Behaviorally-Based Attract and Kill Systems for Apple Maggot and Spotted Wing Drosophila

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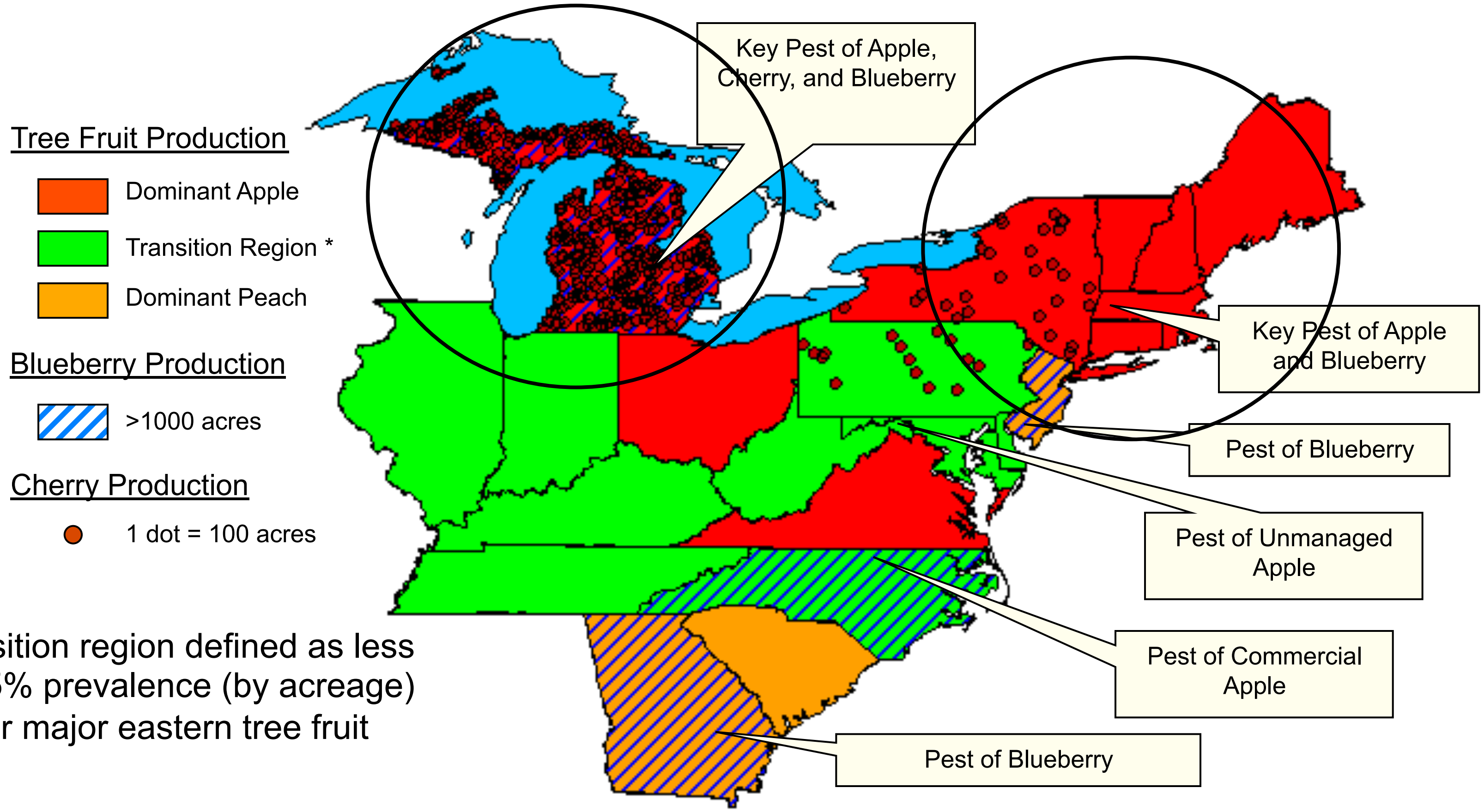
Pest Status of Key Tephritids in Eastern US



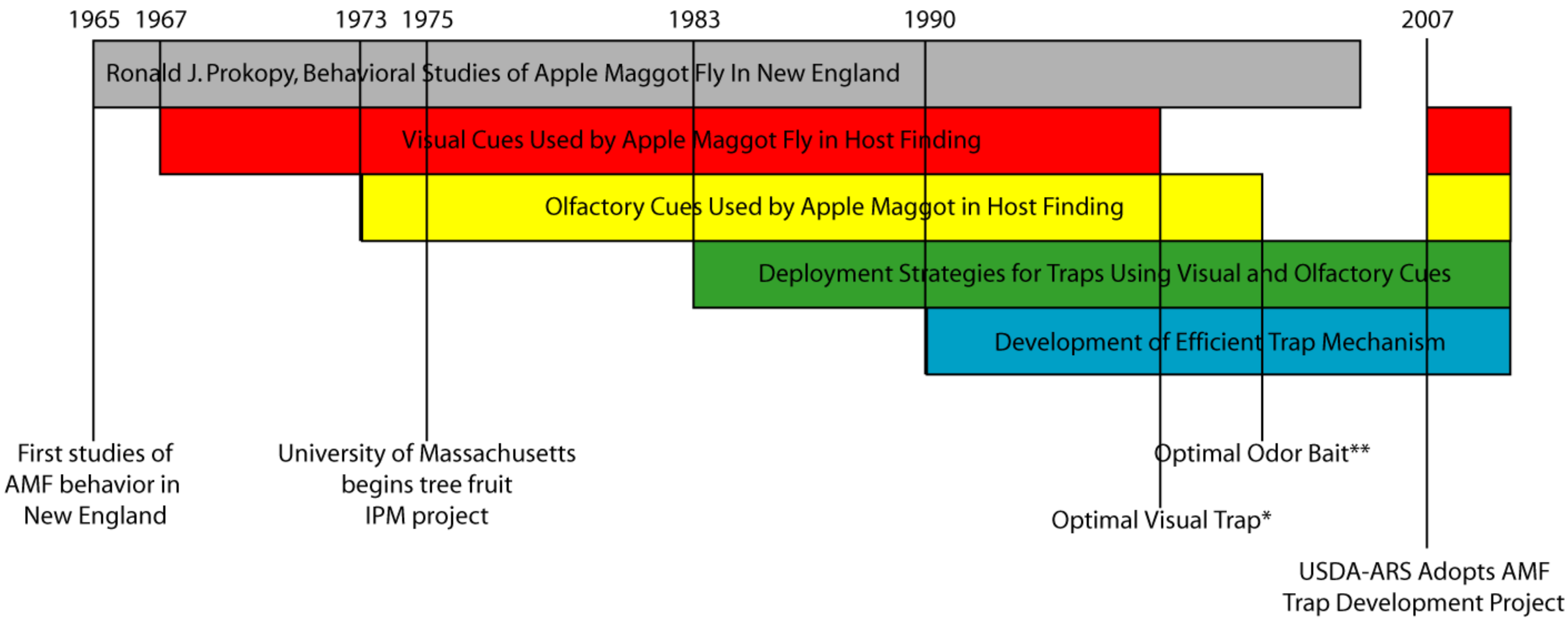
* Transition region defined as less than 85% prevalence (by acreage) of either major eastern tree fruit crop.

Data Source: USDA NASS 2008. Production Statistics for Noncitrus Fruits and Nuts, 2002 Annual Summary

The Challenge of Apple Maggot Fly

Design a trap-based control system for apple maggot fly that can replace broadcast insecticide sprays in commercial orchards with no loss in pest control and little increase in cost.

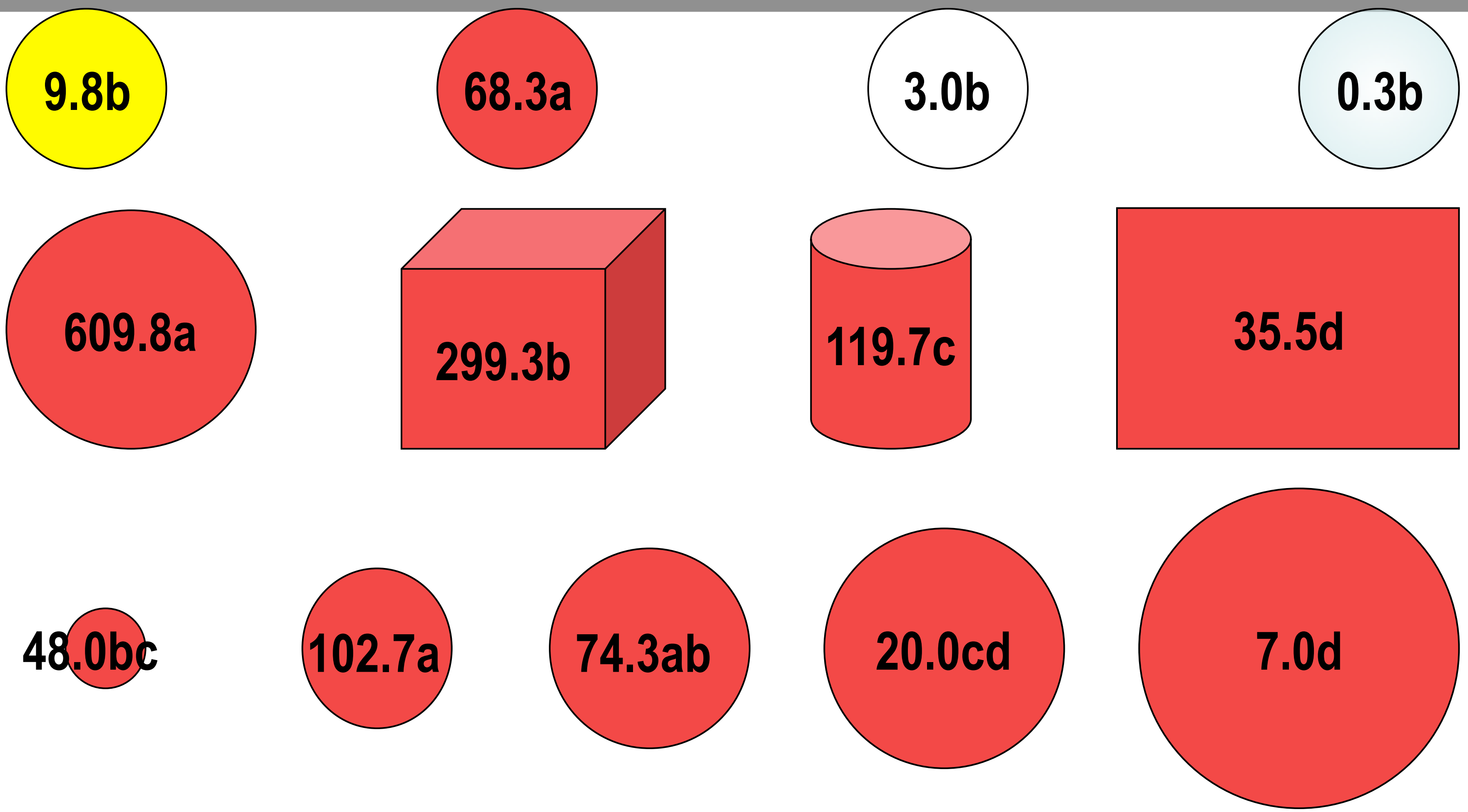
Building a Trap-Based Control System Background Research



Optimizing Components of Trap-Based Monitoring and Management Systems

- Visual Stimulus
- Olfactory Stimulus
- Deployment Strategy
- Capture Mechanism

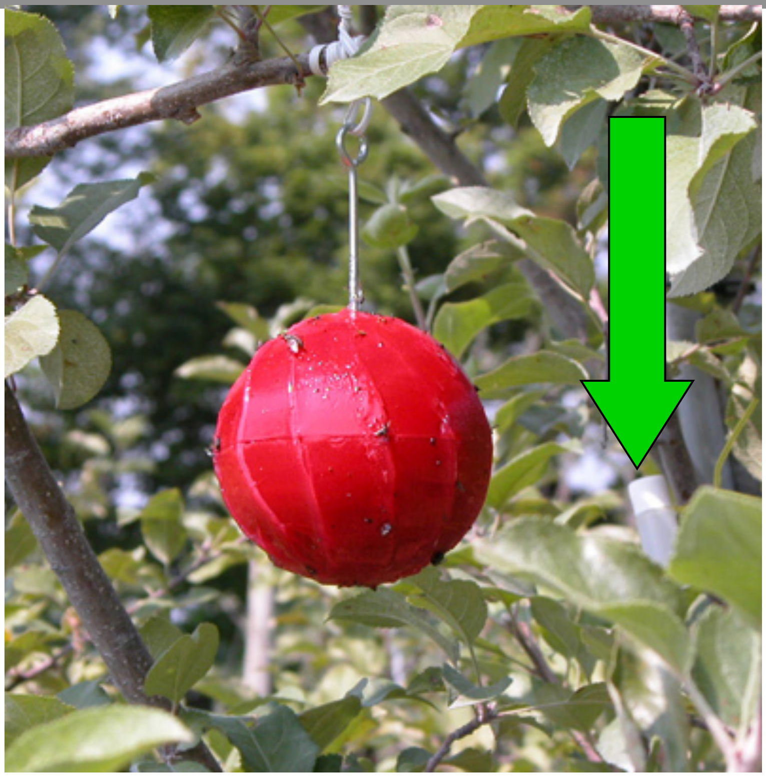
Optimizing Components of the Trapping System
Visual Stimulus



Optimizing Components of the Trapping System
Olfactory Stimulus

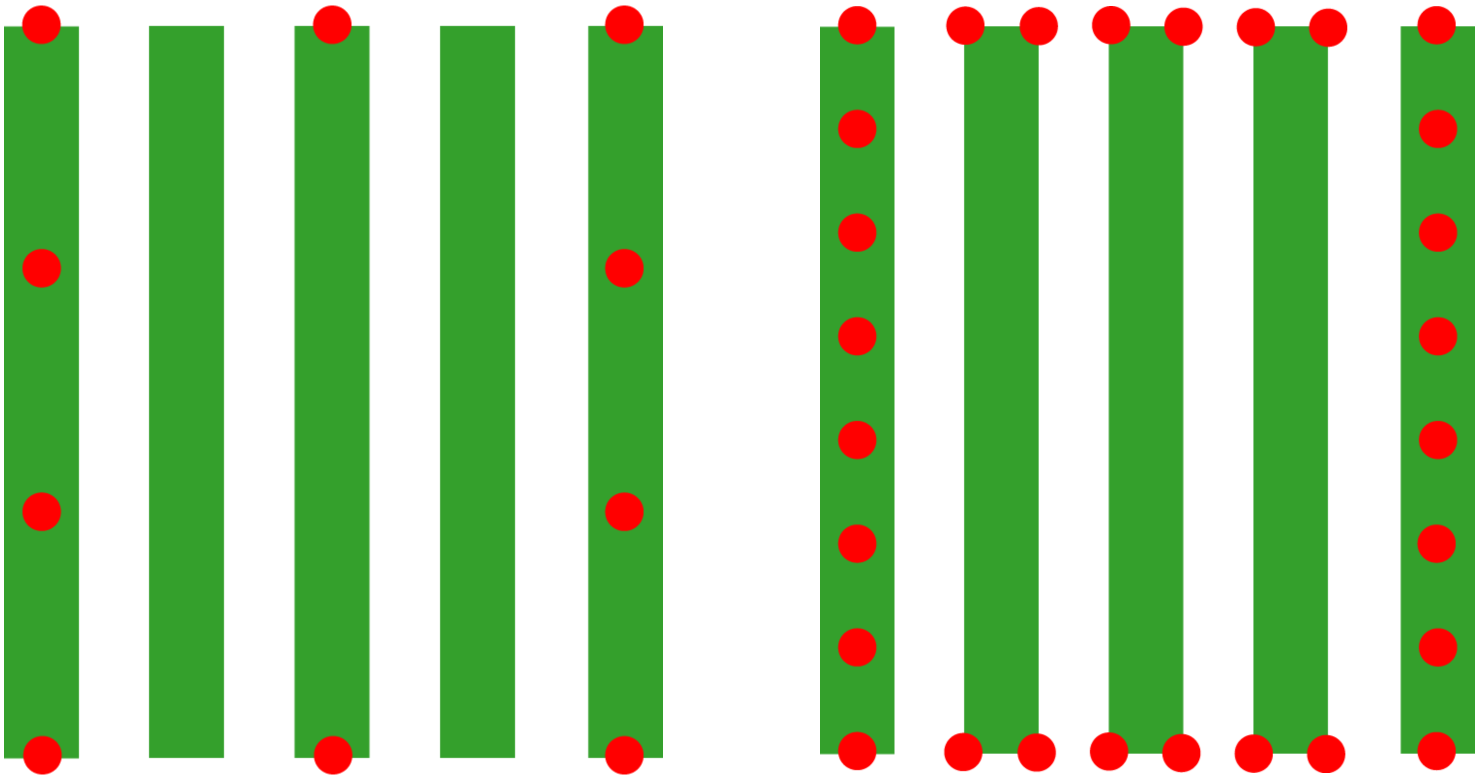
- AMF attracted to odor of ripening apple.
- 5-component blend outperforms a single compound (Zhang et al. 1999).

Unbaited	Single Component	Multiple Component
98.9 c	247.2 b	500.5 a



Optimizing Components of the Trapping System
Deployment Strategy

- Perimeter deployment, risk-based



Trap spacing based on scale of threat and susceptibility of plot.

Optimizing Components of the System
Capture Mechanism



From 1991-1996, attempts to sustain effectiveness of pesticide-treated spheres using chemical and physical barriers.

Optimizing Components of the System
Renewal of Feeding Stimulant

Internal Renewal

External Renewal

In 1996, began prototyping of traps that were renewed by environmental moisture, rather than depleted.

Meeting the Environmental Challenges

Inherent challenges with deploying starch-based structure in nature.
Does not fit the context of the cropping system.

External Renewal of Feeding Stimulant

1997

1998

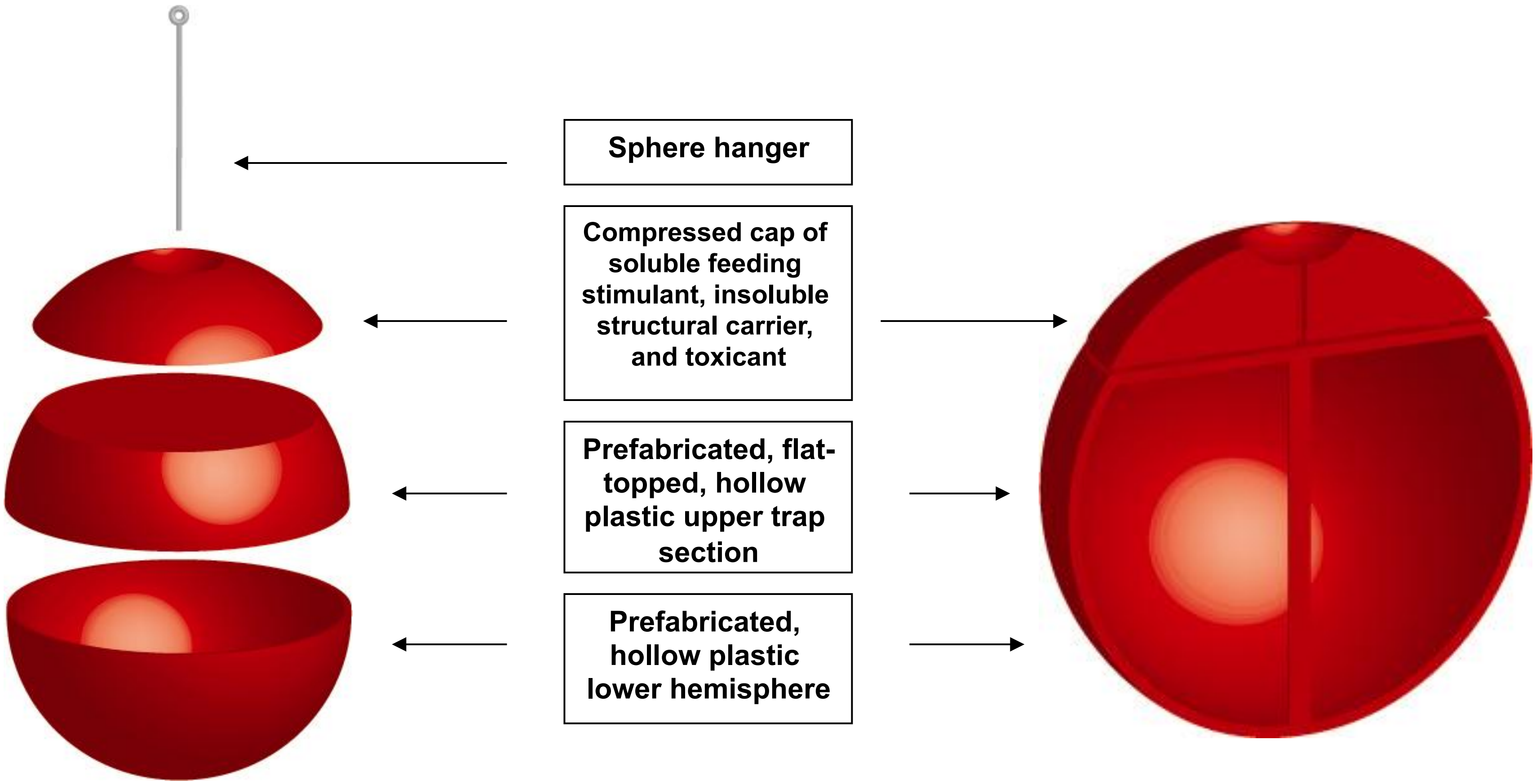
1999

2000

2001

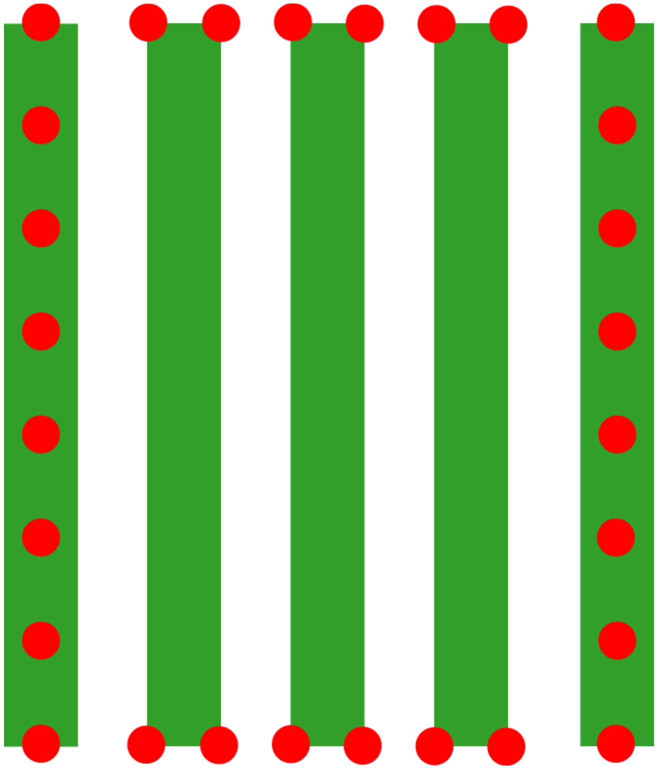
Slow progress toward feeding stimulant release mechanism that would last 15 weeks without regard to field conditions.

Attracticidal Sphere Components



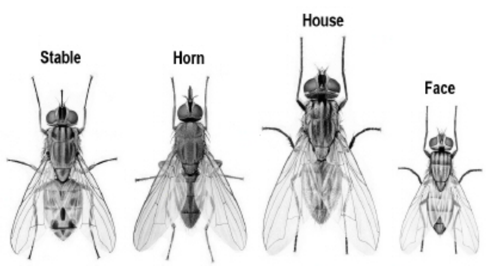
Visually integrated cap and sphere body, nonpersistent toxicant bound in expendable cap

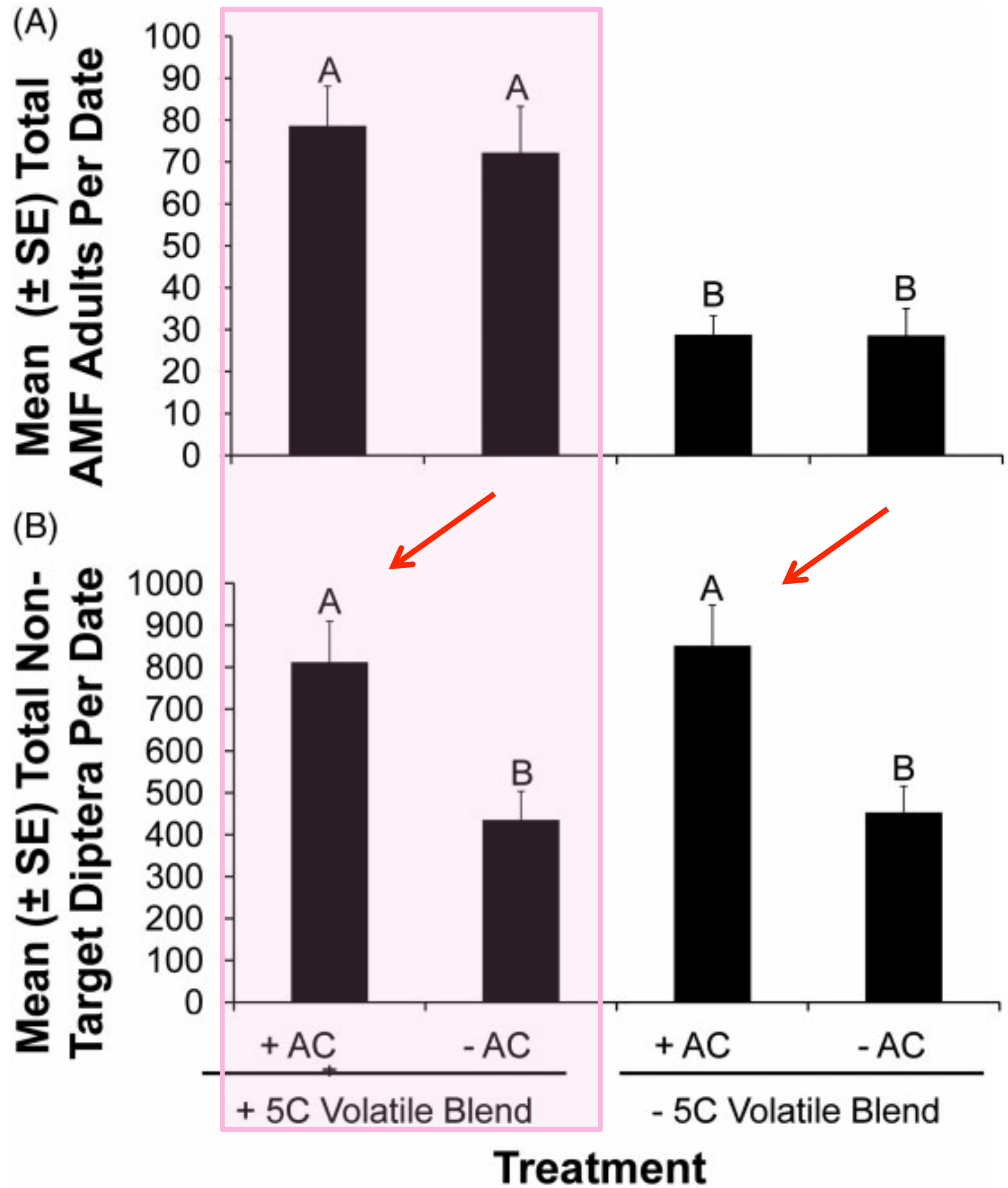
Perimeter-Based Attract and Kill System for Apple Maggot



Wright et al. 2012

Enhancing Attract and Kill for Apple Maggot





Morrison et al. 2016

Field Performance in Commercial Orchards
0.5% Spinosad + 10% AC

Treatment	Damage			
	Total fruit sampled	No. of damaged fruit	% Damaged fruit	χ^2
2010				
Red sphere	997	29	2.91%	a
Grower control	1,023	30	2.93%	a
2011				
Red sphere	751	25	3.33%	a
Grower control	961	17	1.77%	a

No. Insecticide Sprays
Control = 3.0 per season
Sphere = 0.3 per season

Morrison et al. 2016

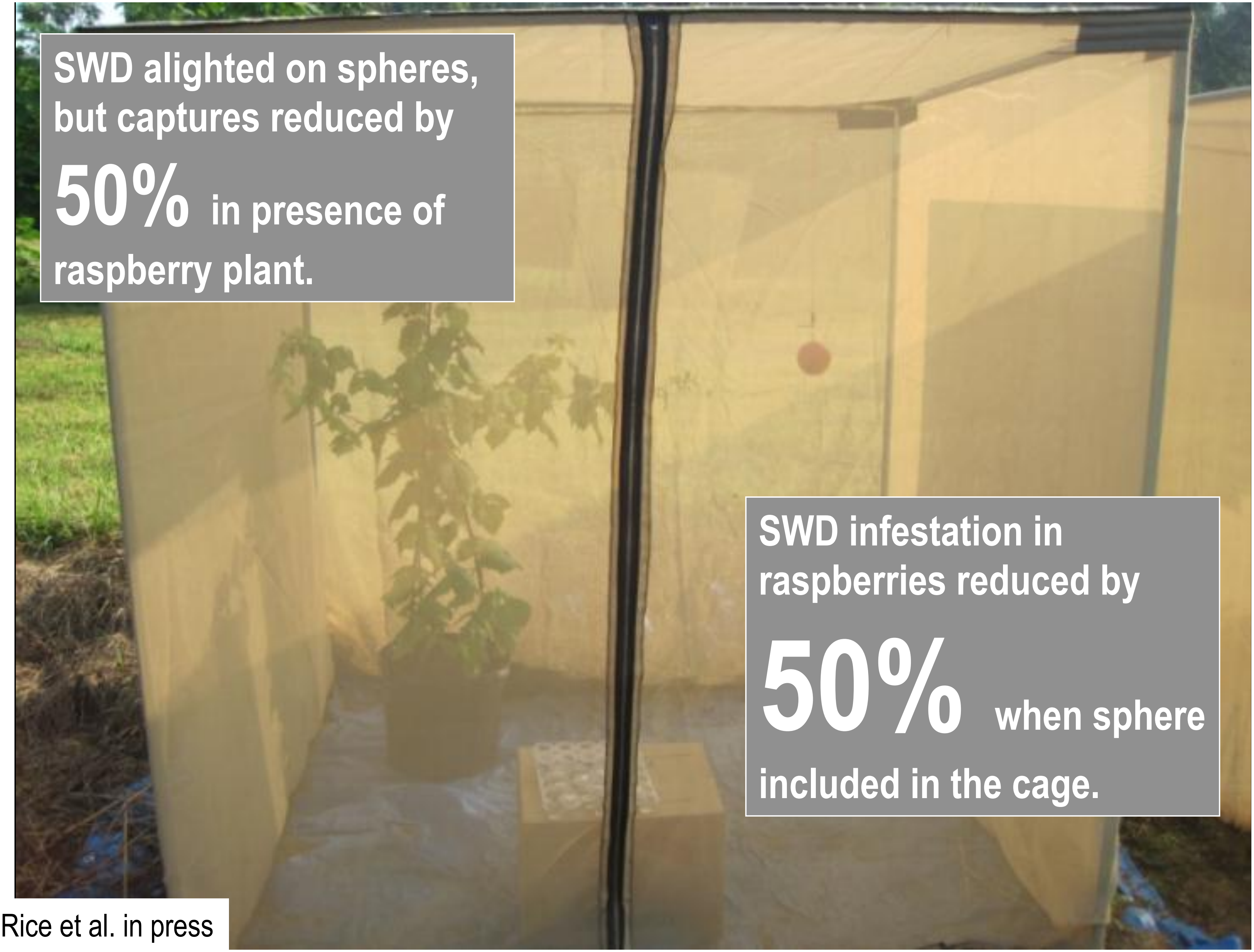

Griffin Dill

Can we use attracticidal sphere system developed for apple maggot for SWD?

"Proof of Concept" Attract-and-Kill Study

Will SWD alight on red spheres?
What effect does their presence have on infestation?

- Released 25 males and 25 females into field cages.
- Treatments
  - Sphere Alone
  - Sphere + Raspberry Plant
  - Raspberry Plant Alone
  - Control
- Flies foraged freely for 48 h.
- Recorded number of SWD captured on spheres and number of SWD recovered from fruit.



Rice et al. in press

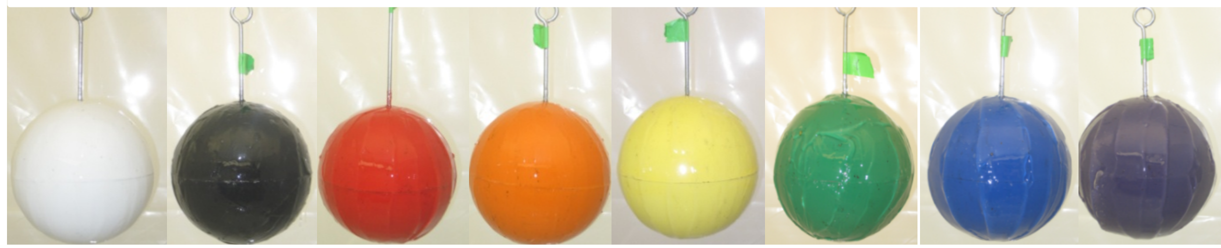
Can We Develop an Attract and Kill System for SWD?

- Visual Stimulus
- Olfactory Stimulus
- Deployment Strategy
- Capture or Kill Mechanism

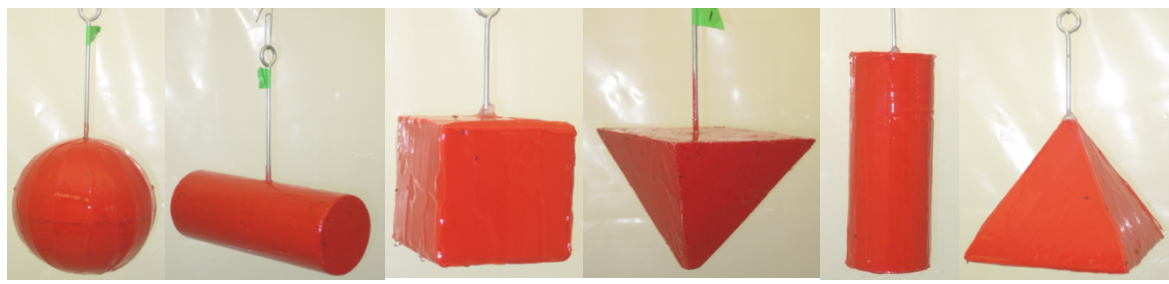
Does SWD Respond To Visual Cues?

Visual Stimuli

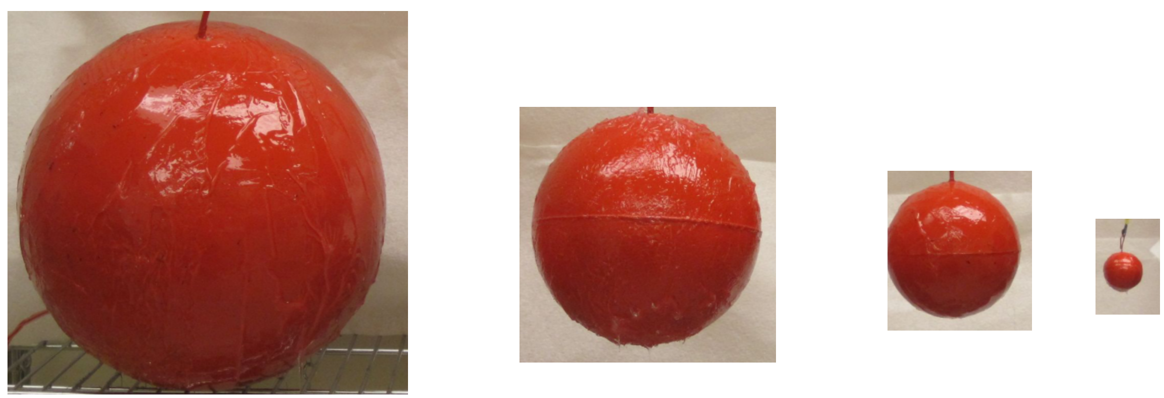
Color



Shape

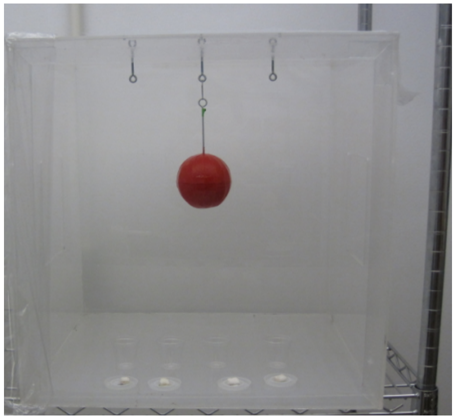


Size



Laboratory

- Release 20 colony-reared, mature anesthetized SWD into cage.
- SWD permitted to freely forage for 6h.

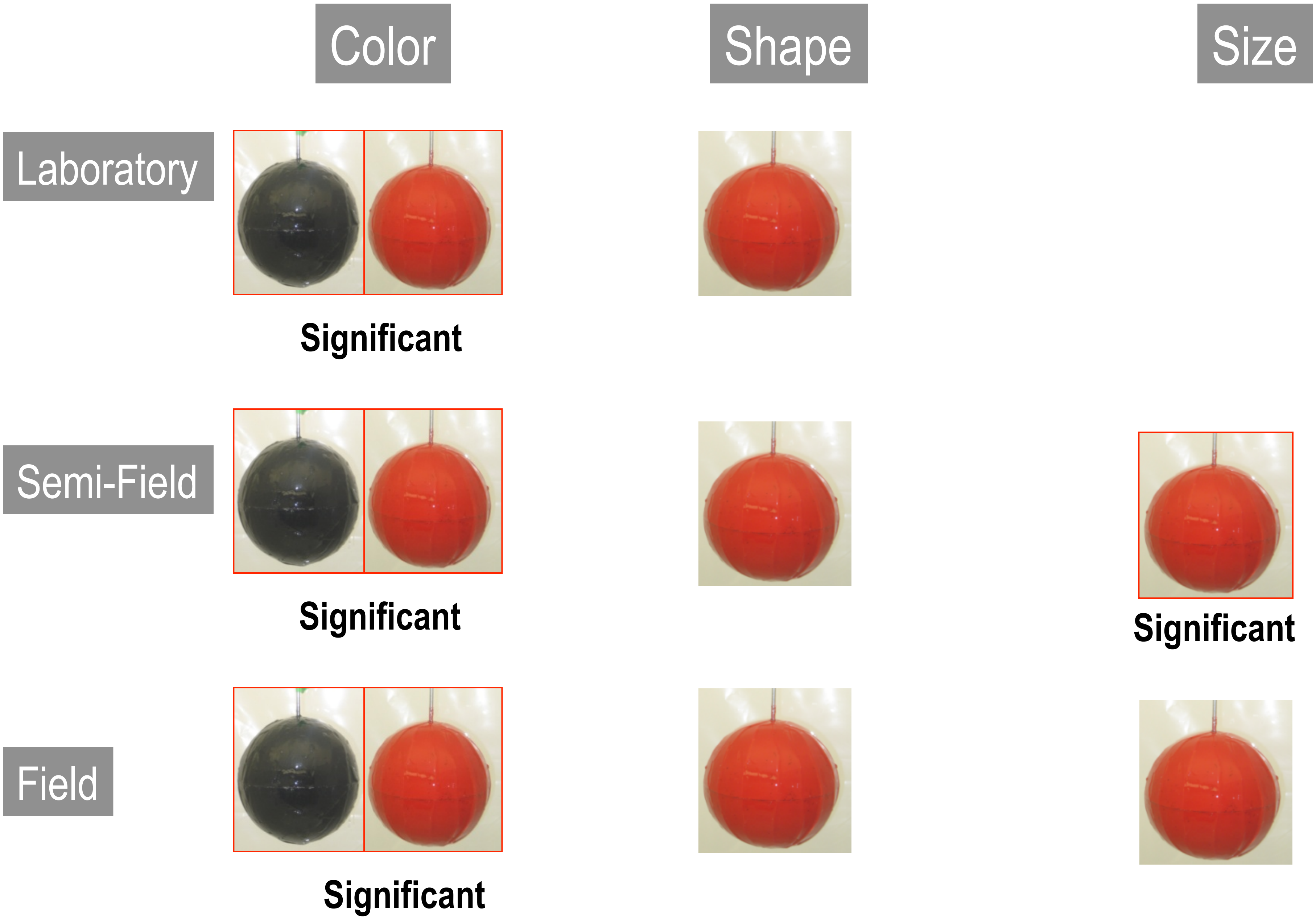


Semi-Field

- Release 30 colony-reared, mature anesthetized SWD.
- SWD permitted to freely forage for 48h.

Field

- Assess response of wild SWD populations.
- Stimuli in field for 48h.



Rice et al. 2016

Conclusions From Visual Ecology Trials

- SWD do respond to visual cues.
- Color appears important as black and red routinely outperformed other colors.
- A spherical shape with a size greater than 2.5 cm appears acceptable.

Rice et al. 2016

Capture or Kill Mechanism

While Tangletrap is a good capture and kill mechanism, it requires a great deal of labor, is messy and not likely to be adopted.

Can We Replace Tangletrap as the Capture or Killing Agent?

- Evaluate lethality of attracticidal spheres developed for AMF for SWD.

- Cap contains a feeding stimulant (sugar) and toxicant.

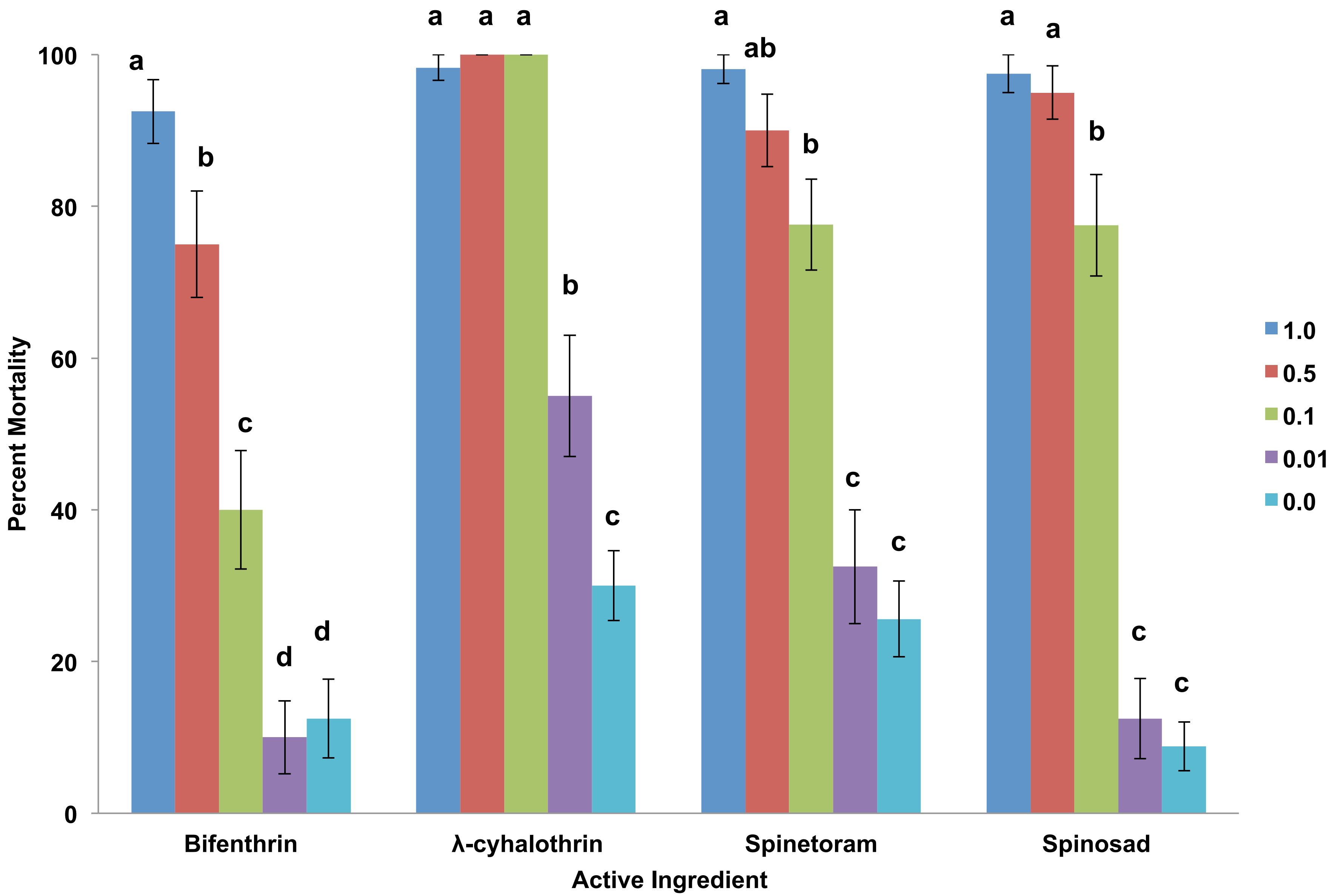
- Exploits environmental moisture to continuously renew toxicant on sphere surface.

Morrison et al. 2016, Wright et al. 2012

Laboratory Evaluation of Lethality

- Insecticides: Bifenthrin, Lambda-cyhalothrin, Spinetoram, and Spinosad.
- Rates: 0.0, 0.01, 0.1, 0.5 and 1.0% a.i.
- Evaluated a minimum 20 males and 20 females/insecticide/rate.
- Released at sphere equator and allowed to forage freely for 5 min. Measured foraging time.
- Evaluated toxic effects at 0, 24 and 48 h after exposure

Laboratory Lethality Results



Additional Lethality Trials

- **Conventional**
  - Dinotefuran
  - Imidacloprid
  - Spinetoram
  - Acephate
  - Permethrin
  - Lambda-Cyhalothrin

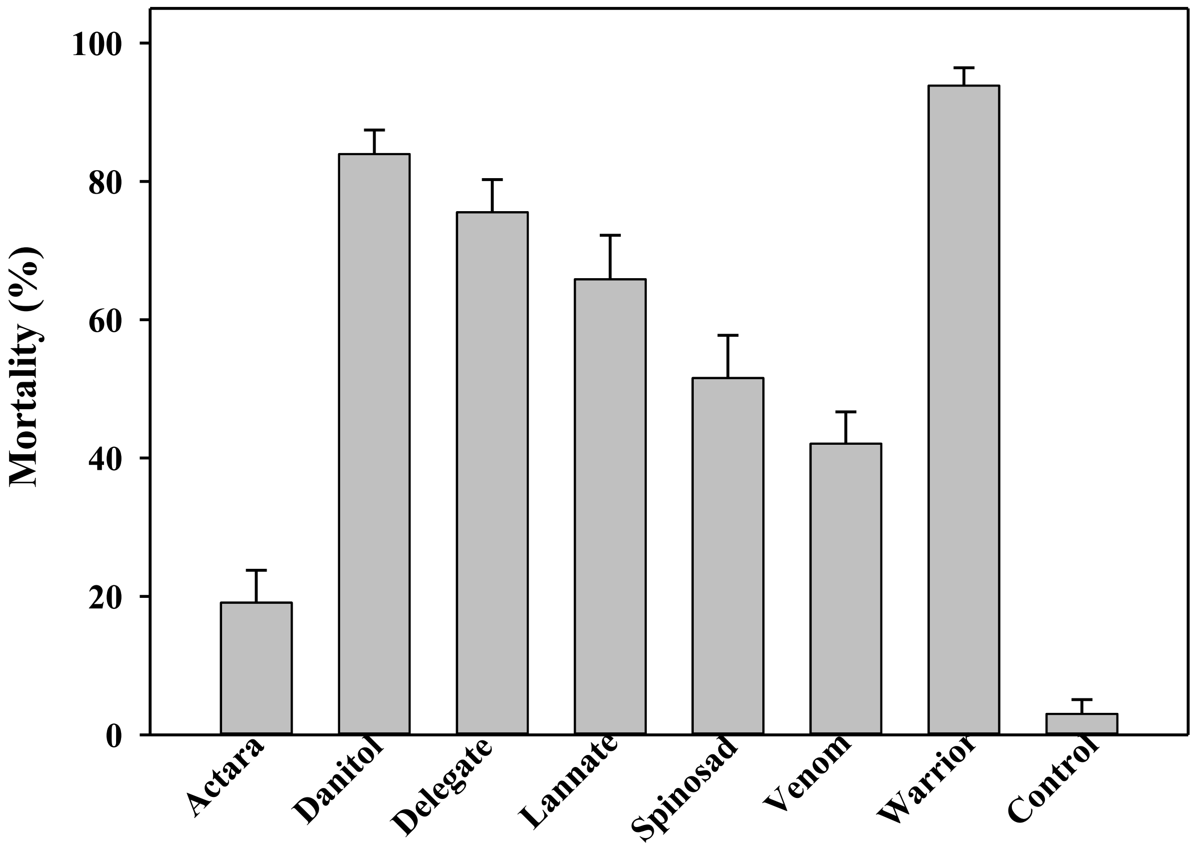
- **Organic**
  - Spinosad
  - Grandevo
  - Boric Acid

Insecticide	Rate (% A.I)	Mortality (%)
Dinotefuran	**1.0**	**100.0**
Dinotefuran	**0.5**	**92.5**
Dinotefuran	**0.1**	**70.0**
Imidacloprid	**1.0**	**55.0**
Imidacloprid	**0.5**	**70.0**
Imidacloprid	**0.1**	**80.0**
Spinetoram	**1.0**	**100.0**
Spinosad	**1.0**	**100.0**
Boric Acid	10	5.0
Boric Acid	**0.1**	**21.0**
Acephate	**1.0**	**90.0**
Acephate	**0.5**	**95.0**
Acephate	**0.1**	**77.5**
Permethrin	**1.0**	**100.0**
Lambda-Cyhalothrin (CS)	**1.0**	**100.0**
Lambda-Cyhalothrin (WG)	**1.0**	**100.0**
Chromobacterium subtsugae	0.1	7.5
Chromobacterium subtsugae	1.0	15.0
Chromobacterium subtsugae	10.0	16.7

The goal is to create a system that remains lethal and visually attractive for a 12 week period. This includes exposure to UV and rainfall (1”/week)

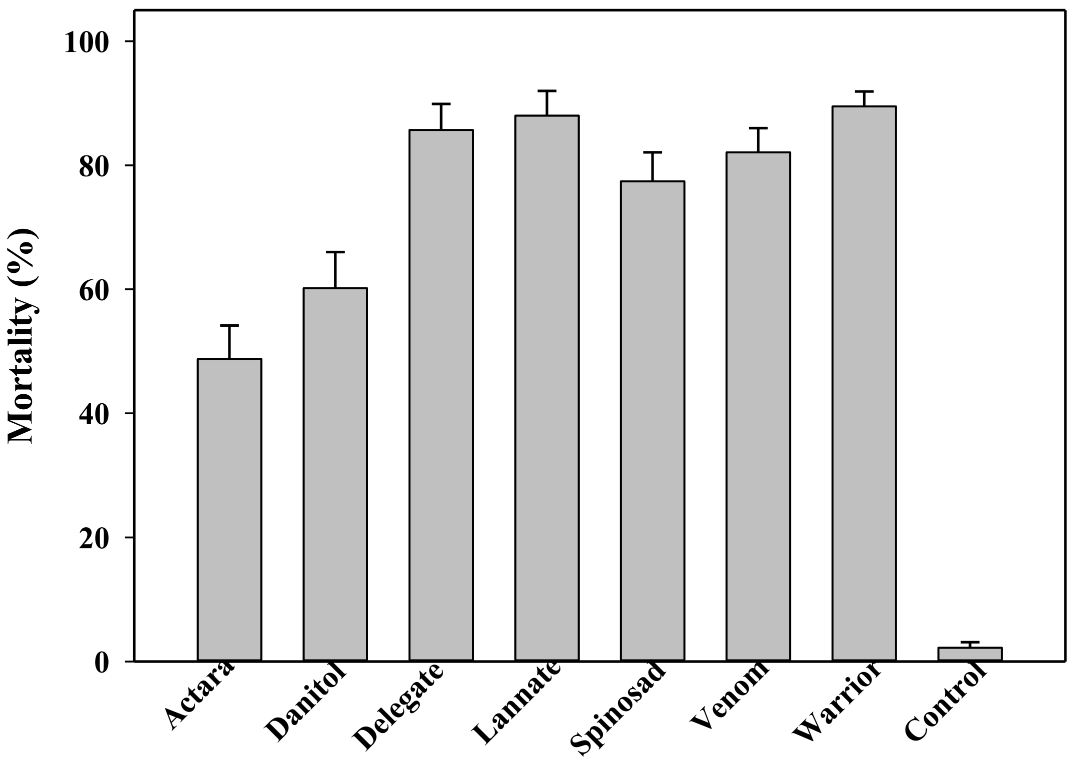
How Quickly Does Rain Degrade Spheres?

- 1 " rainfall/week for 6 weeks (equivalent to average rainfall rates during summer)
- SWD exposed to sphere 5 min.
- Mortality assessed at 48 hrs



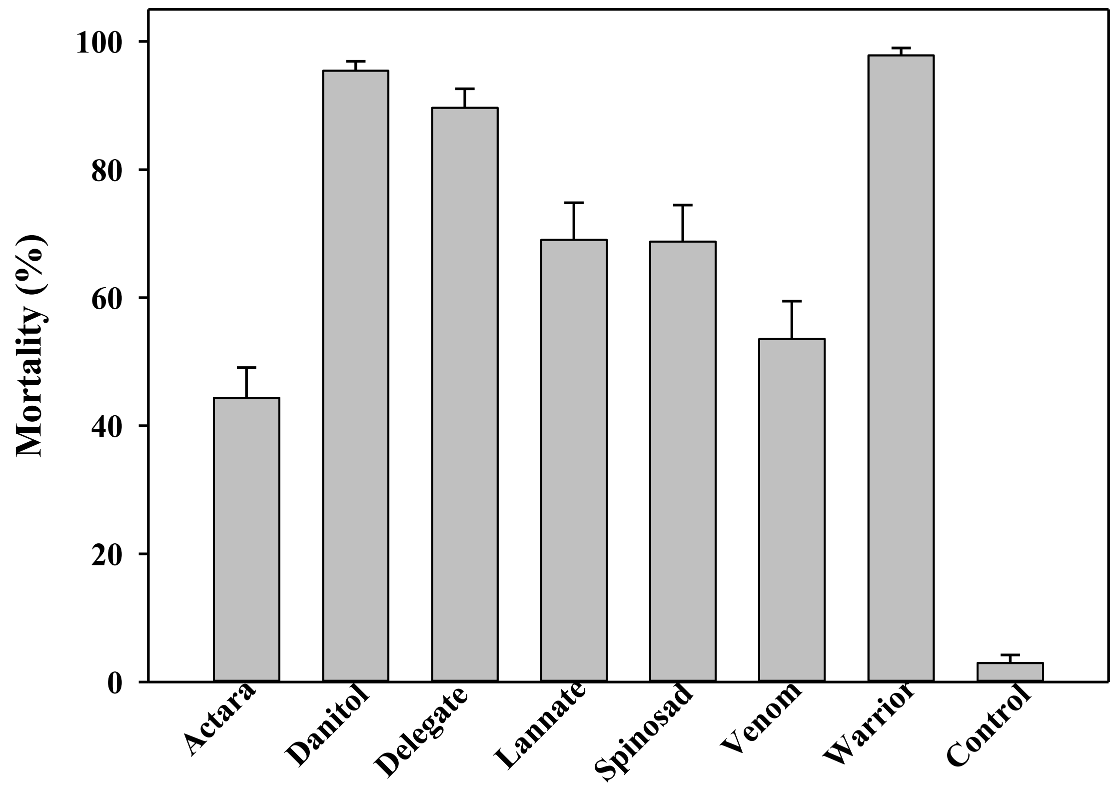
How Quickly Does UV Degrade Spheres?

- Full spectrum light 16:8 (L:D) for 6 weeks (equivalent to 6 weeks of UV exposure during summer)
- SWD exposed to sphere for 5 min
- Mortality assessed 48 hrs



How quickly does the combination?

- Light may dry excess moisture providing improved efficacy compared with rain-only treatment.



****In 2017, spheres will be exposed to natural environmental conditions**

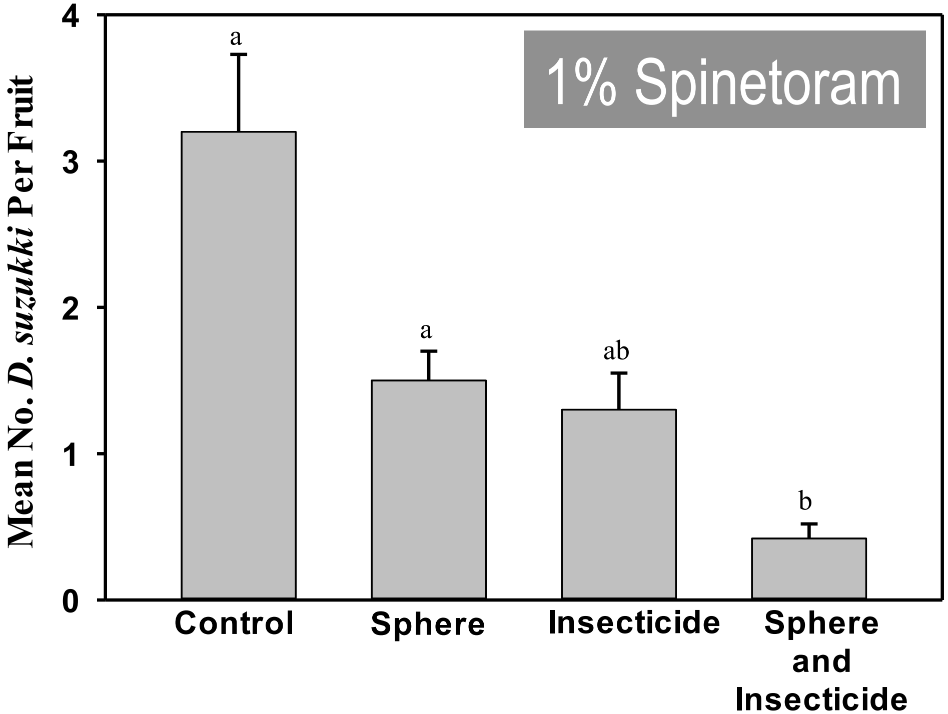
Field Evaluation Attracticidal Spheres

Can we reduce SWD infestation in a susceptible crop using attracticidal spheres?

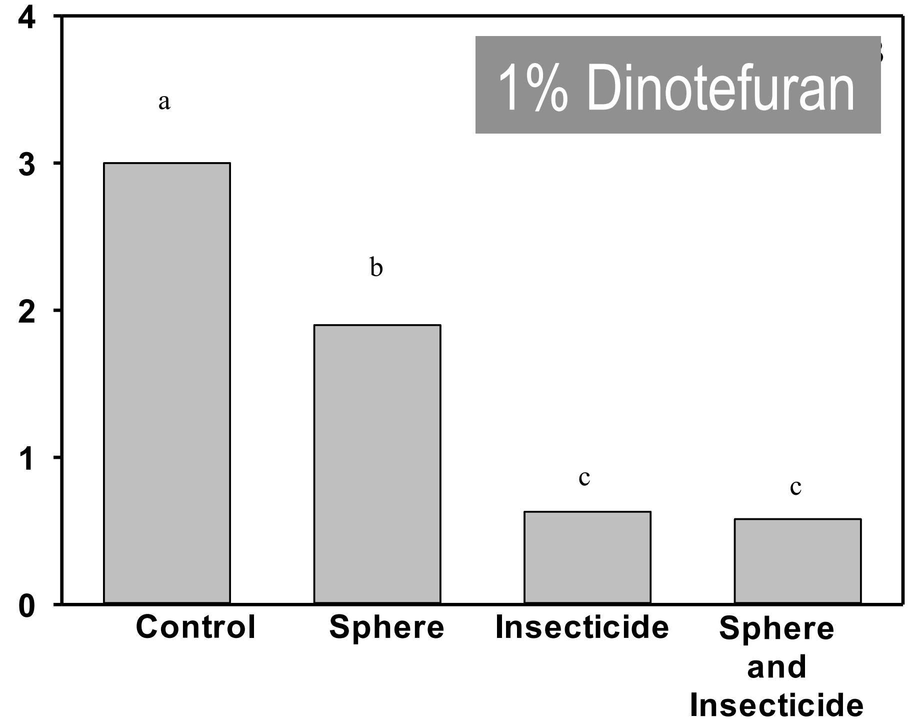
Experimental Set-Up

- Four experimental treatments evaluated for SWD management.
  1) weekly sprays (Brigade, Entrust or Danitol)
  2) 1% Delegate/Spinetoram (2013) and 1% Venom/Dinotefuran (2014) attracticidal spheres at a rate of 1/plant
  3) sprays + spheres
  4) Control
- Monitored SWD populations with traps baited with yeast/sugar.
- Harvested ripe berries and evaluated infestation rates.

Experimental Set-Up



All Ripe Fruit Harvested



Subsample of Fruit Taken

Rice et al. in press

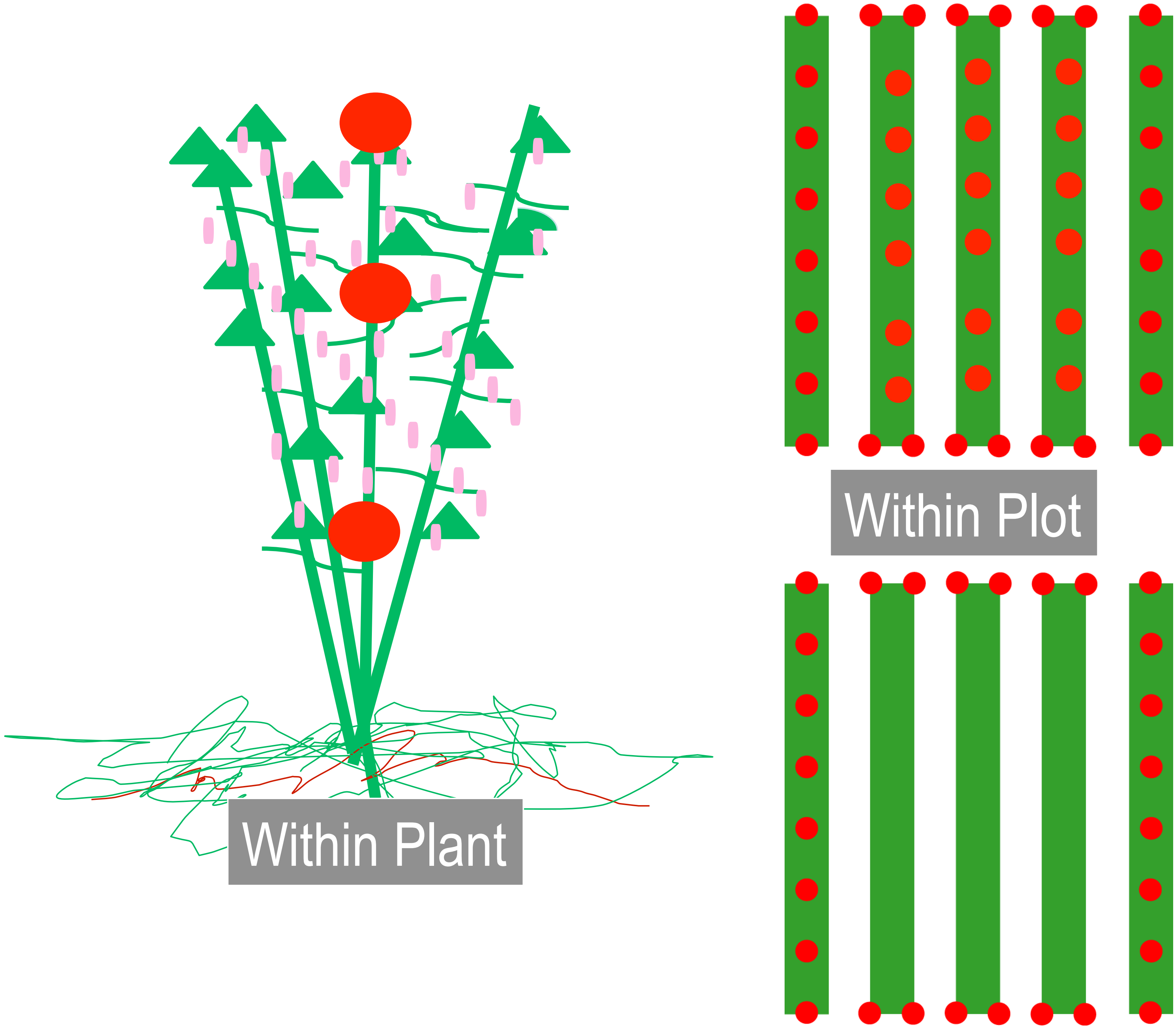
Tentative Conclusions and Key Questions

- We can replace Tangletrap with attracticidal spheres as capture/ kill mechanism.
  - *Optimal insecticides and % AI for organic and conventional plantings?*
- Attracticidal spheres reduced infestations of SWD infestations in experimental plantings.
  - *How does other horticultural practices influence overall efficacy?*
- Spheres hung at top of plant.
  - *What is the optimal deployment strategy?*

Deployment Strategy For Attracticidal Spheres

Deployment Strategy For Attracticidal Spheres

- Where do SWD prefer to forage within a single host plant?
- How do SWD move among plants within plots?


Within Plot
Within Plant

Where do SWD Choose To Forage Within a Host Plant?

Clean, ripe berries for oviposition

Tangletrap-coated ripe berries for alightment

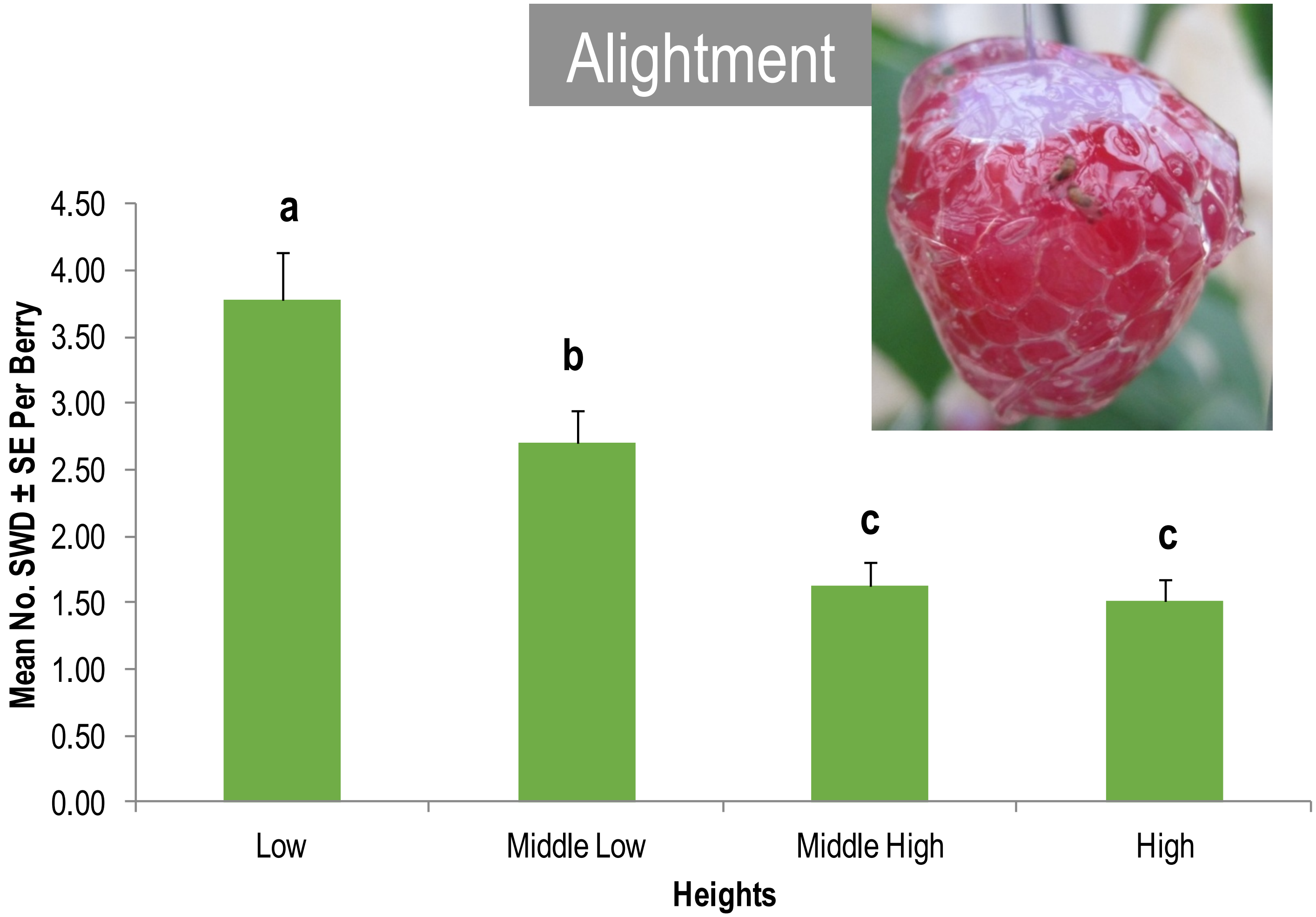
Within-Plant Foraging Semi-Field Bioassay

Where do SWD Choose To Forage Within a Host Plant?

- 4 heights.
- 5 berries per height. Four exterior berries and one center.
- Release 120 sexually mature adults.
- Recovered after 24h.

Influence of Berry Height

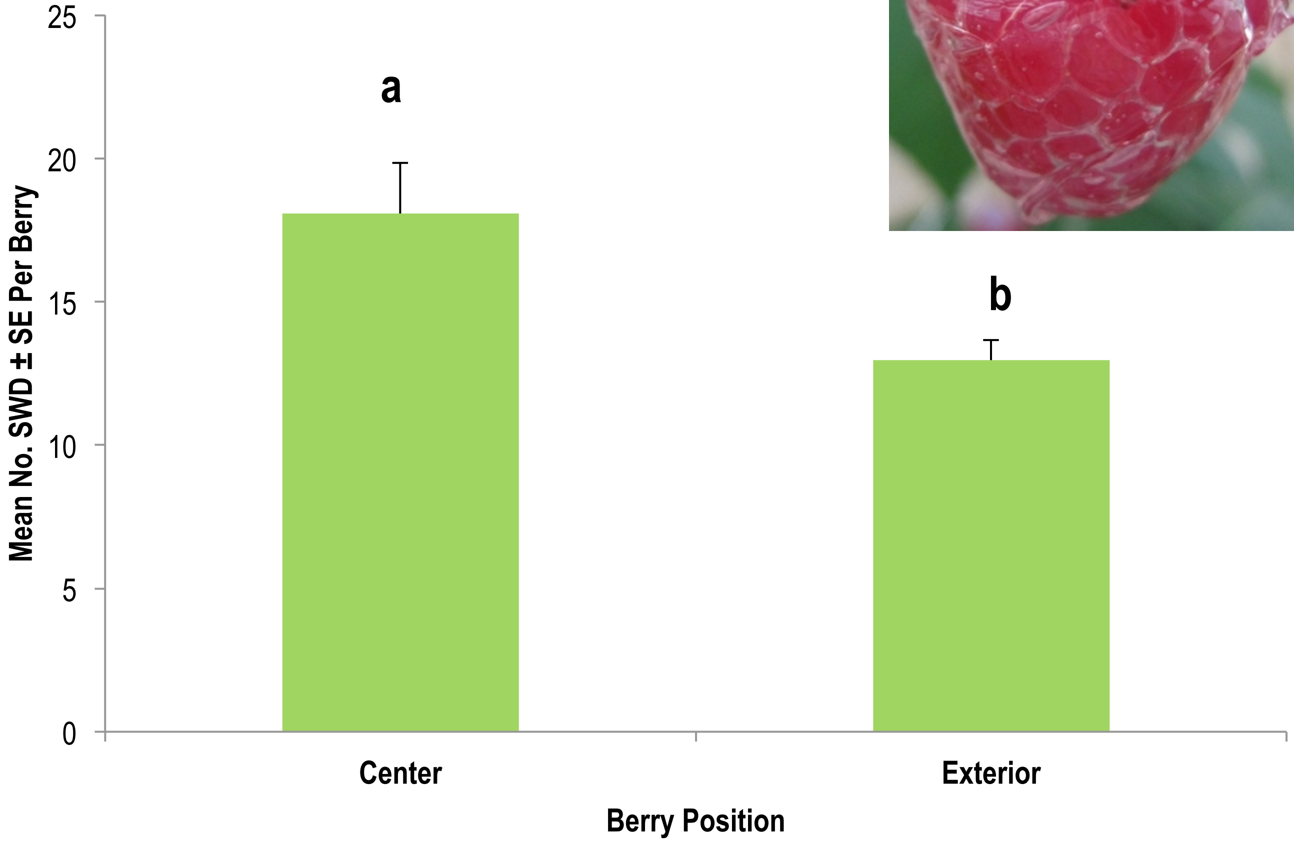
Alightment



Rice et al. submitted

Influence of Berry Position

Alightment



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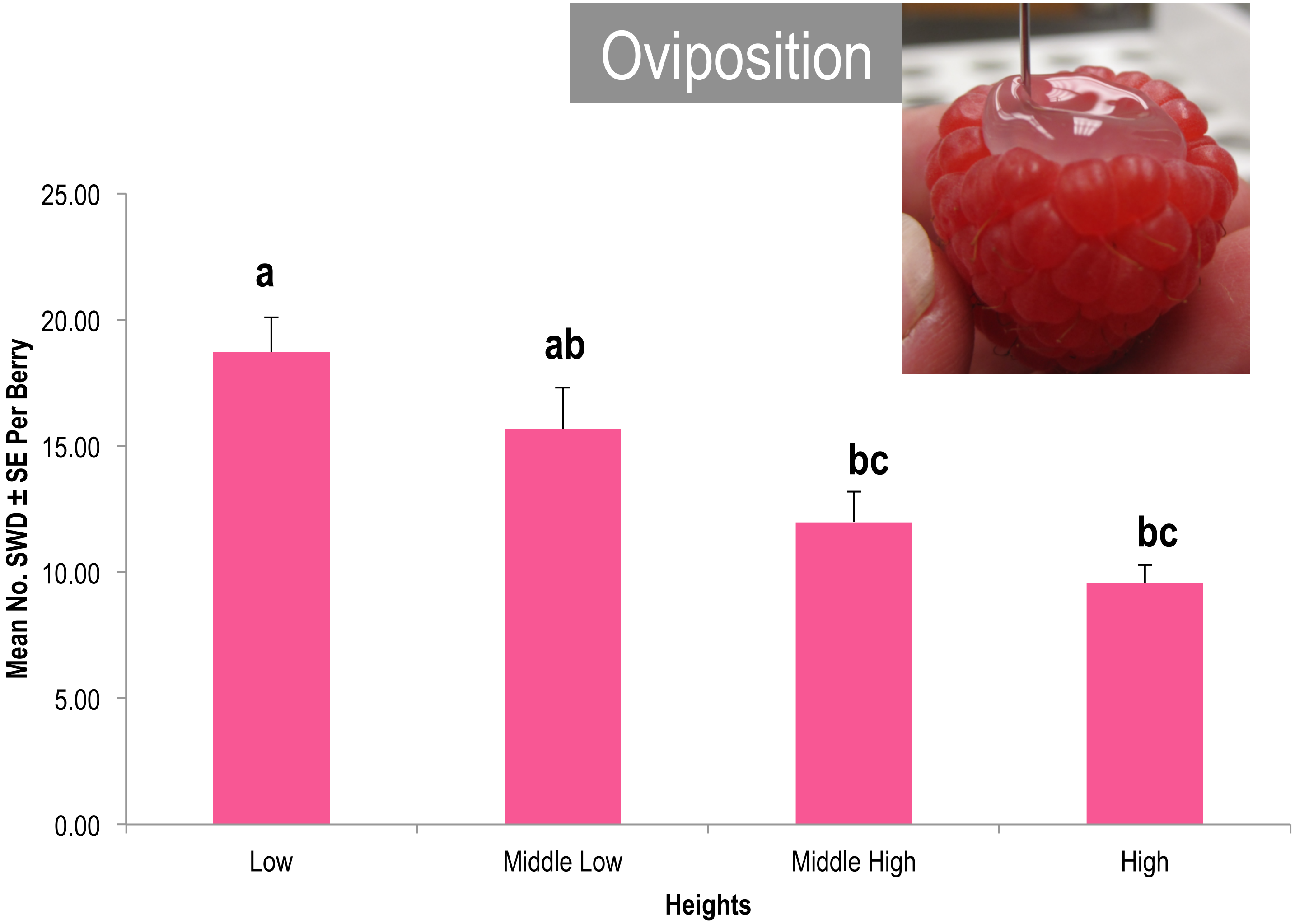
Where do SWD Choose To Forage Within a Host Plant?

Oviposition



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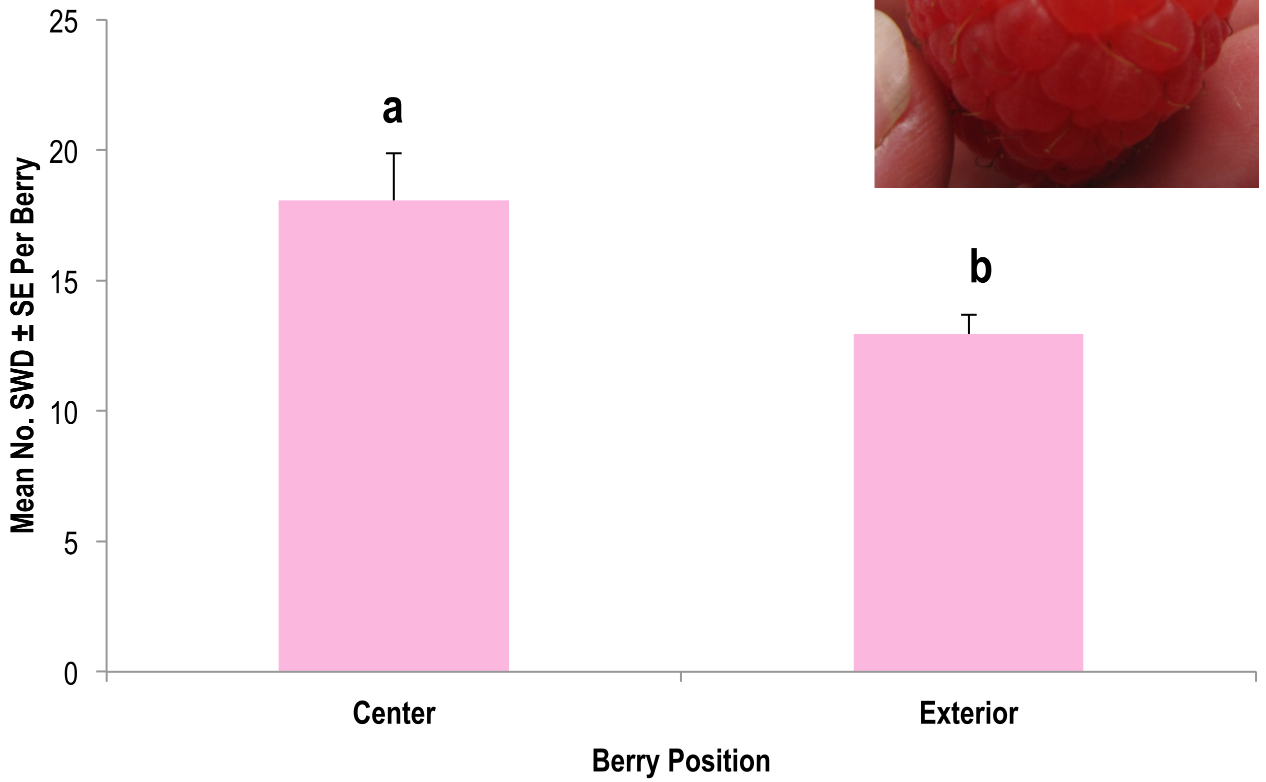
Where do SWD Choose To Forage Within a Host Plant?

Oviposition



Rice et al. submitted

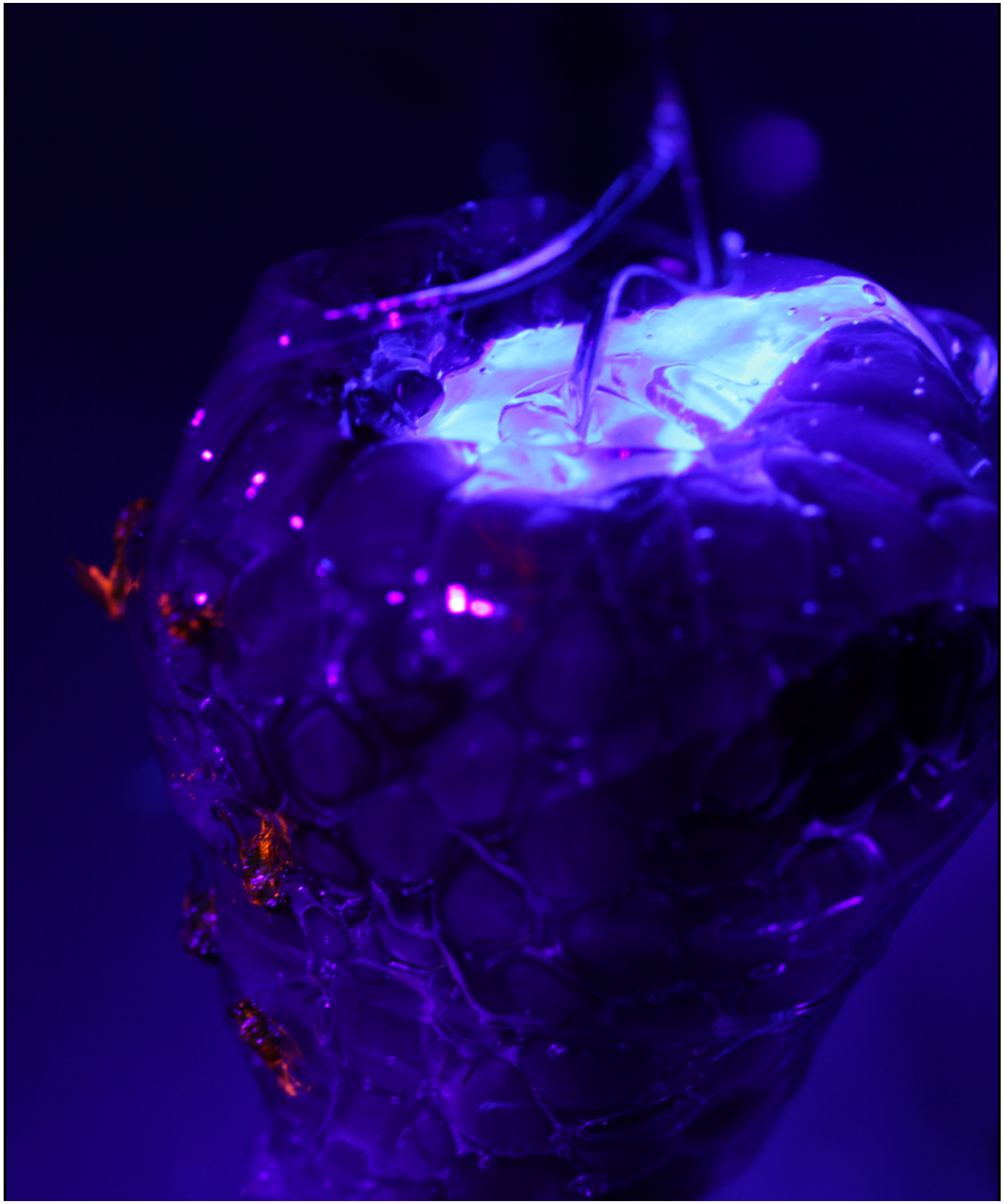
Deployment Strategy For Attracticidal Spheres

- Where do SWD prefer to forage within a single host plant?
- How do SWD move among plants within plots?

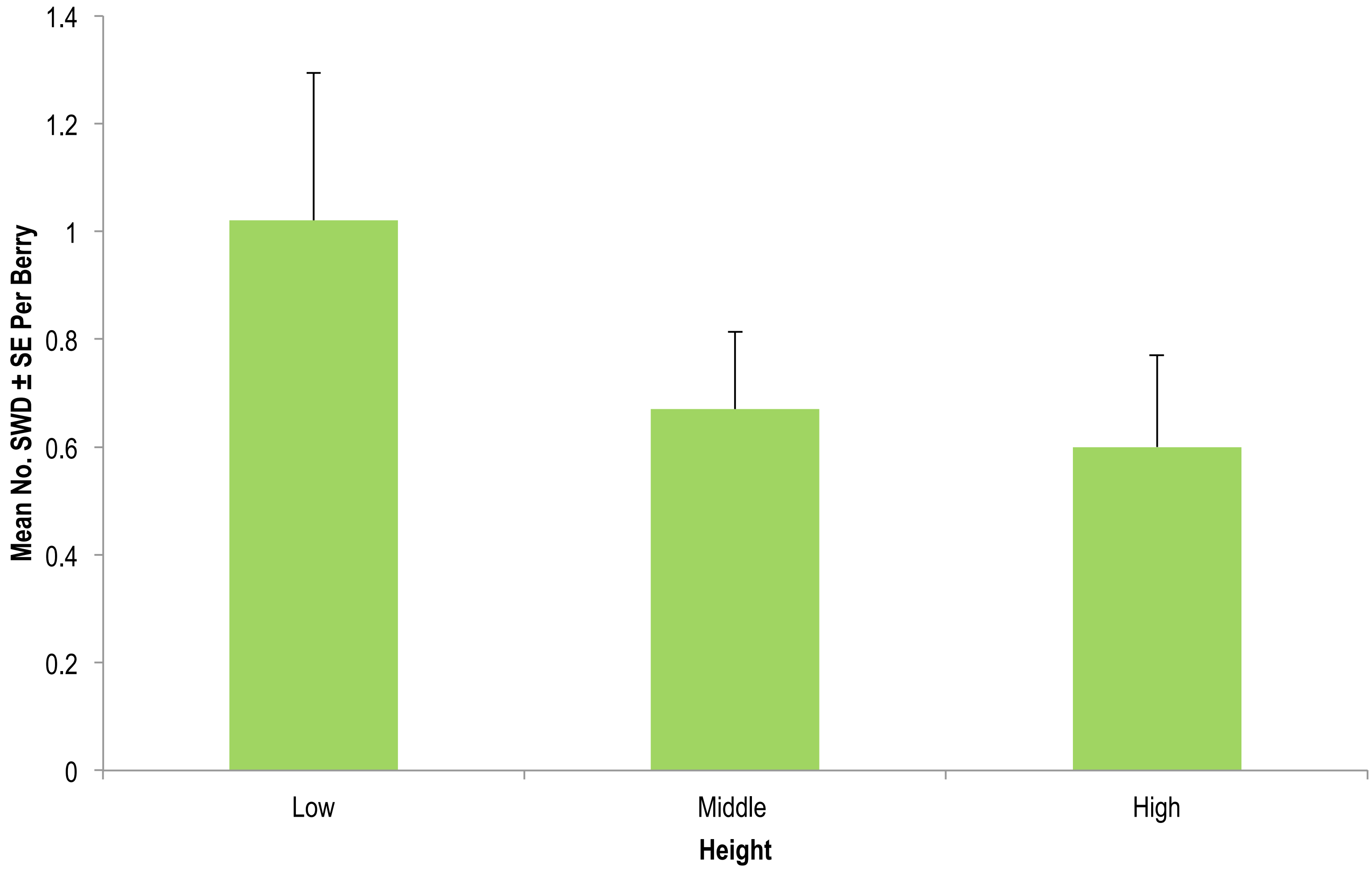
Mark-Release-Recapture Study

Sticky Sentinel Berries

1.8% Non-Fliers
2.3% Recaptured



Where do SWD Choose To Forage Within a Host Plant?



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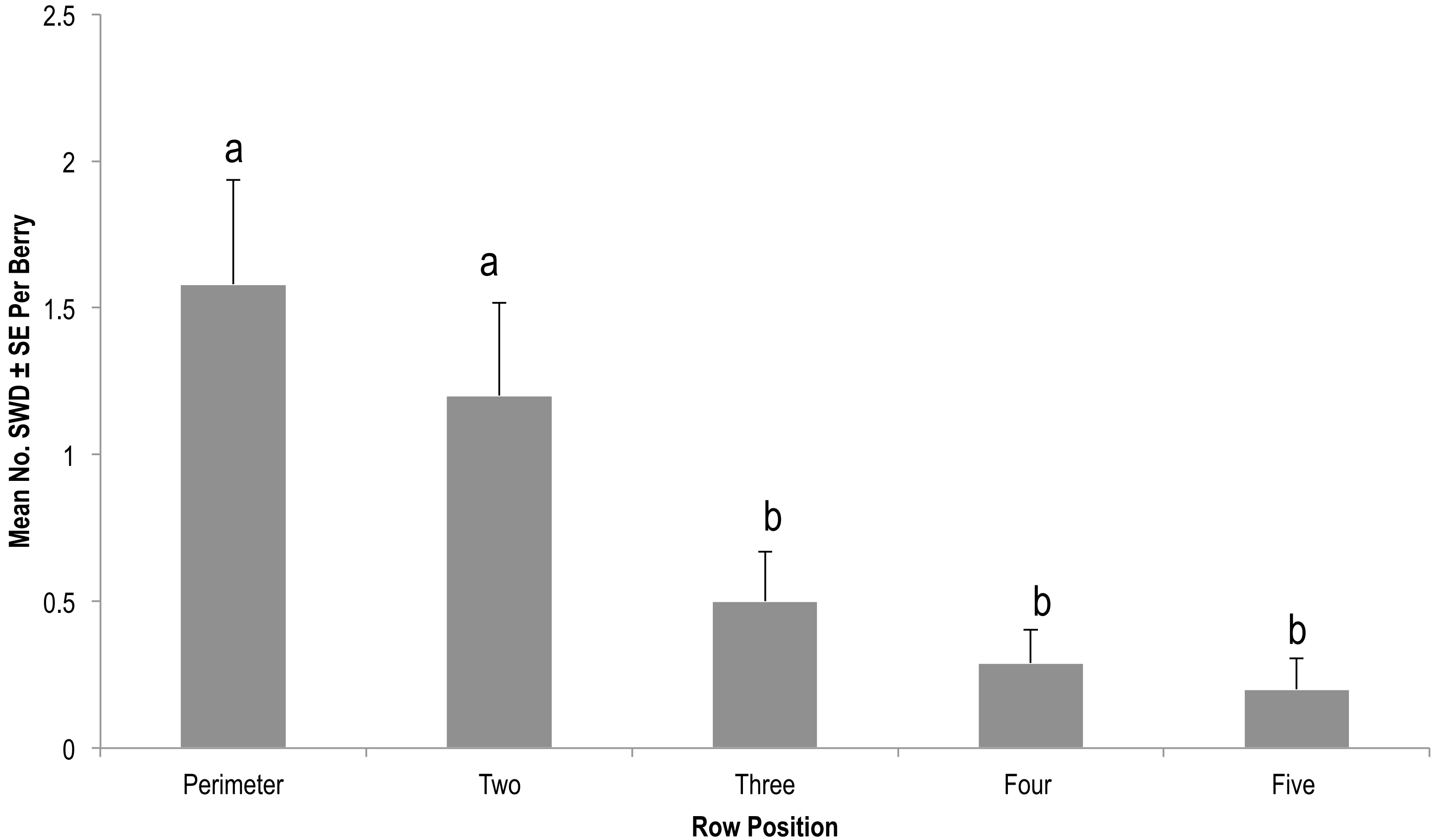
Where do SWD Choose To Forage Within a Plot?



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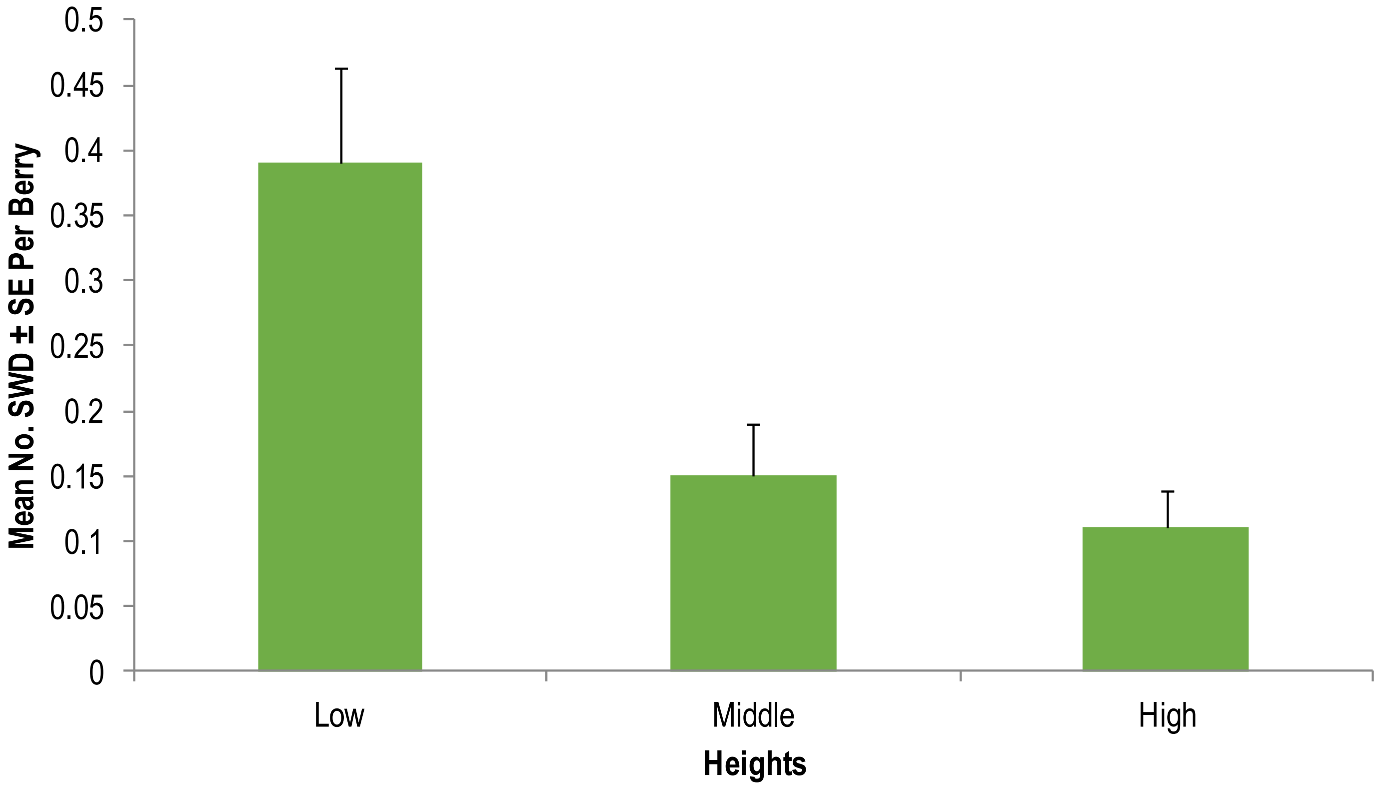
Wild Populations

Where do SWD Choose To Forage Within a Host Plant?



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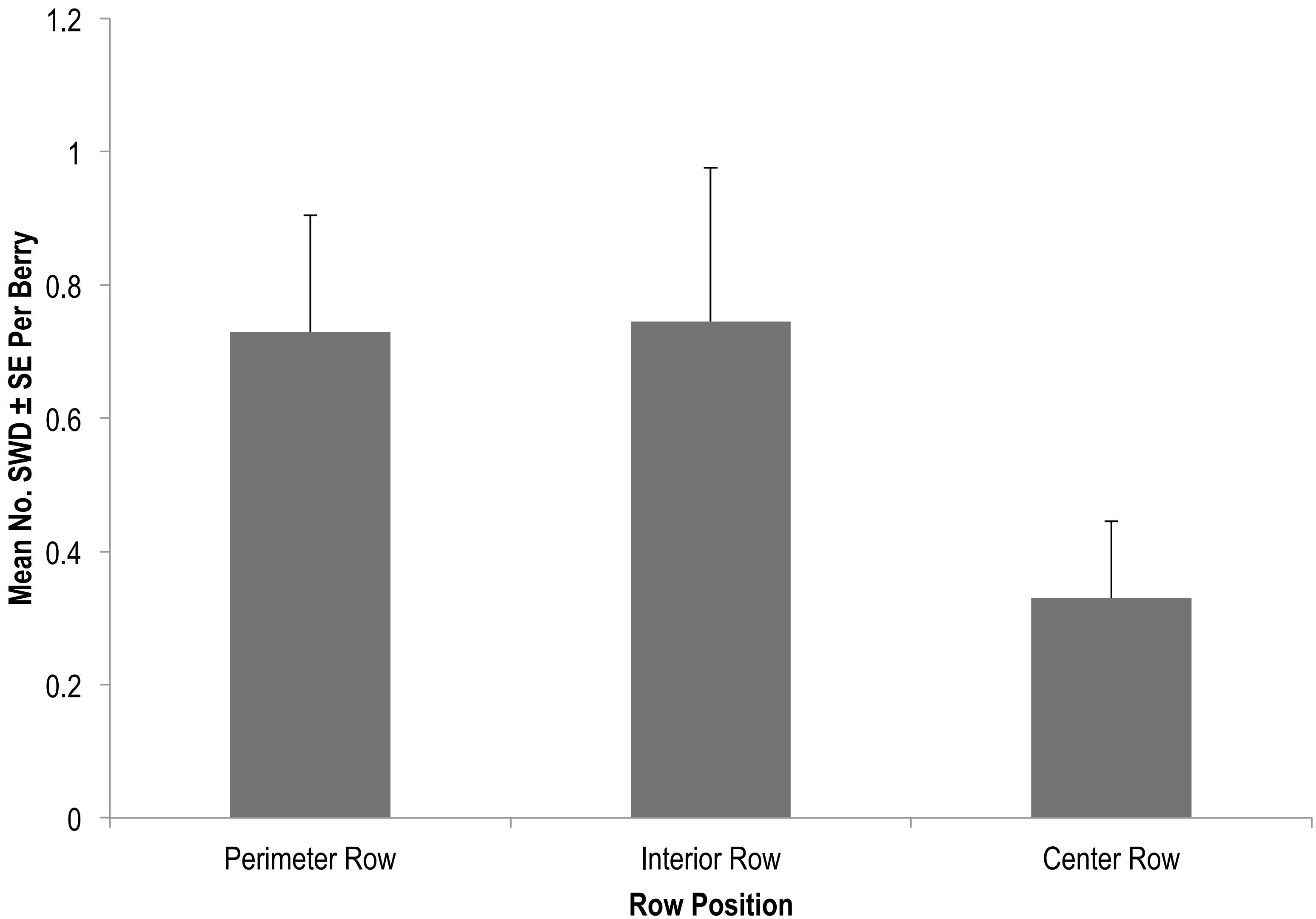
Where do SWD Choose To Forage Within a Plot?



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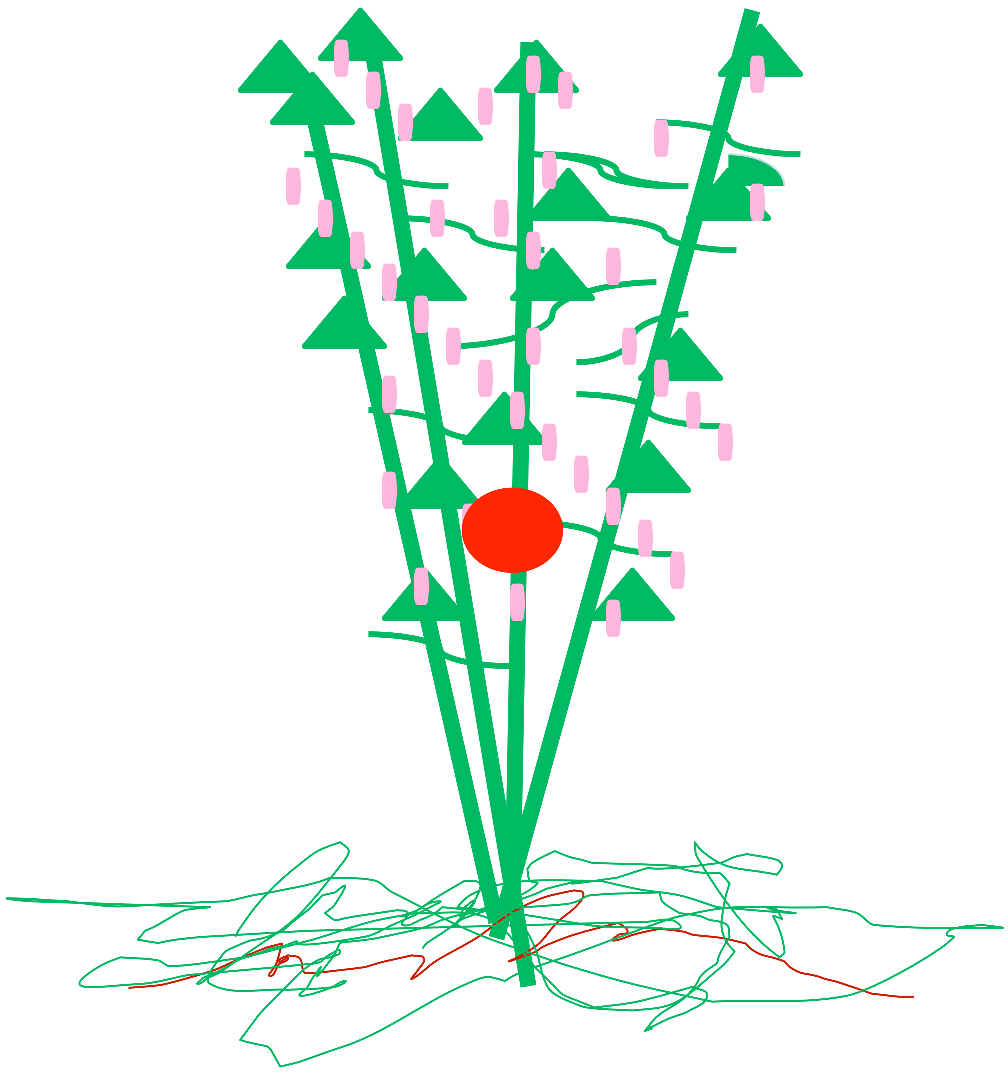
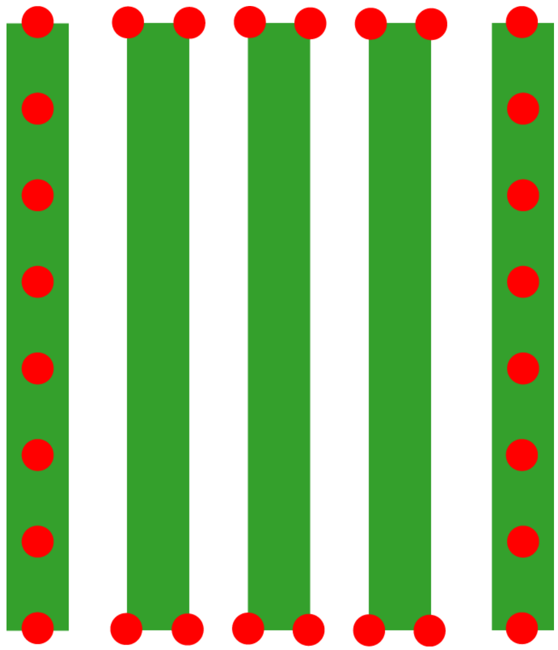
Potential Deployment Strategies?





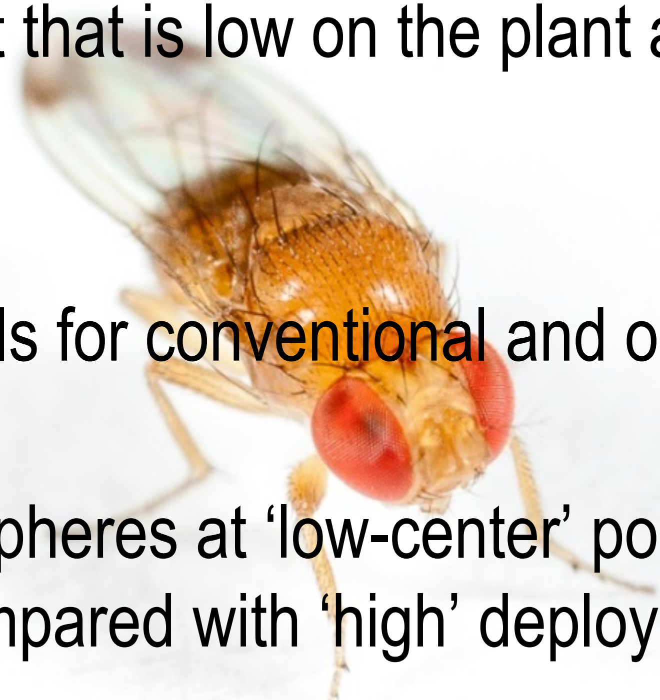
Optimization of Attract and Kill for SWD

If we allow SWD to persist, patterns within plants and within plots break down.

Optimization of Attract and Kill for SWD

Tentative Conclusions and Next Steps

- Attract and kill holds promise for SWD. Attracticidal spheres reduced SWD infestation in small plot trials.
- SWD appear to prefer fruit that is low on the plant and at the center of the canopy.



- What are the best materials for conventional and organic systems?
- If we deploy attracticidal spheres at ‘low-center’ positions, does this reduce infestation compared with ‘high’ deployment sites?
- What is the influence of horticultural practices on the system?

- Olfactory cues or baits?

Can We Develop an Attract and Kill System for SWD?

- Visual Stimulus
- Olfactory Stimulus
- Deployment Strategy
- Capture or Kill Mechanism

Acknowledgements

- Northeastern Regional IPM Award
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