL



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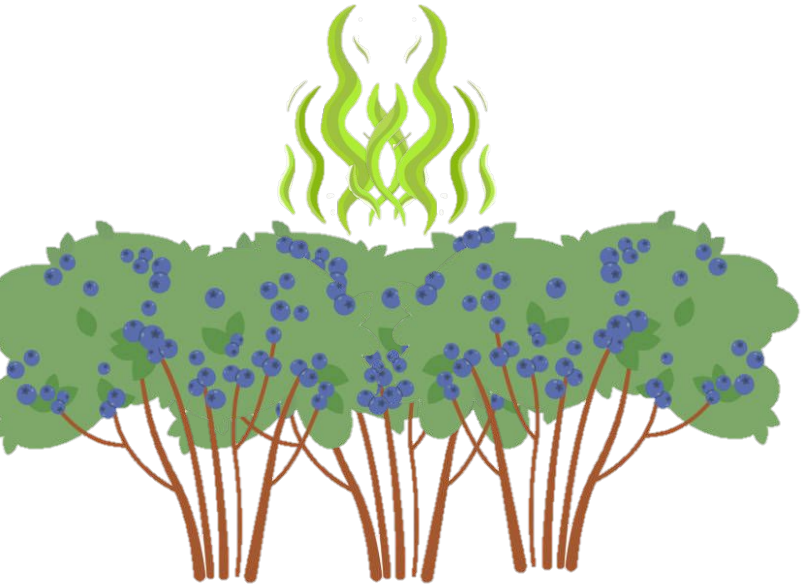
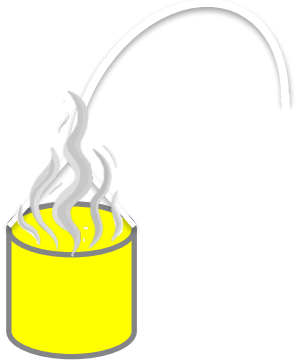
PUSH-PULL

- Alternative, behavioral control strategy
- Combines a repellent/oviposition deterrent and attractant





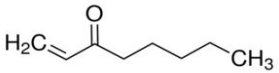
PUSH-PULL

Challenges to Developing Repellents

- Discovery/Sources of repellents
  - -Botanicals

Rosemary Oil

  - -Microbes



1-octen-3-ol

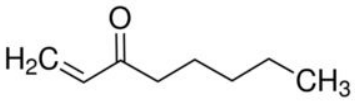
  - -Serendipity

- Safety (Human and Environment)
- Deployment
- Costs

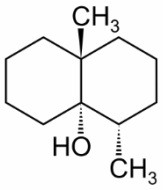
PUSH-PULL

SWD Repellents Previously Tested

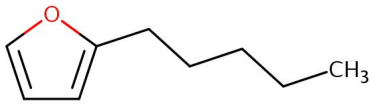
1-Octen-3-ol



Geosmin



2-Pentylfuran

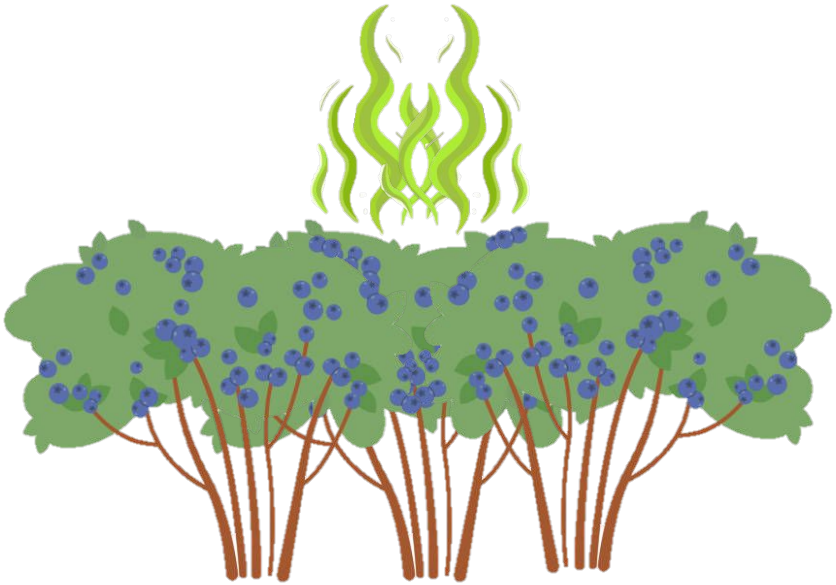


PUSH-PULL

Novel Sources of Repellents

1. Repellents from pathogenic fungi odors

2. Repellents from fermented apple juice



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FUNGAL-INDUCED ODORS

Grey mold
Botrytis cinerea

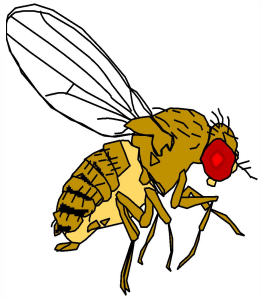
Cha et al.
Insect Science **2019**

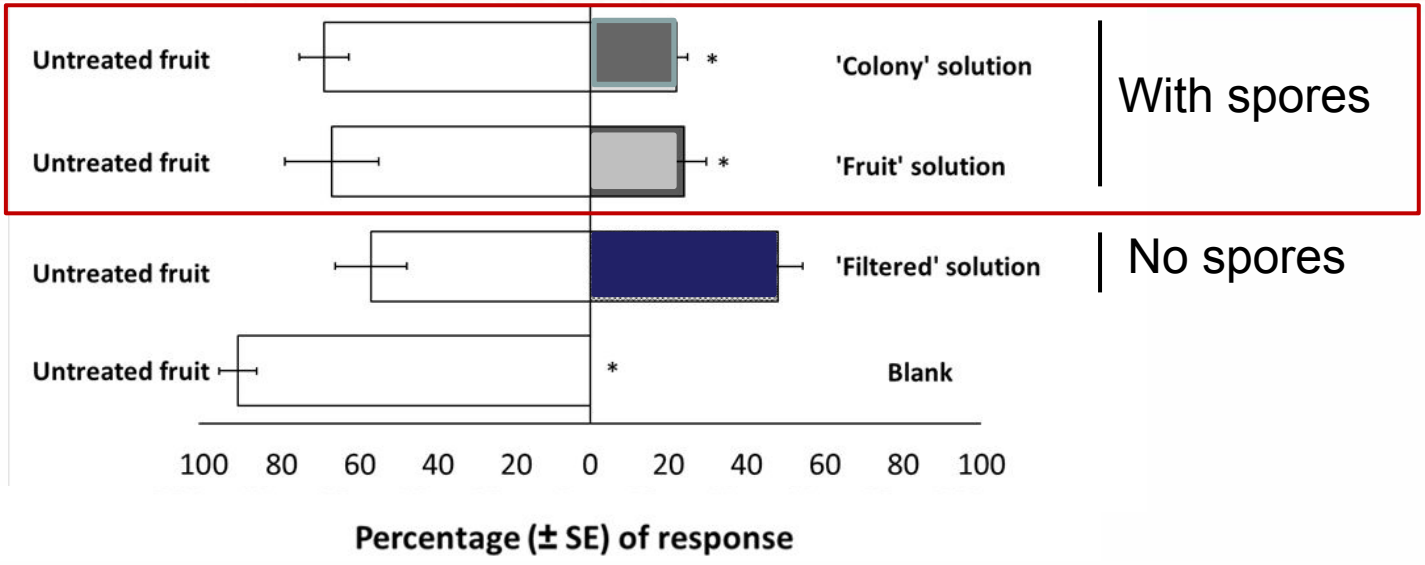
Anthracnose fruit rot
Colletotrichum fioriniae

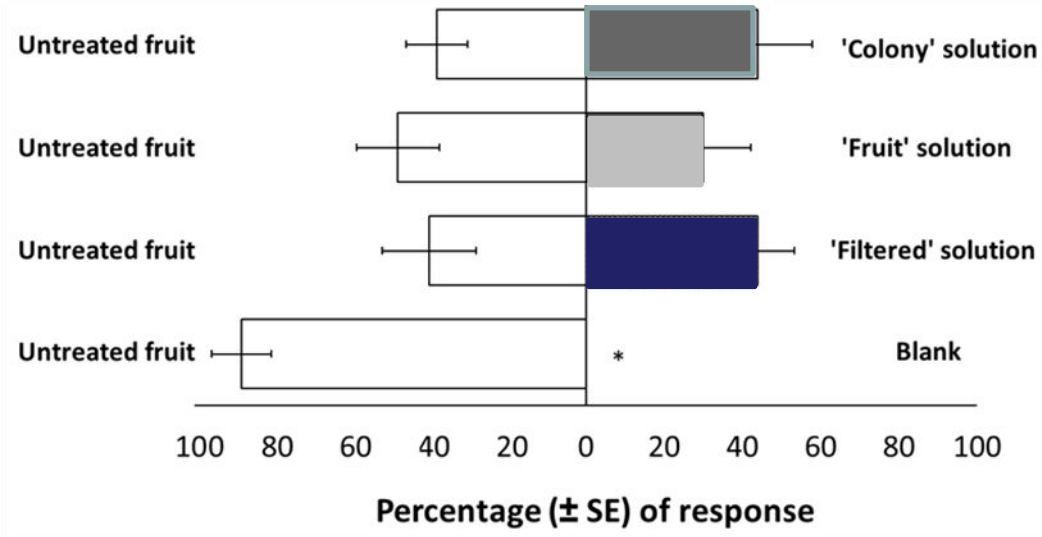
- SWD adults repelled *B. cinerea* infected raspberries.
- SWD oviposited fewer eggs on infected raspberry fruit.
- Larval survival was reduced when reared on infected raspberry.

DOES ANTHRACNOSE-INFECTED FRUIT ODORS REPEL SWD?

FUNGAL-INDUCED ODORS







Urbaneja-Bernat, Rodriguez-Saona et al. 2020

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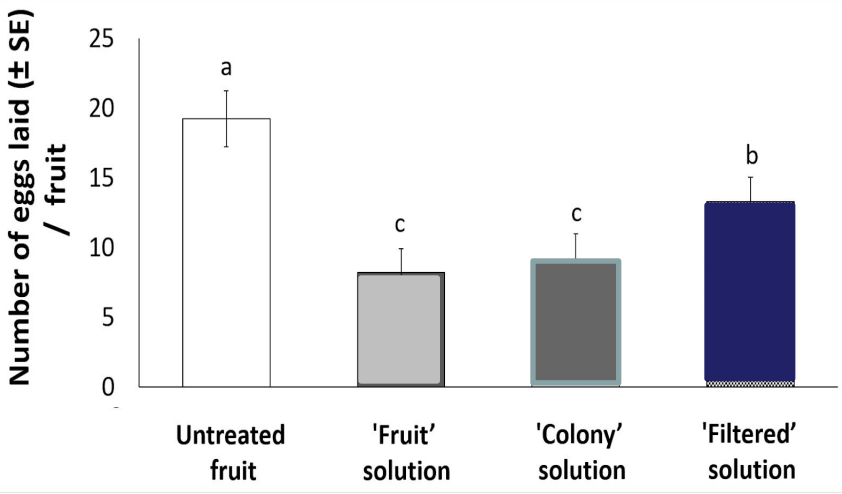
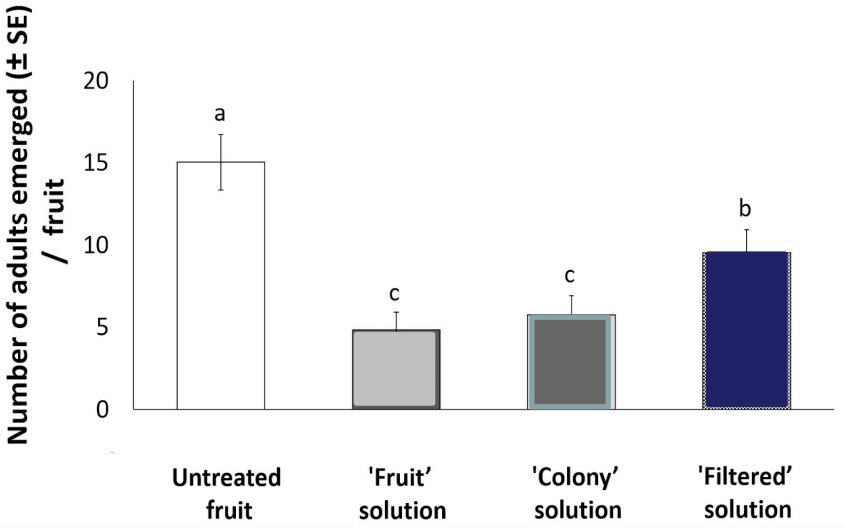
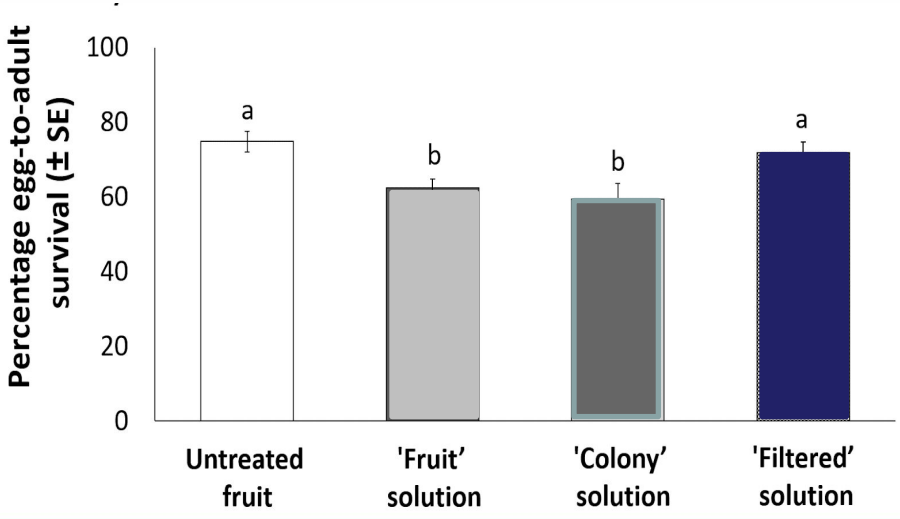
FUNGAL-INDUCED ODORS





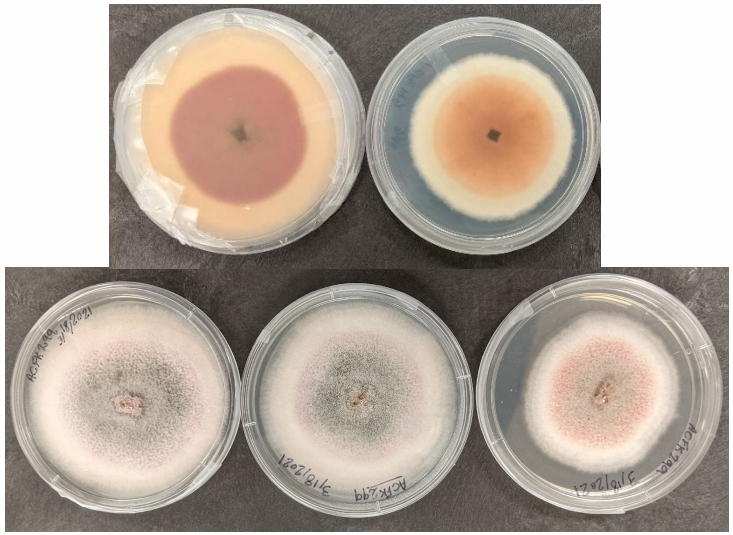


Urbaneja-Bernat, Rodriguez-Saona et al. 2020

FUNGAL-INDUCED ODORS

Objective: Identify volatiles emitted from anthracnose-infected fruit

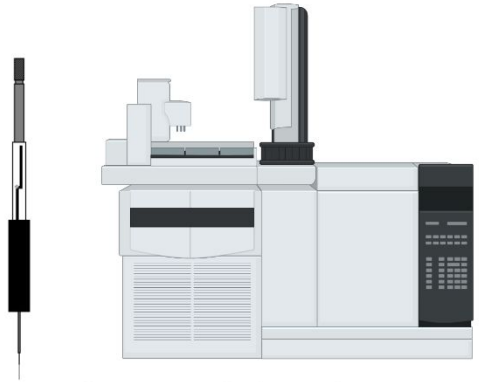
5 *Colletotrichum fioriniae* strains



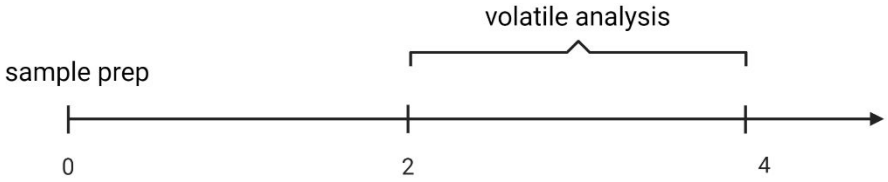
Khodadadi et al. 2020 *Scientific Reports*

n = 3 replicates per treatment
~10 g blueberry sample

FUNGAL-INDUCED ODORS



SPME GC-MS



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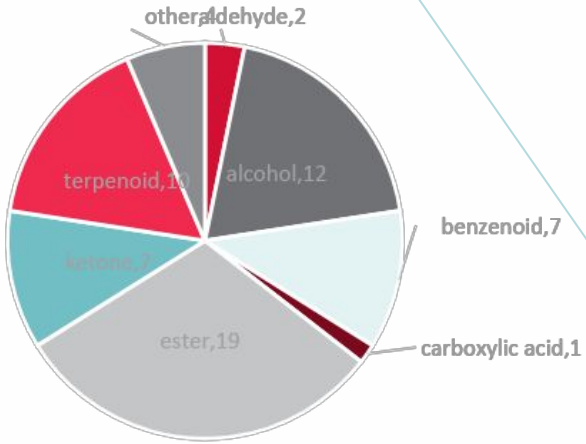
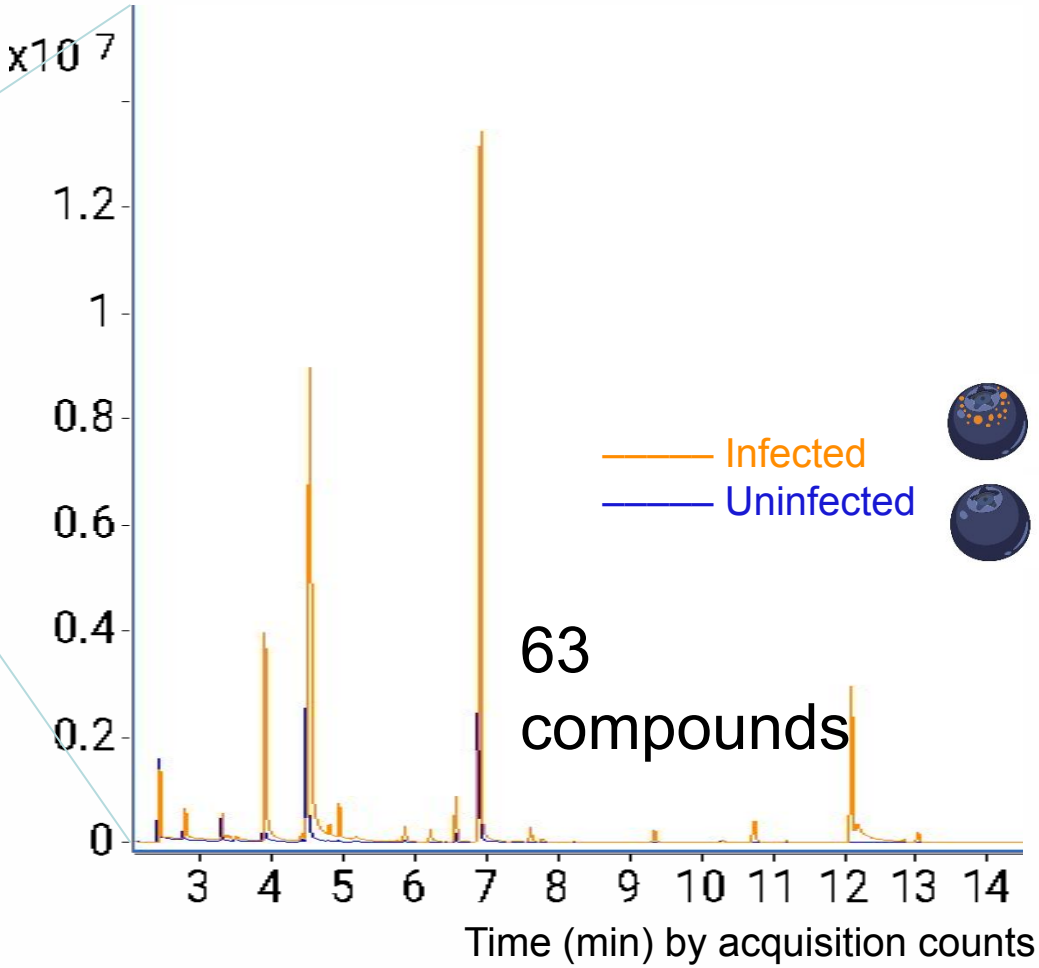
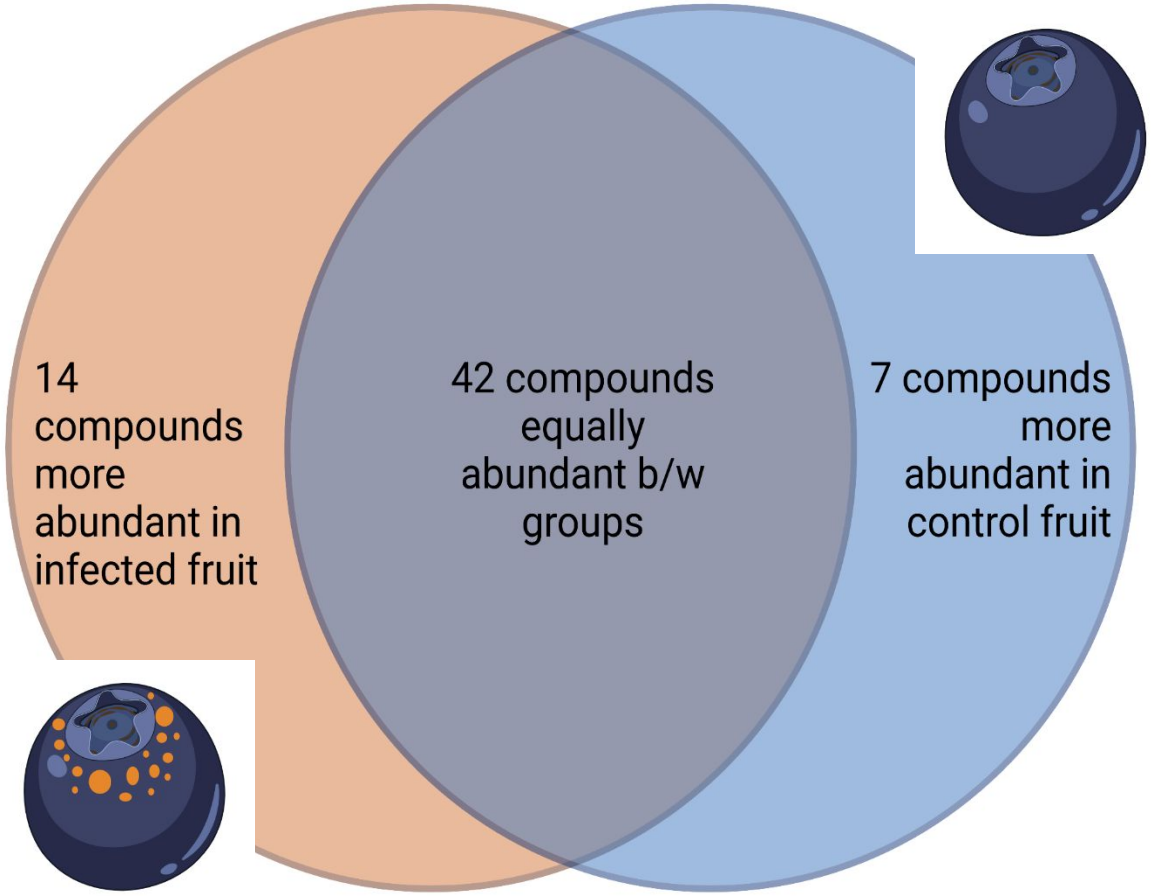
FUNGAL-INDUCED ODORS





Rering, Rodriguez-Saona et al. 2023

FUNGAL-INDUCED ODORS



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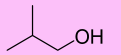
FUNGAL-INDUCED ODORS

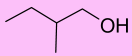
aldehyde

2-methylpropanal

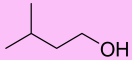
alcohols



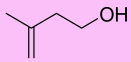
isobutanol



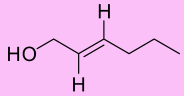
2-methyl-1-butanol



3-methyl-1-butanol

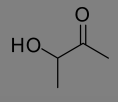


3-methyl-3-butenol



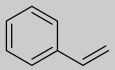
trans-2-hexenol

ketone

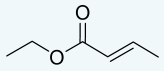


3-hydroxy-2-butanone

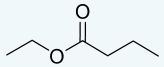
benzenoid


styrene

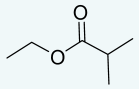
esters



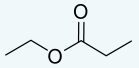
ethyl crotonate



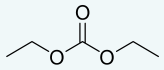
ethyl butyrate



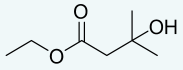
ethyl isobutyrate



ethyl propanoate



diethyl carbonate

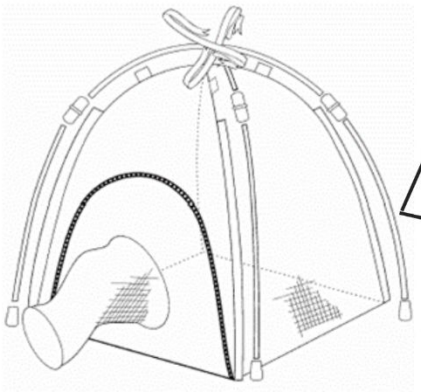


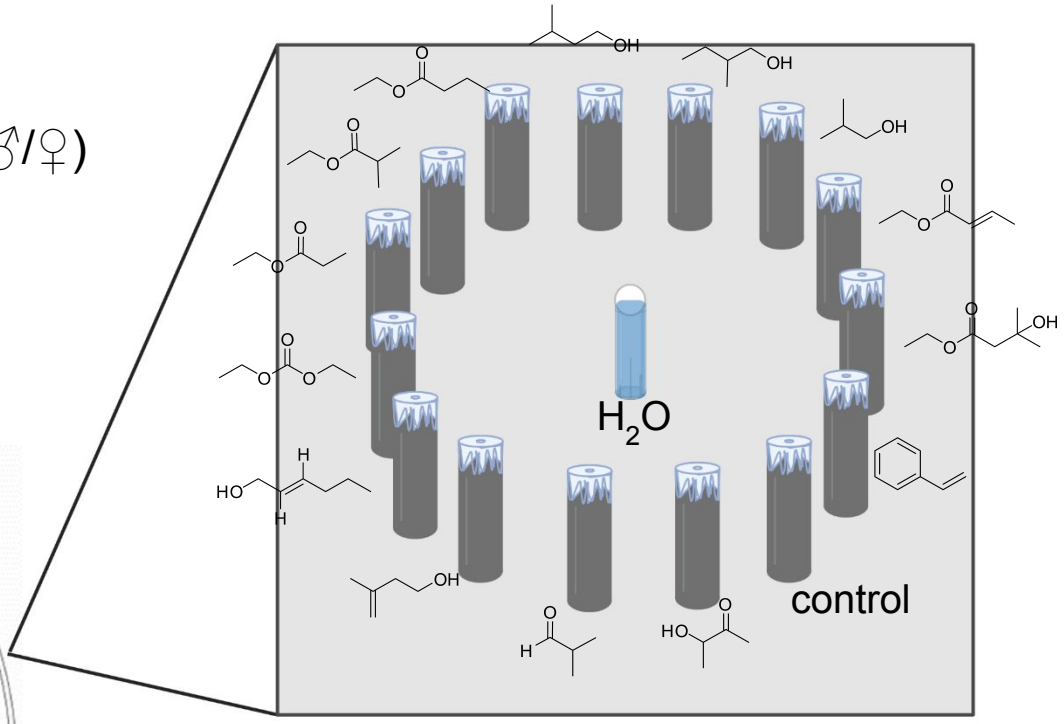
ethyl 3-hydroxy-3-methylbutanoate

FUNGAL-INDUCED ODORS

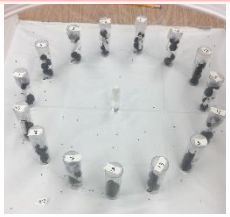
Objective: Test volatiles emitted from anthracnose-infected fruit on SWD

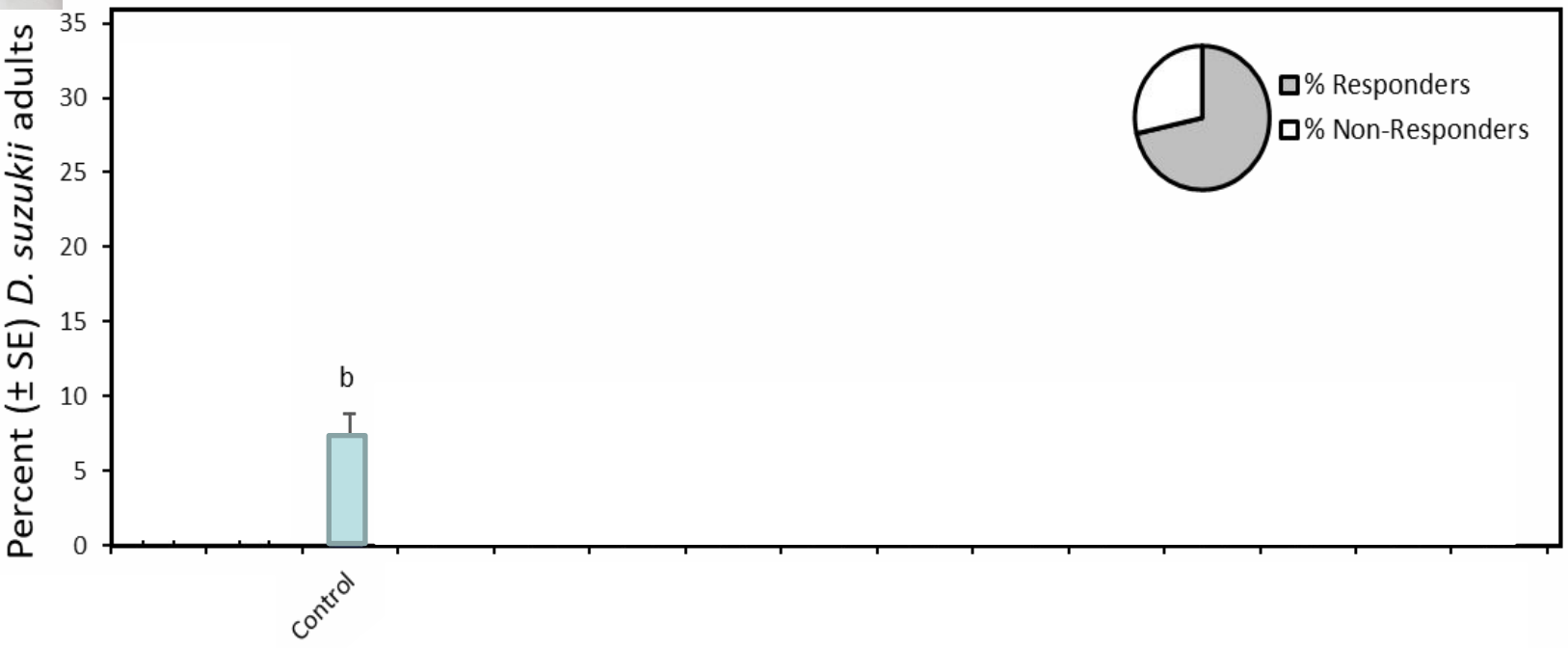
300 flies/rep (1:1 ♂/♀)
x 4 reps





FUNGAL-INDUCED ODORS





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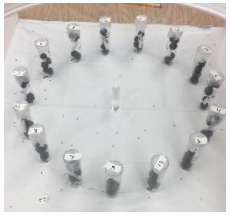
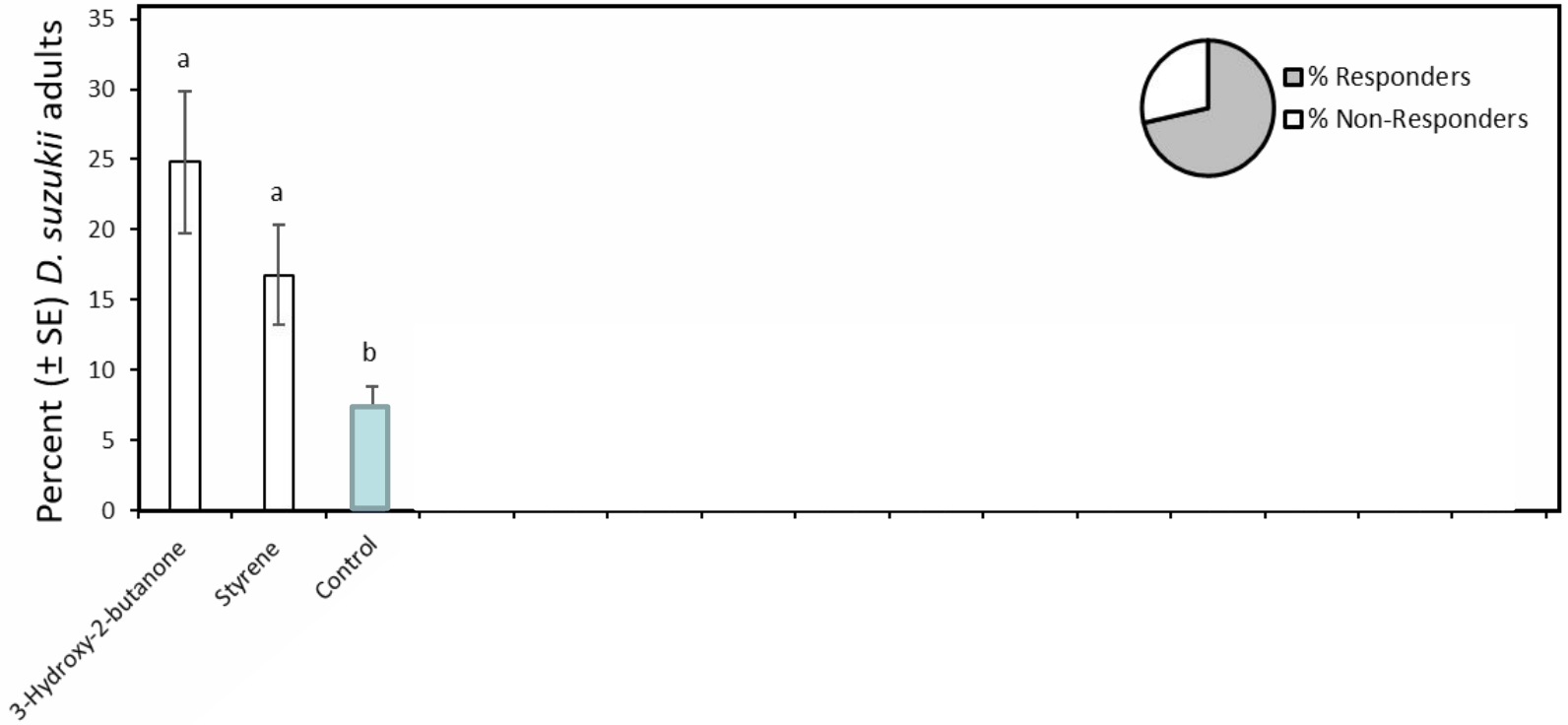
FUNGAL-INDUCED ODORS





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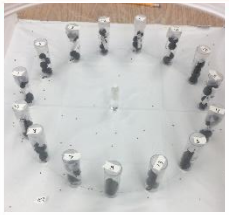
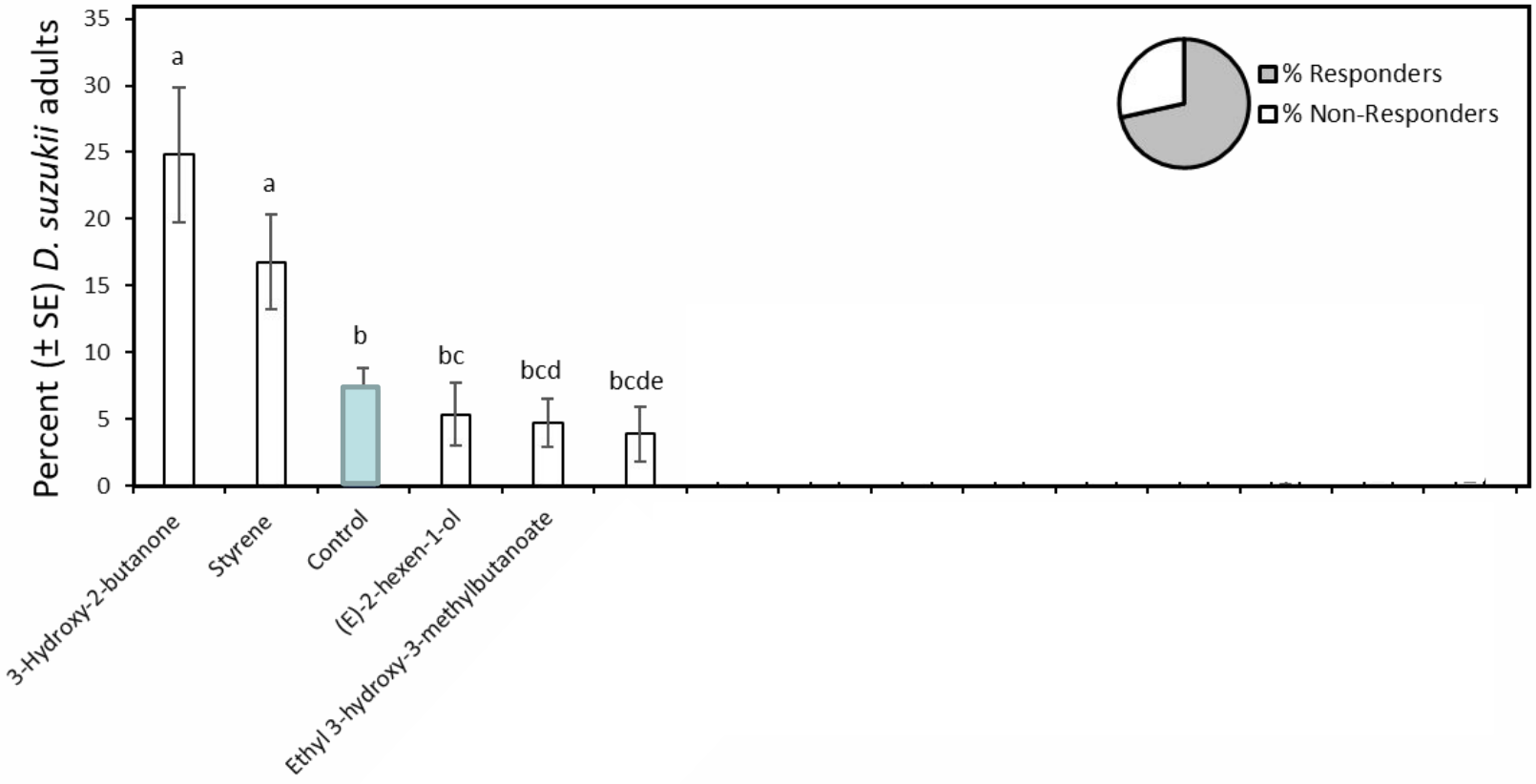
FUNGAL-INDUCED ODORS





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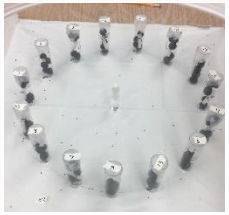

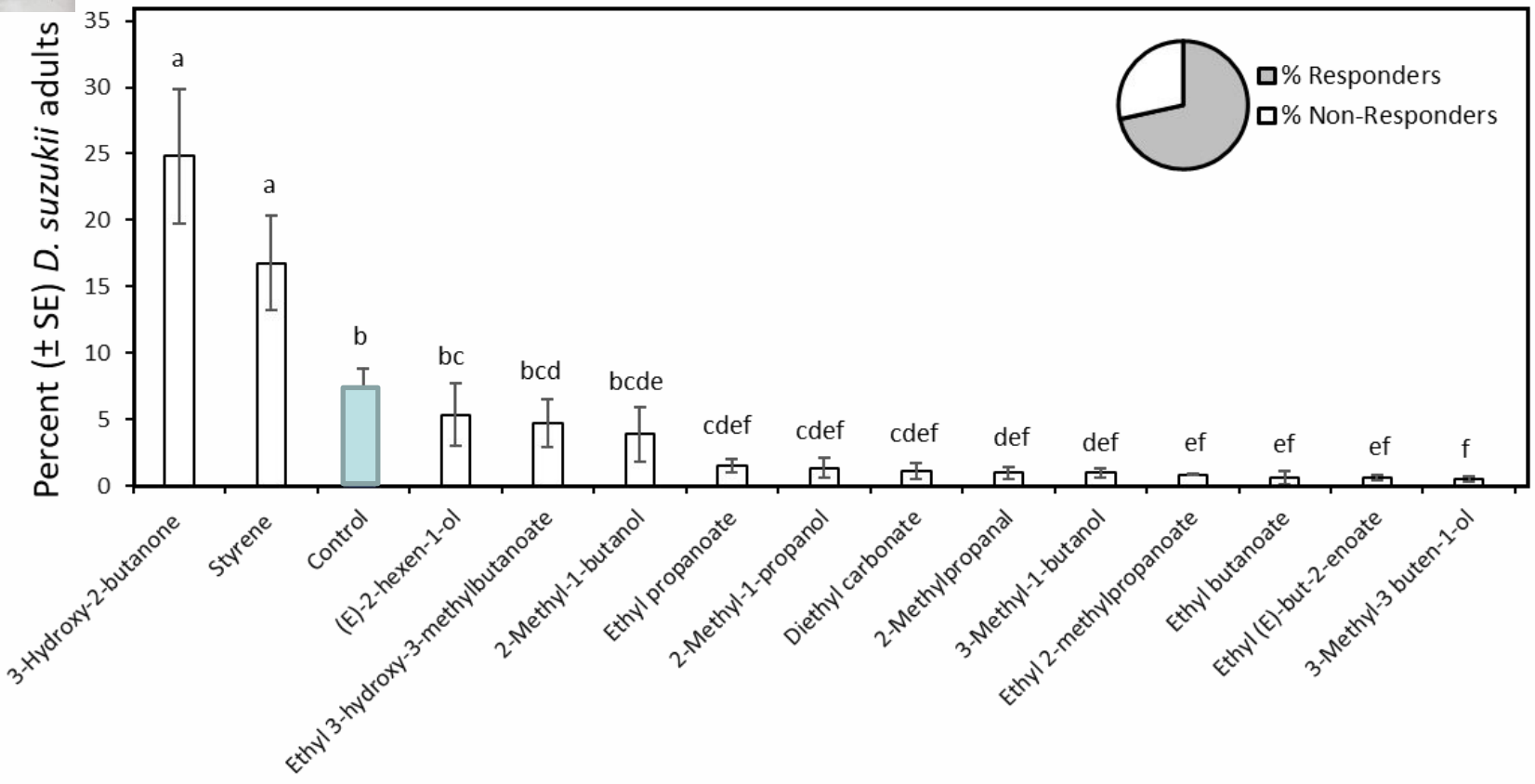

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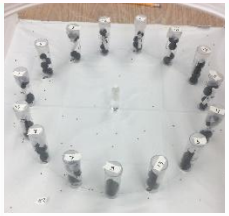
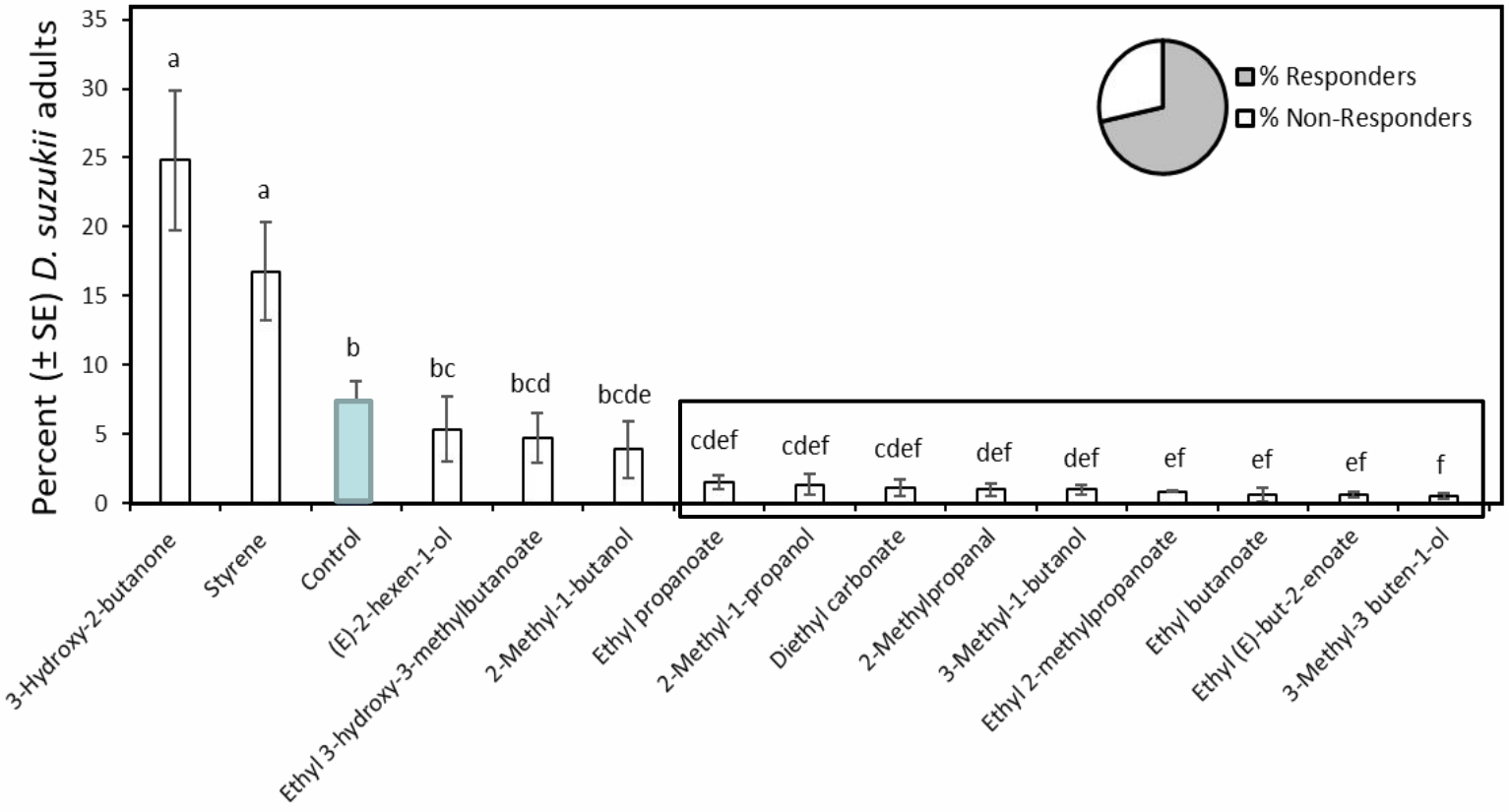
FUNGAL-INDUCED ODORS





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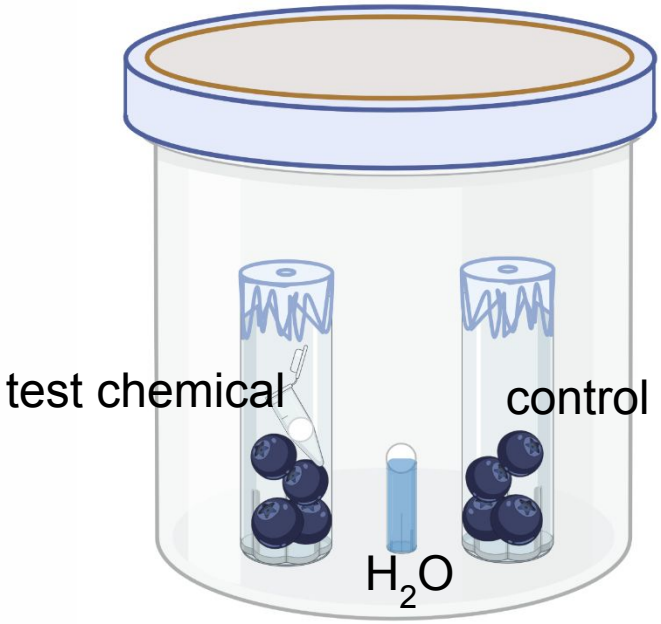
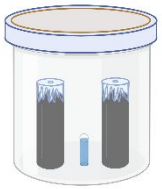
FUNGAL-INDUCED ODORS

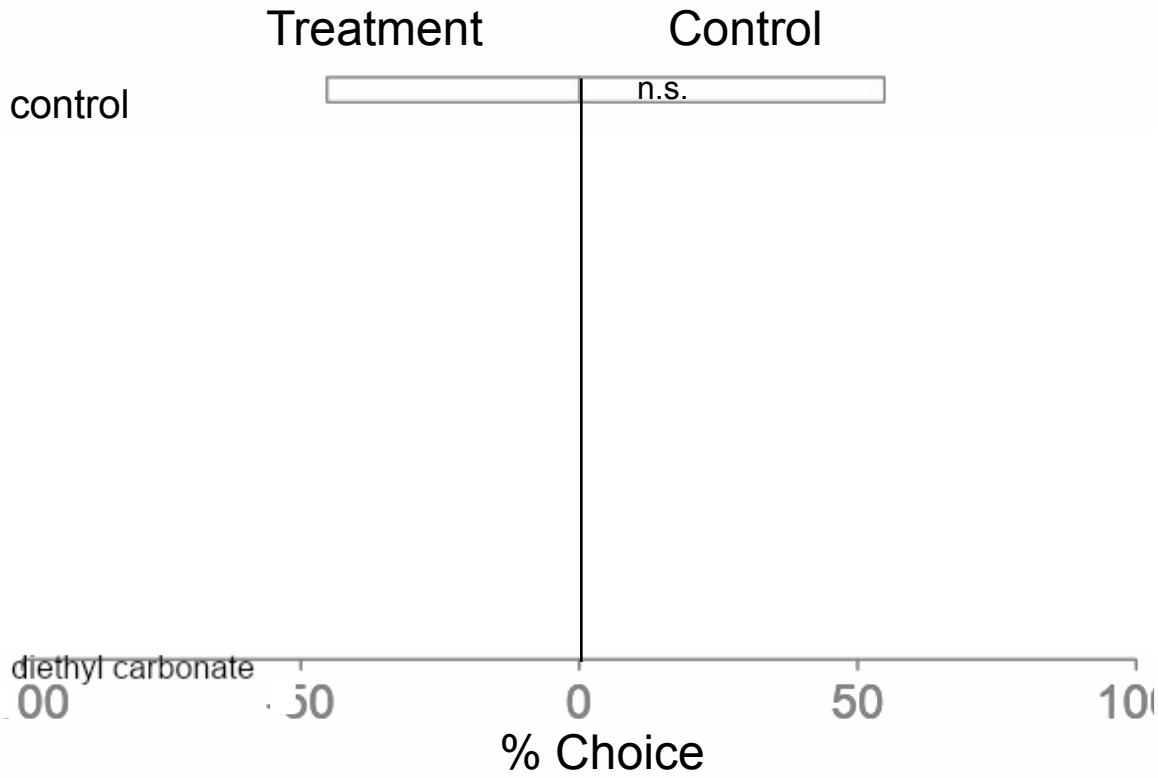
Objective: Test individual volatiles emitted from anthracnose-infected fruit on SWD



20 flies/replicate (1:1 ♂/♀)
x 5 assays/volatile

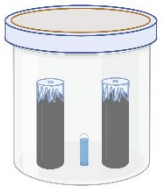
FUNGAL-INDUCED ODORS

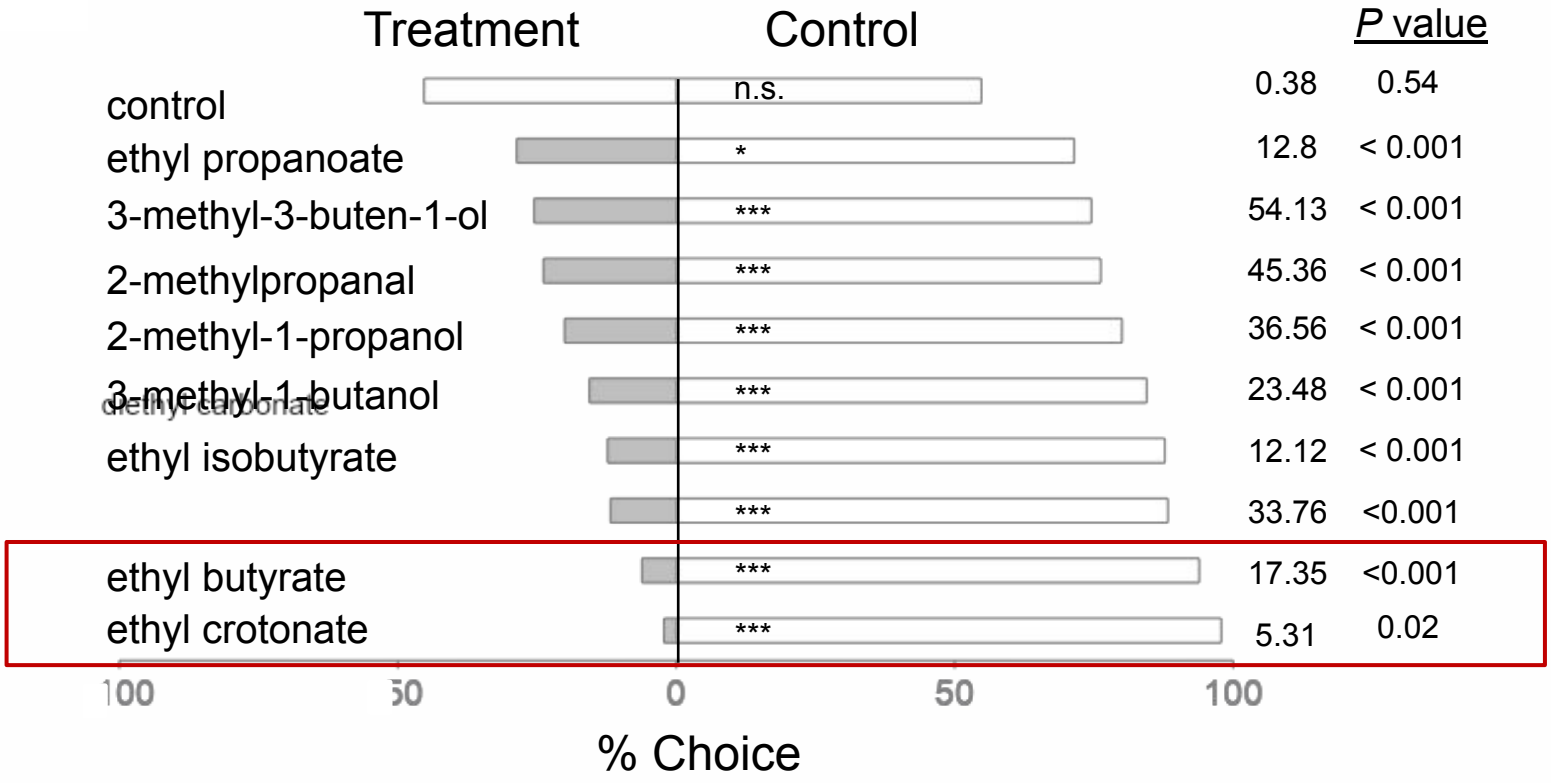




Rering, Rodriguez-Saona et al. 2023

FUNGAL-INDUCED ODORS





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FUNGAL-INDUCED ODORS

Objective: Test 2 most repellent volatiles on SWD

Cage Field Trial

- 1.8 x 1.8 x 1.8 m (10 m apart)

- Replicated 10 times for each treatment

Within each cage:
- 2 potted blueberry bushes (3-4 years old)

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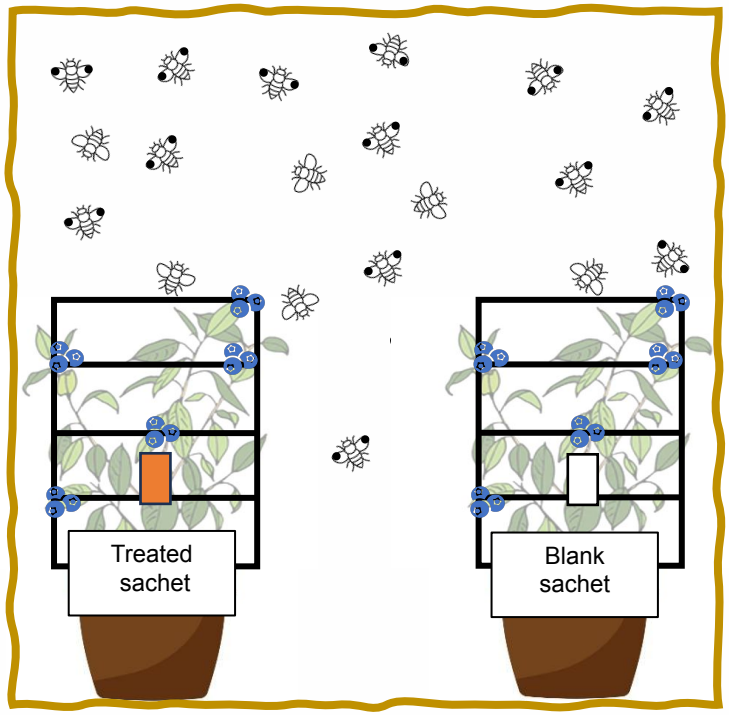
FUNGAL-INDUCED ODORS



- 5 clusters of ~10 berries hung randomly around each cage

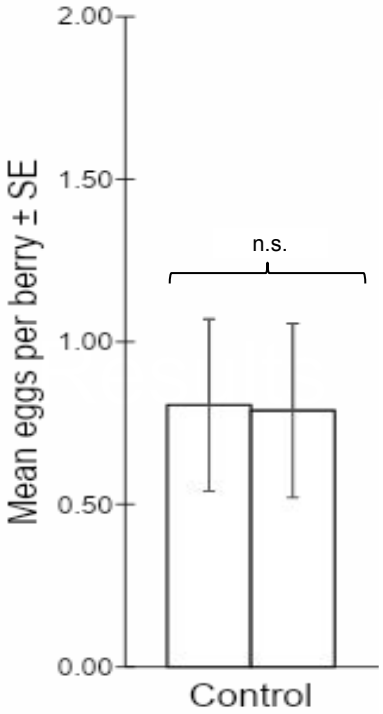
- One bush contained a treated sachet (2.5 mL pipetted onto felt), the other contained a blank sachet

- 50 SWD (1:1 M:F)

- 24 hours

- Berries inspected for number of eggs laid and incubated for adult emergence

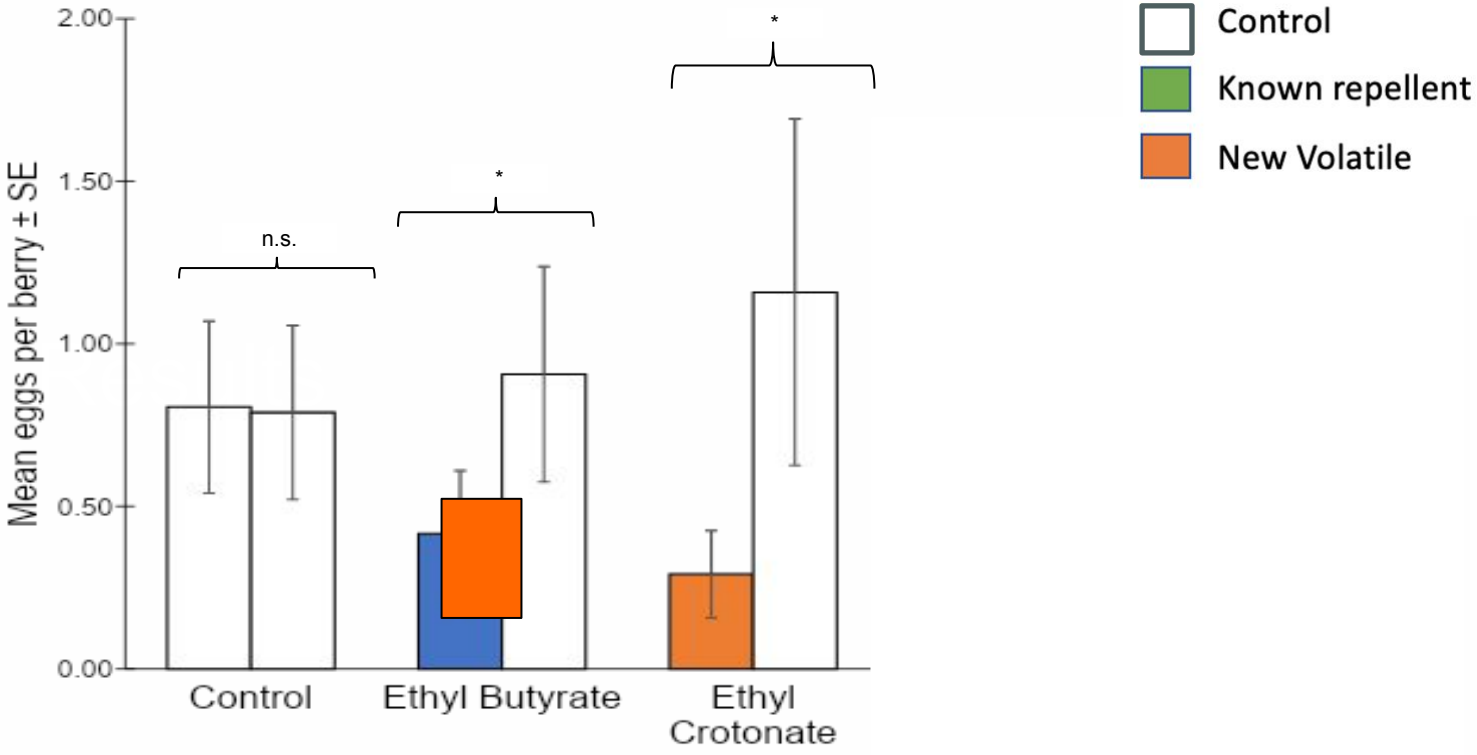
FUNGAL-INDUCED ODORS



Control
Known repellent
New Volatile

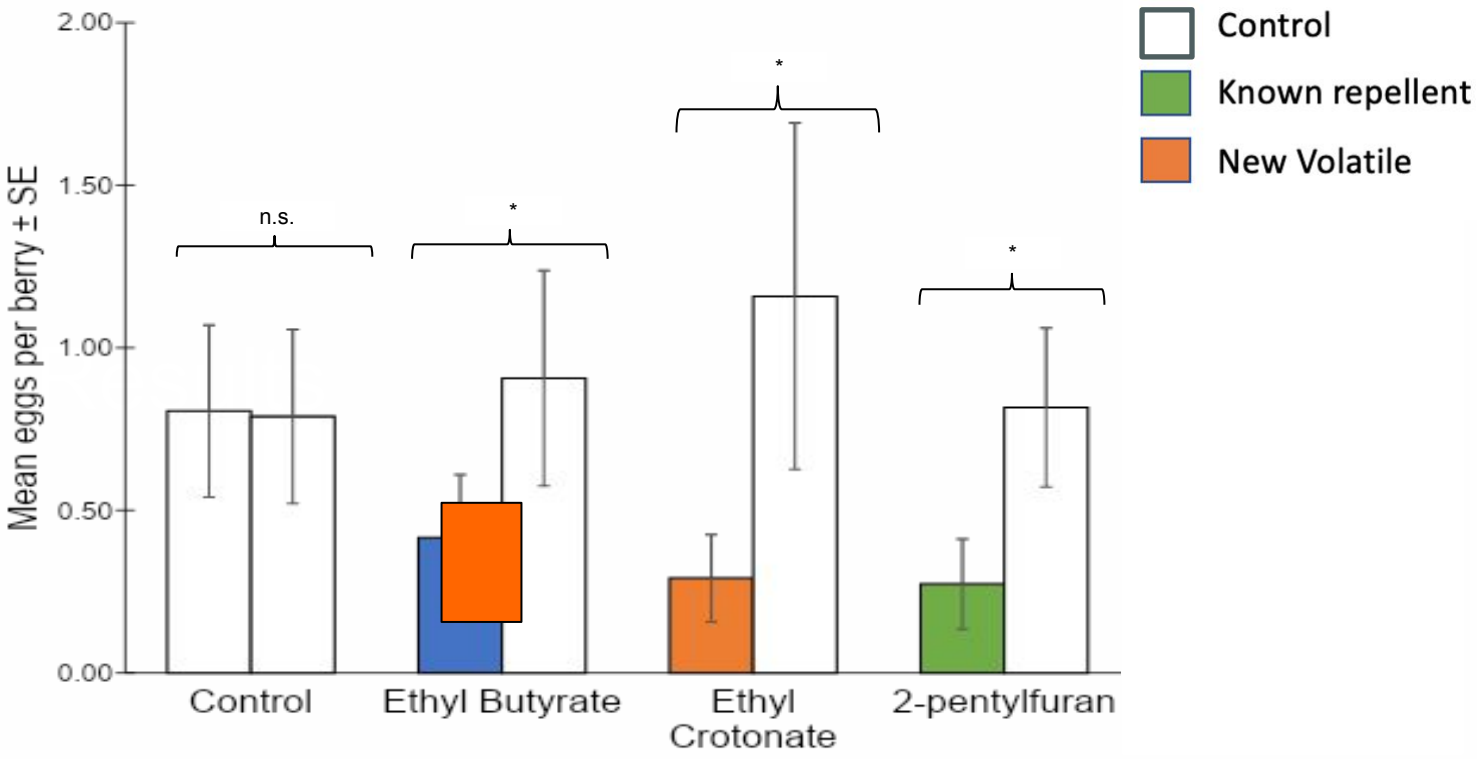
Unpublished data

FUNGAL-INDUCED ODORS



Unpublished data

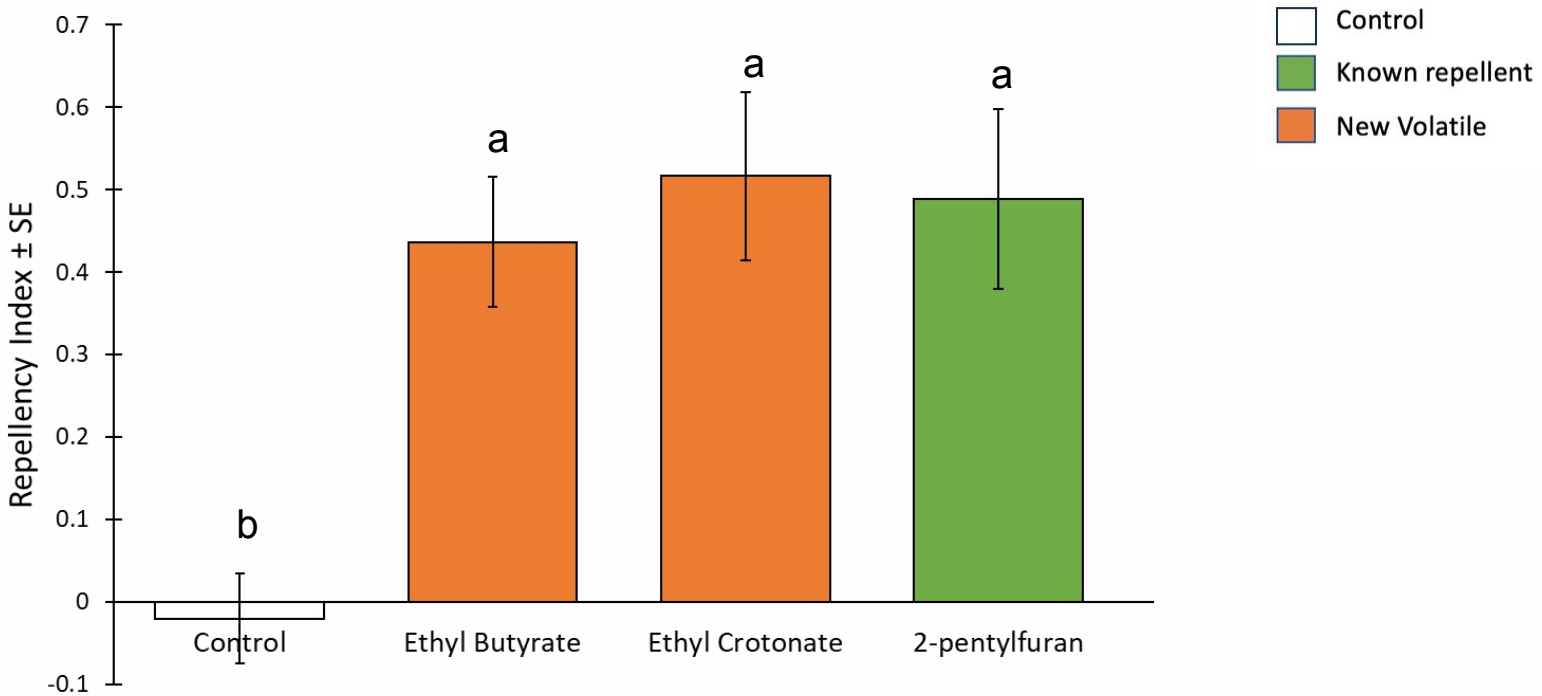
FUNGAL-INDUCED ODORS



Unpublished data

FUNGAL-INDUCED ODORS

Repellency Index = $(n_{control} - n_{volatile})/ n_{total}$



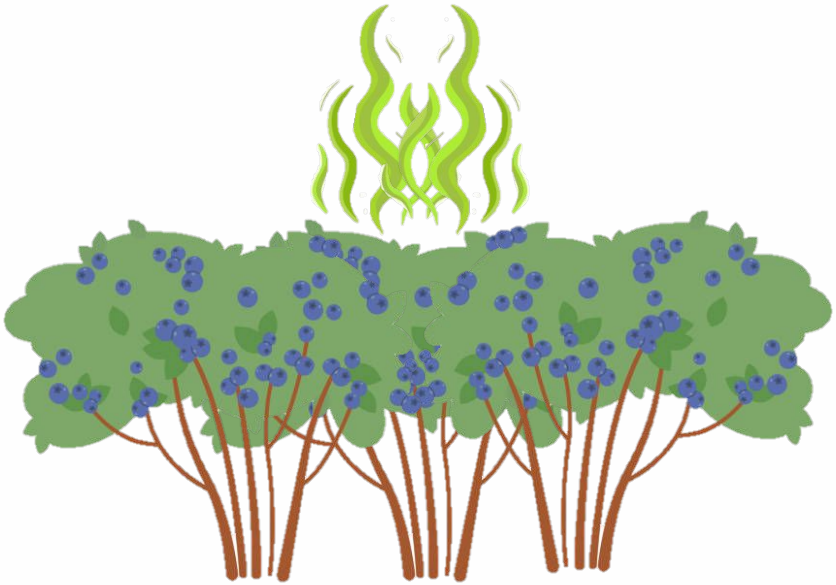
Unpublished data

PUSH-PULL

Novel Sources of Repellents

1. Repellents from pathogenic fungi odors

2. Repellents from fermented apple juice



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New Jersey Agricultural Experiment Station

METHYL BENZOATE

- Demonstrated repellent/toxicity effects in laboratory setting (Feng and Zhang 2017).
- Floral volatile found in many plants.
- Low toxicity towards non-target insects (Zhu et al. 2019, Mostafiz et al. 2019, 2020).

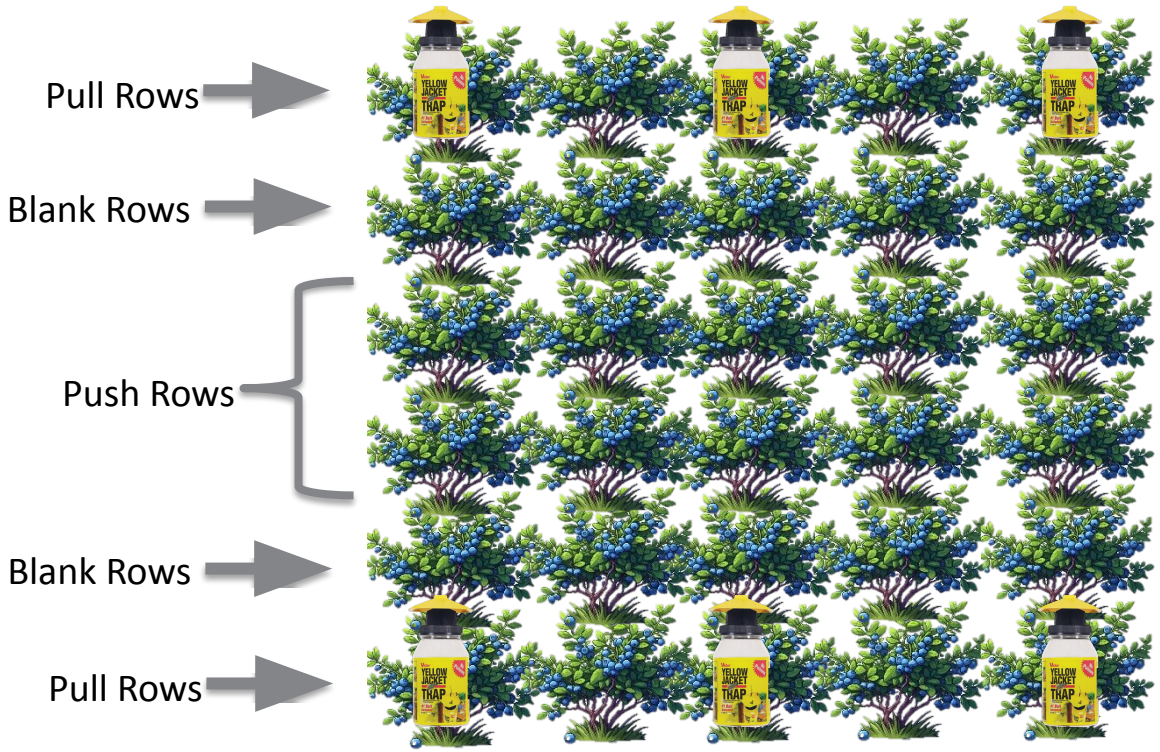
Objective

Assess the potential of Methyl Benzoate as an SWD repellent/oviposition deterrent in highbush blueberry

METHYL BENZOATE

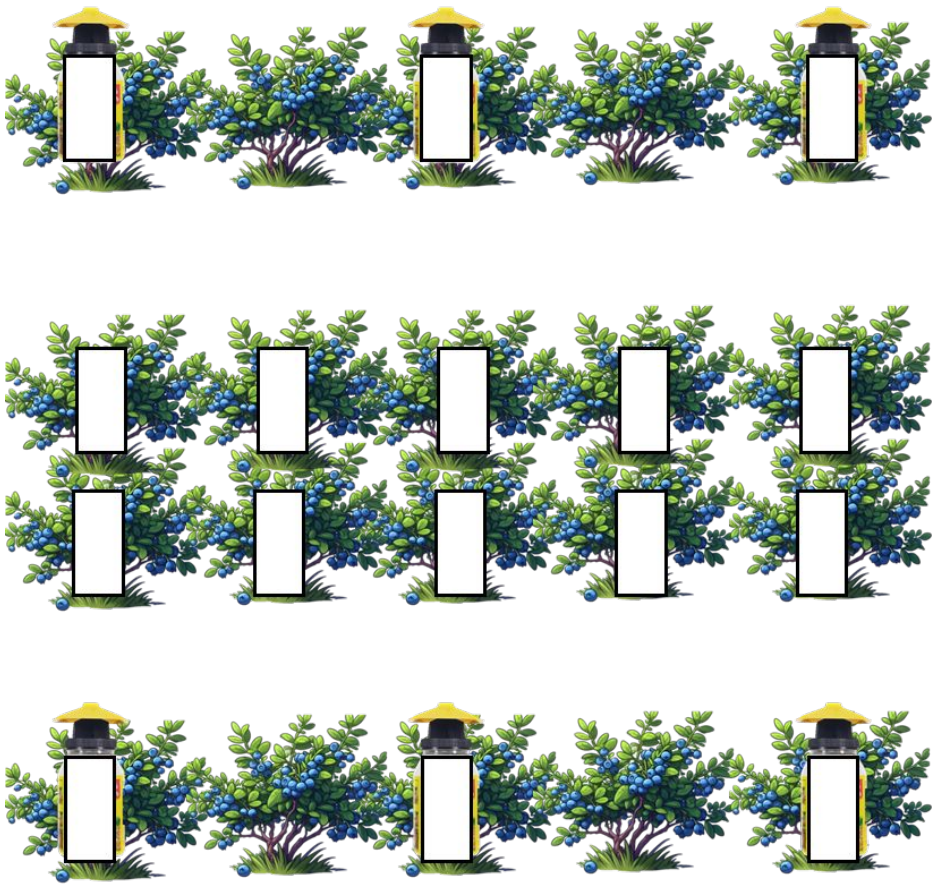
Experimental Design

Conducted on U-pick farms in Maryland and New Jersey



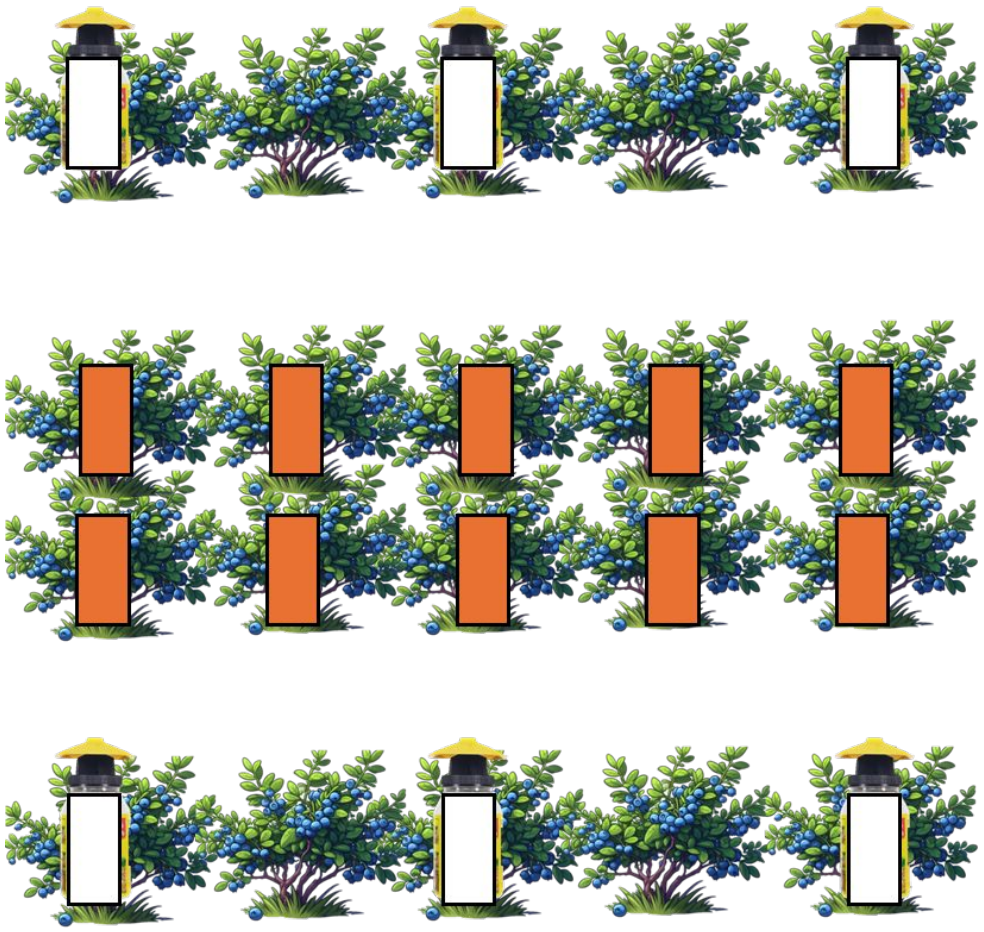
METHYL BENZOATE

Experimental Design: Control



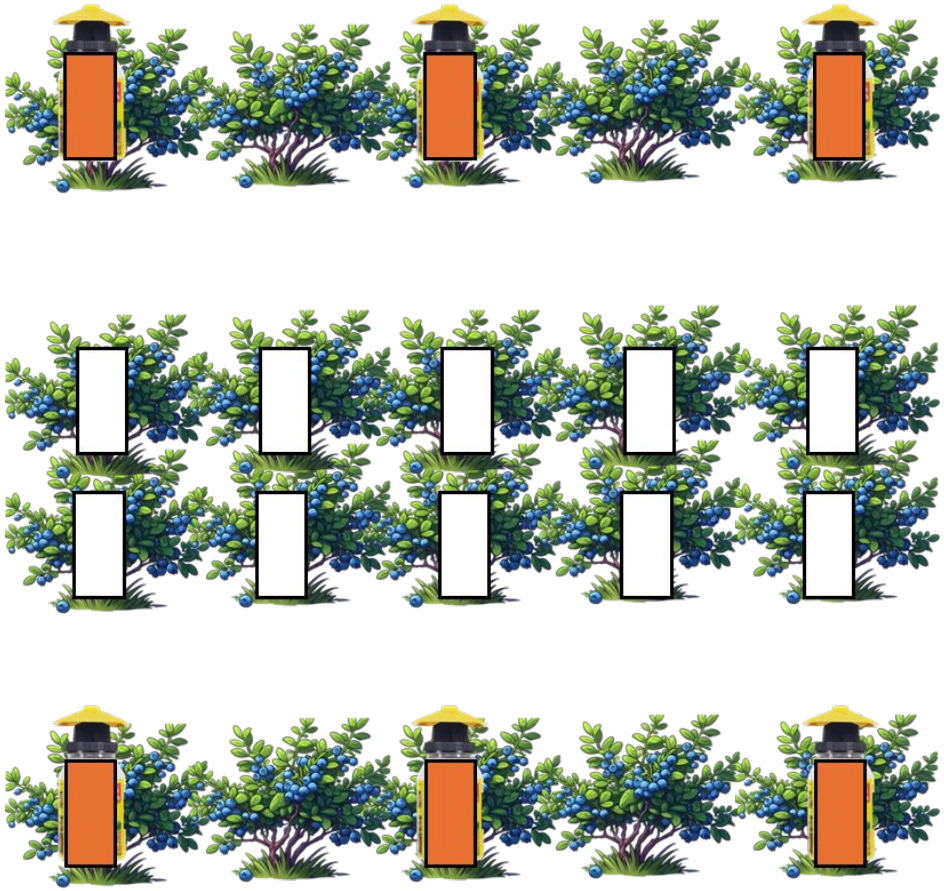
METHYL BENZOATE

Experimental Design: Push



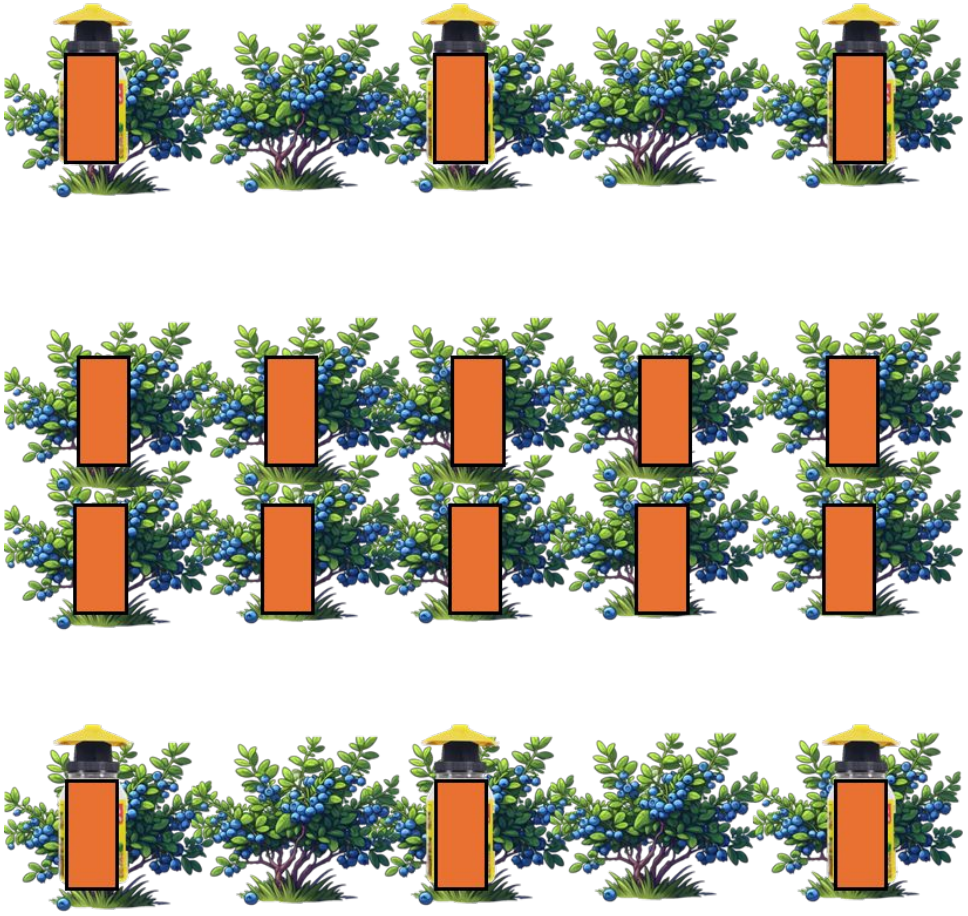
METHYL BENZOATE

Experimental Design: Pull



METHYL BENZOATE

Experimental Design: Push-Pull



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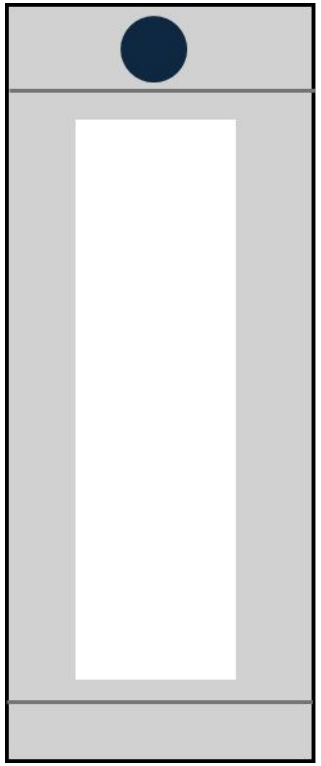
METHYL BENZOATE

- Sachet made with polyethylene tubing
  - Push: Methyl Benzoate (8ml, n=3/bush)
  - Pull: Quinary blend (13ml total volume, n=1/trap)
  - Control: Blank sachet
- Onset of sampling after sachets were placed for a week, then once weekly
  - Empty and count SWD in traps
  - 2 berries sampled per bush (n=20/plot) and eggs counted within 24hrs



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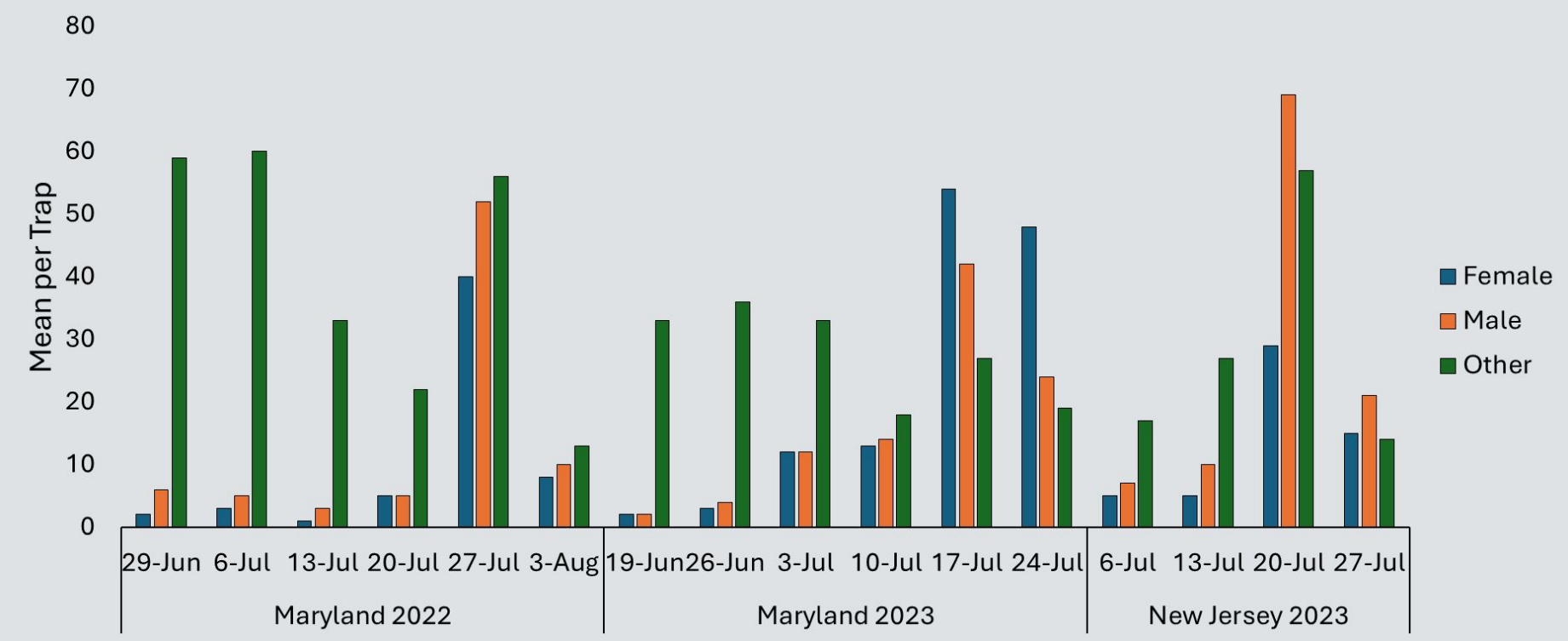
METHYL BENZOATE

Trap Catch



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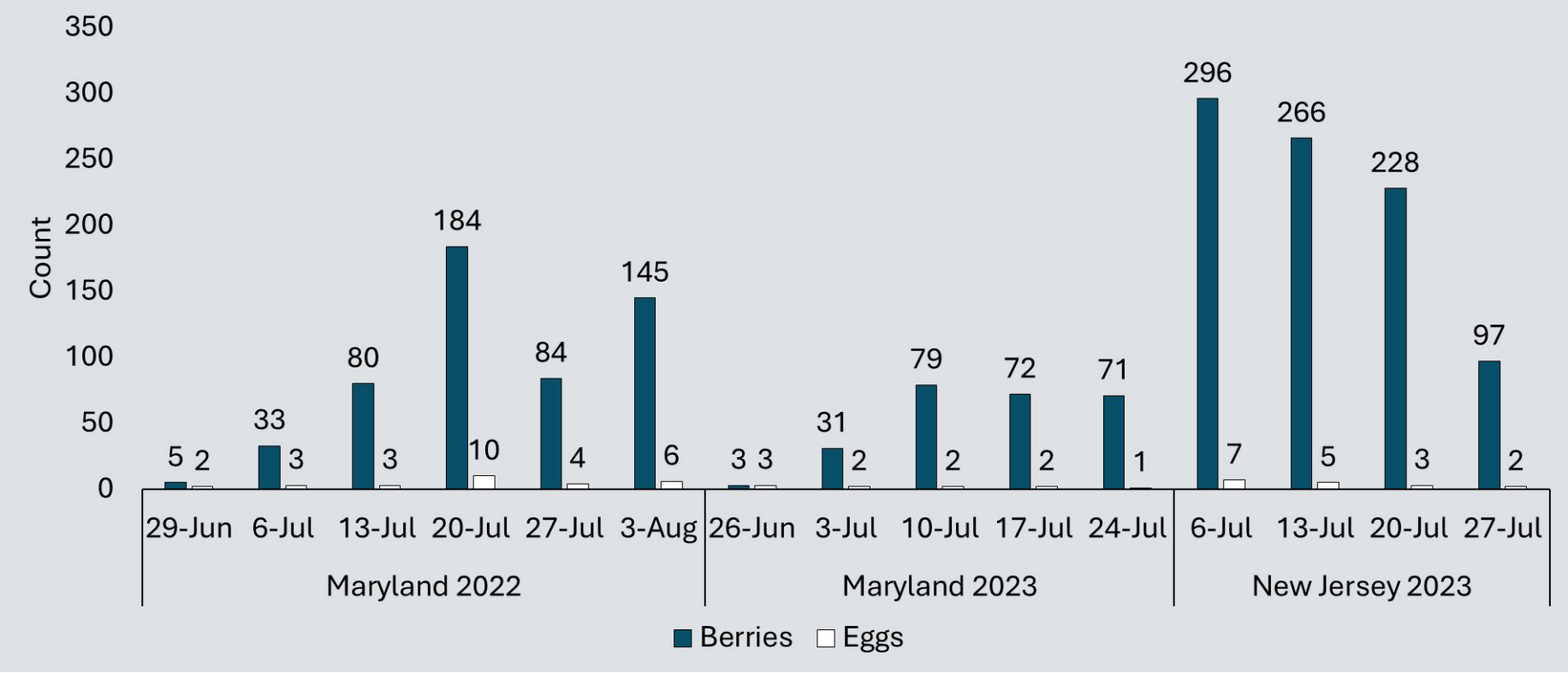
Berry Infestation



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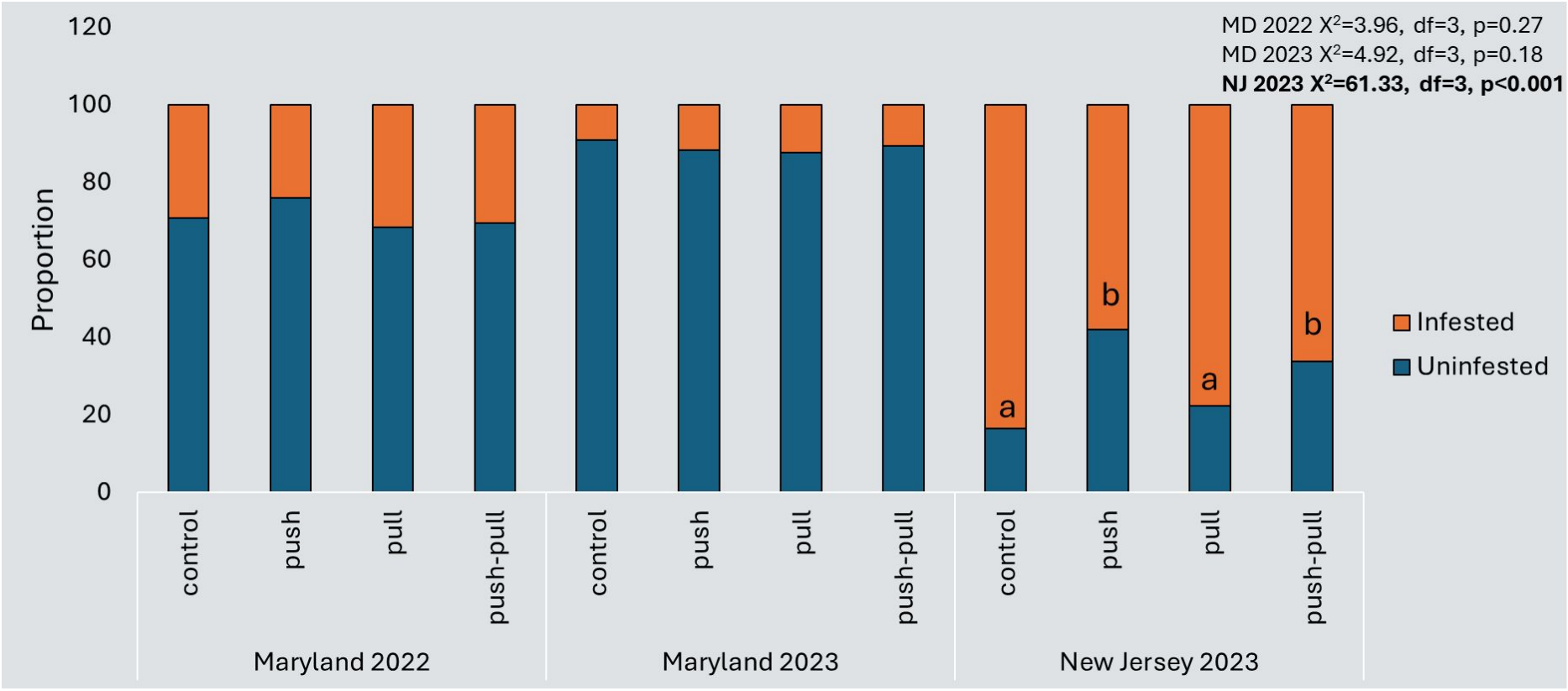
Frequency of Infestation



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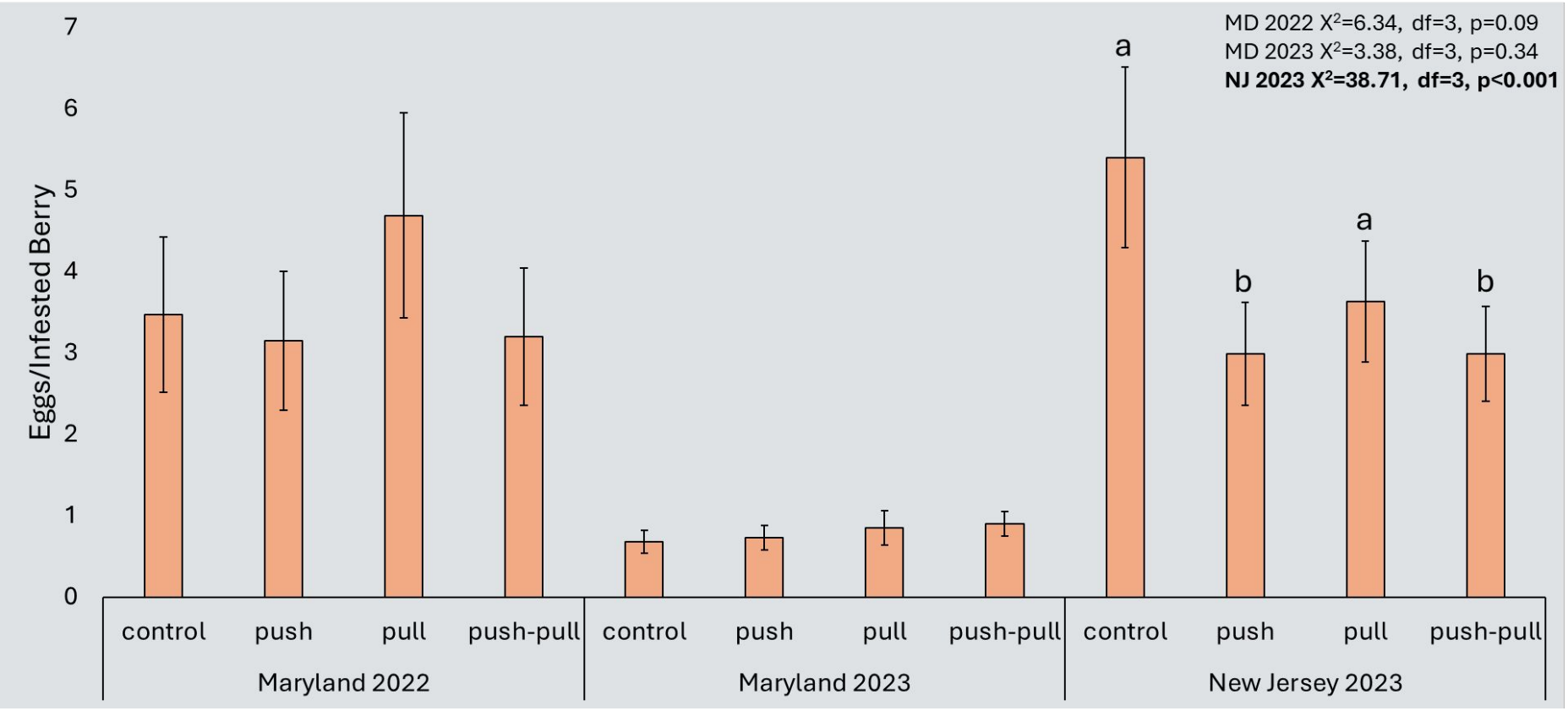
METHYL BENZOATE

Extent of Infestation



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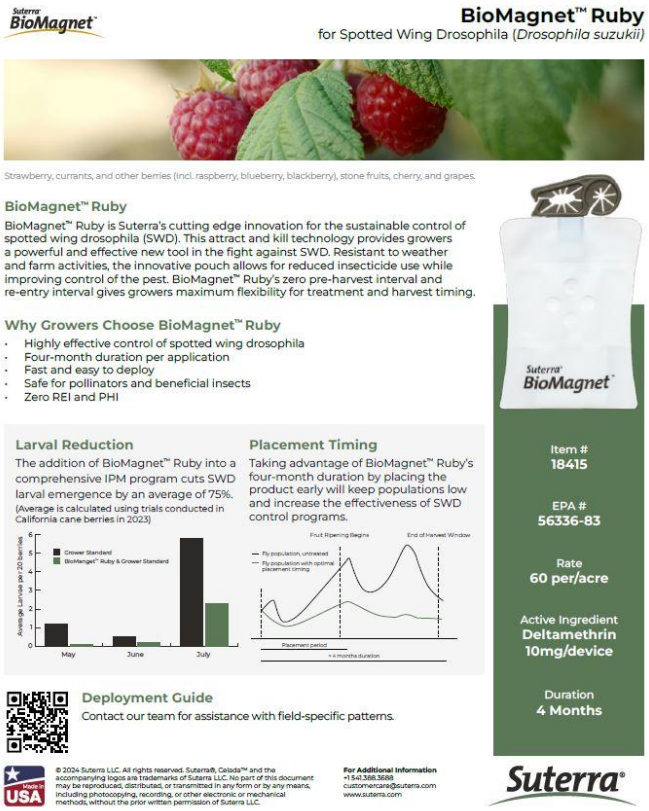
CONCLUSIONS

- Attract-and-kill approaches show promise in reducing SWD infestation
- But could be enhanced with the use of repellents/oviposition deterrent compounds (PUSH-PULL)
- Anthracnose-infected fruit also reduces SWD oviposition and repels flies.
- A volatile from fermented apple juice reduces SWD oviposition and repels flies.

FUTURE DIRECTIONS

- Incorporation into existing IPM programs.
- Further work on deployment and field-scale effectiveness needed.
- Testing new behavior-based products (BioMagnet Ruby, Decoy, etc.).



Suterra BioMagnet

BioMagnet™ Ruby
for Spotted Wing Drosophila (*Drosophila suzukii*)

Strawberry, currants, and other berries (Incl. raspberry, blueberry, blackberry), stone fruits, cherry, and grapes.

BioMagnet™ Ruby

BioMagnet™ Ruby is Suterra's cutting edge innovation for the sustainable control of spotted wing drosophila (SWD). This attract and kill technology provides growers a powerful and effective new tool in the fight against SWD. Resistant to weather and farm activities, the innovative pouch allows for reduced insecticide use while improving control of the pest. BioMagnet™ Ruby's zero pre-harvest interval and re-entry interval gives growers maximum flexibility for treatment and harvest timing.

Why Growers Choose BioMagnet™ Ruby

- Highly effective control of spotted wing drosophila
- Four-month duration per application
- Fast and easy to deploy
- Safe for pollinators and beneficial insects
- Zero REI and PHI

Larval Reduction

The addition of BioMagnet™ Ruby into a comprehensive IPM program cuts SWD larval emergence by an average of 75%. (Average is calculated using trials conducted in California cane berries in 2023)

Placement Timing

Taking advantage of BioMagnet™ Ruby's four-month duration by placing the product early will keep populations low and increase the effectiveness of SWD control programs.

Deployment Guide

Contact our team for assistance with field-specific patterns.

For Additional Information
+1.541.388.3688
customercare@suterra.com
www.suterra.com

Suterra BioMagnet

Item # 18415

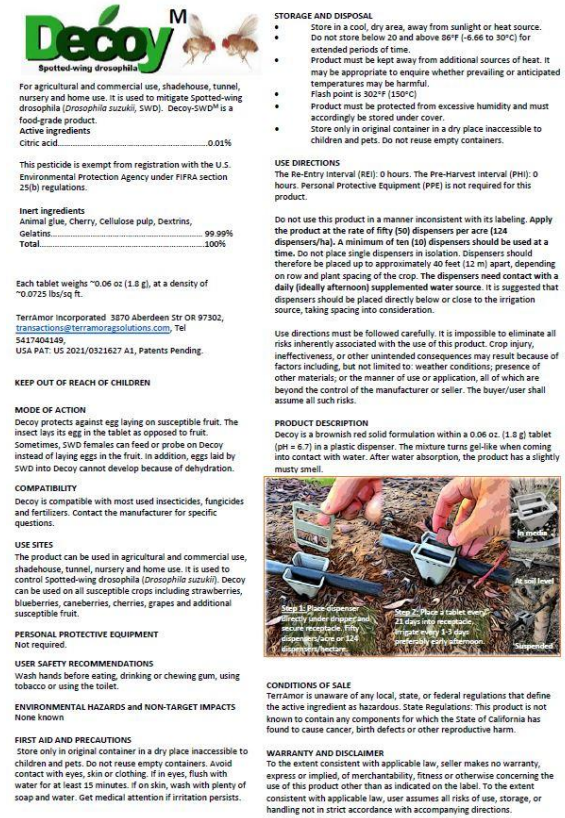
EPA # 56336-83

Rate 60 per/acre

Active Ingredient Deltamethrin 10mg/device

Duration 4 Months

Suterra



Decoy™
Spotted-wing drosophila

For agricultural and commercial use, shadehouse, tunnel, nursery and home use. It is used to mitigate Spotted-wing drosophila (*Drosophila suzukii*, SWD). Decoy-SWD™ is a food-grade product.

Active ingredients
Citric acid.....0.01%

This pesticide is exempt from registration with the U.S. Environmental Protection Agency under FIFRA section 25(b) regulations.

Inert ingredients
Animal glue, Cherry, Cellulose pulp, Dextrins, Gelatins.....99.99%
Total.....100%

Each tablet weighs ~0.06 oz (1.8 g), at a density of ~0.0725 lbs/sq ft.

TerrAmor Incorporated 3870 Aberdeen Str OR 97302, transactions@terramoragsolutions.com, Tel 5417404149,
USA PAT. US 2021/0321627 A1, Patents Pending.

KEEP OUT OF REACH OF CHILDREN

MODE OF ACTION
Decoy protects against egg laying on susceptible fruit. The insect lays its egg in the tablet as opposed to fruit. Sometimes, SWD females can feed or probe on Decoy instead of laying eggs in the fruit. In addition, eggs laid by SWD into Decoy cannot develop because of dehydration.

COMPATIBILITY
Decoy is compatible with most used insecticides, fungicides and fertilizers. Contact the manufacturer for specific questions.

USE SITES
The product can be used in agricultural and commercial use, shadehouse, tunnel, nursery and home use. It is used to control Spotted-wing drosophila (*Drosophila suzukii*). Decoy can be used on all susceptible crops including strawberries, blueberries, caneberries, cherries, grapes and additional susceptible fruit.

PERSONAL PROTECTIVE EQUIPMENT
Not required.

USER SAFETY RECOMMENDATIONS
Wash hands before eating, drinking or chewing gum, using tobacco or using the toilet.

ENVIRONMENTAL HAZARDS and NON-TARGET IMPACTS
None known

FIRST AID AND PRECAUTIONS
Store only in original container in a dry place inaccessible to children and pets. Do not reuse empty containers. Avoid contact with eyes, skin or clothing. If in eyes, flush with water for at least 15 minutes. If on skin, wash with plenty of soap and water. Get medical attention if irritation persists.

STORAGE AND DISPOSAL
- Store in a cool, dry area, away from sunlight or heat source.
- Do not store below 20 and above 86°F (-6.66 to 30°C) for extended periods of time.
- Product must be kept away from additional sources of heat. It may be appropriate to enquire whether prevailing or anticipated temperatures may be harmful.
- Flash point is 302°F (150°C)
- Product must be protected from excessive humidity and must accordingly be stored under cover.
- Store only in original container in a dry place inaccessible to children and pets. Do not reuse empty containers.

USE DIRECTIONS
The Re-Entry Interval (REI): 0 hours. The Pre-Harvest Interval (PHI): 0 hours. Personal Protective Equipment (PPE) is not required for this product.

Do not use this product in a manner inconsistent with its labeling. **Apply the product at the rate of fifty (50) dispensers per acre (124 dispensers/ha). A minimum of ten (10) dispensers should be used at a time.** Do not place single dispensers in isolation. Dispensers should therefore be placed up to approximately 40 feet (12 m) apart, depending on row and plant spacing of the crop. **The dispensers need contact with a daily (ideally afternoon) supplemented water source.** It is suggested that dispensers should be placed directly below or close to the irrigation source, taking spacing into consideration.

Use directions must be followed carefully. It is impossible to eliminate all risks inherently associated with the use of this product. Crop injury, ineffectiveness, or other unintended consequences may result because of factors including, but not limited to: weather conditions; presence of other materials; or the manner of use or application, all of which are beyond the control of the manufacturer or seller. The buyer/user shall assume all such risks.

PRODUCT DESCRIPTION
Decoy is a brownish red solid formulation within a 0.06 oz. (1.8 g) tablet (pH = 6.7) in a plastic dispenser. The mixture turns gel-like when coming into contact with water. After water absorption, the product has a slightly musty smell.

CONDITIONS OF SALE
TerrAmor is unaware of any local, state, or federal regulations that define the active ingredient as hazardous. State Regulations: This product is not known to contain any components for which the State of California has found to cause cancer, birth defects or other reproductive harm.

WARRANTY AND DISCLAIMER
To the extent consistent with applicable law, seller makes no warranty, express or implied, of merchantability, fitness or otherwise concerning the use of this product other than as indicated on the label. To the extent consistent with applicable law, user assumes all risks of use, storage, or handling not in strict accordance with accompanying directions.

Thank you

New Jersey Blueberry Cranberry Research Council

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

SARE Sustainable Agriculture Research & Education

The IR-4 Project