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



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

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).





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 Trapping System Capture Mechanism



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

Optimizing Components of the Trapping 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



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



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%	а
Grower control	1,023	30	2.93%	а
2011				
Red sphere	751	25	3.33%	а
Grower control	961	17	1.77%	a

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

Morrison et al. 2016







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.

SWD alighted on spheres, but captures reduced by **50%** in presence of raspberry plant.



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

















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.

Color

Shape



Laboratory



Significant







Significant





Significant







Significant



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.

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.



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.
 - weekly sprays (Brigade, Entrust or Danitol)
 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



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?







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



Influence of Berry Position



Where do SWD Choose To Forage Within a Host Plant?



Where do SWD Choose To Forage Within a Host Plant?



Deployment Strategy For Attracticidal Spheres

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Mark-Release-Recapture Study



Sticky Sentinel Berries



1.8% Non-Fliers2.3% Recaptured





Where do SWD Choose To Forage Within a Host Plant?



Where do SWD Choose To Forage Within a Plot?



Wild Populations





Where do SWD Choose To Forage Within a Host Plant?



Where do SWD Choose To Forage Within a Plot?



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

Influence of horticultural practices? Competition with ripening fruit?

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?

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