Spotted Wing Drosophila - Overview of National Research Programs

Hannah Burrack & Lauren Diepenbrock

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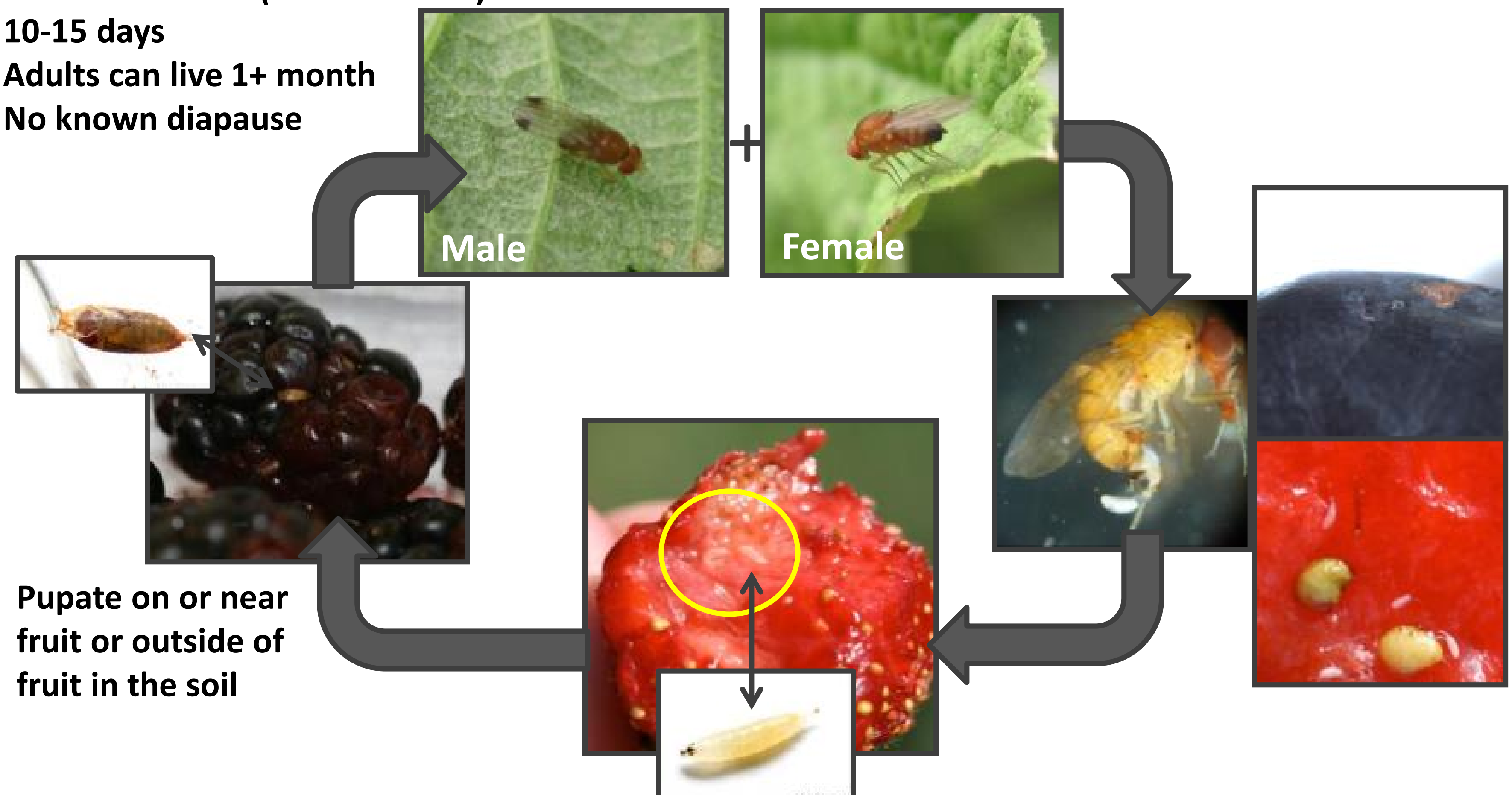
Department of Entomology and Plant Pathology

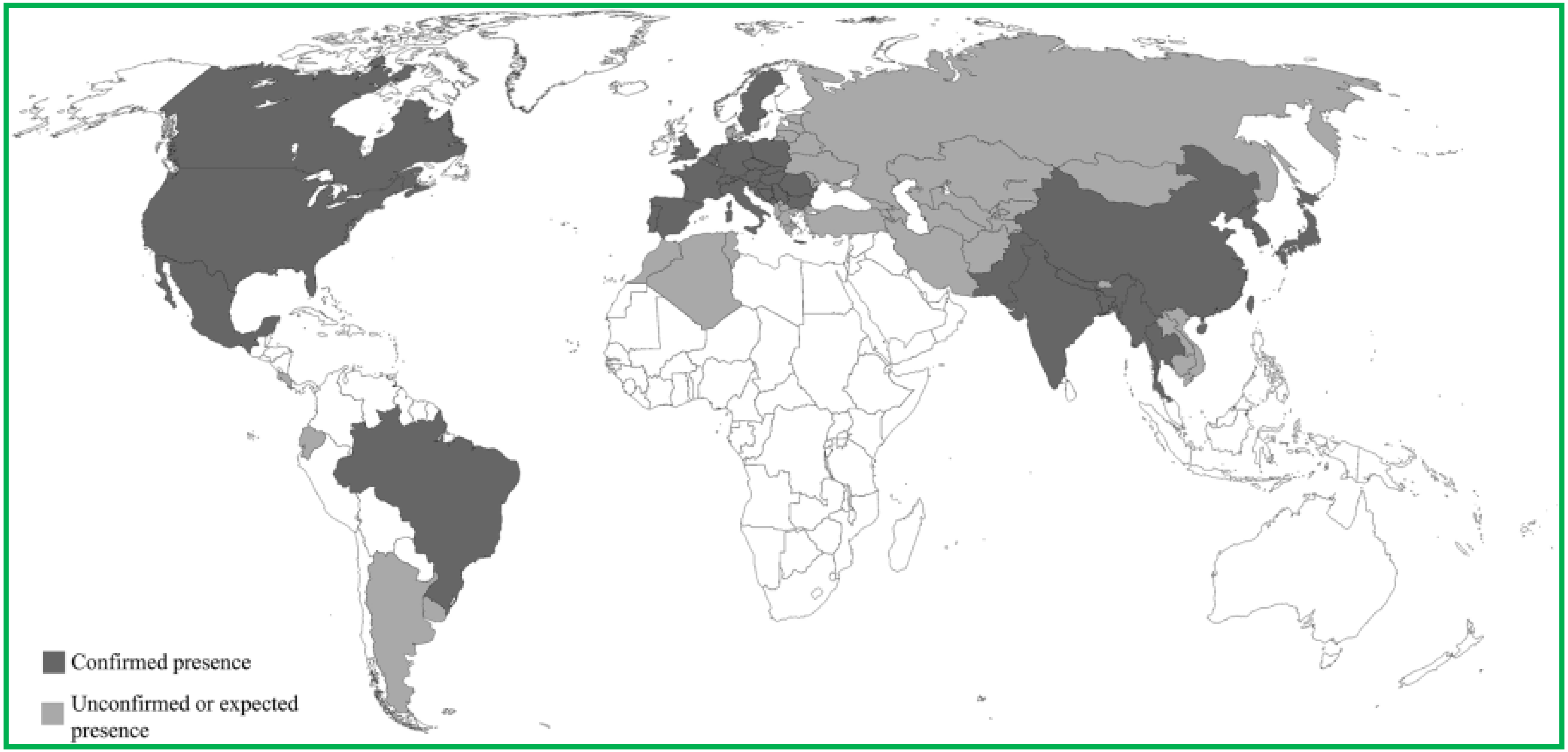
Spotted wing drosophila life cycle

Generation time (adult to adult):
10-15 days
Adults can live 1+ month
No known diapause



Pupate on or near fruit or outside of fruit in the soil

Invasion pathways



Asplen et al. 2015

Challenges for management

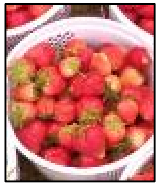
- Fast life cycle → Overlapping generations
- High fecundity
- Highly mobile adults
- Wide range of crop and non-crop hosts












>130 known hosts
31 plant families

Sustainable spotted wing drosophila management for US fruit crops

Project Director: Hannah Burrack[1]
Co Project Directors: Joanna Chiu[2], Rufus Isaacs[4], Greg Loeb[5], Cesar Rodriguez-Saona[6]; Ash Sial[7], Vaughn Walton[8], Miguel Gomez[5]
Co Principle Investigators: Kent Daane[3]; Larry Gut[4]; Zack Brown[1], Ke Dong[4], Frank Drummond[9], Kim Hoelmer[10], Max Scott[1], Zain Syed[11], Nik Wiman[8], Frank Zalom[2]
Project Coordinator: Lauren Diepenbrock[1]

[1]North Carolina State University; [2]University of California, Davis; [3]University of California, Berkeley; [4]Michigan State University; [5]Cornell University; [6]Rutgers University; [7]University of Georgia, Athens; [8]Oregon State University; [9]University of Maine, [10]USDA ARS; [11]Notre Dame University

Project goal

Four year duration: 15 Sept 2015 through 14 Sept 2019

Project goals:

To integrate SWD management practices with those necessary for other pest species, to reduce the reliance on insecticides as the sole means of SWD management, to deliver this information to stakeholders, and to facilitate stakeholder adoption of recommendations.

Objectives

Sustainable SWD Management

Objective 1: Implement and evaluate SWD management programs

Objective 2: Develop tactics and tools that predict SWD risks

Objective 3: Optimize SWD management programs

Objective 1.1: Develop and implement grower-scale best management practices

Lead: Hannah Burrack

Progress to date: During the first two years, we have conducted 35+ on farm research projects in 5 states designed to test best management recommendations in a real-world context.

Best Management Practices Tests

2016

-Using traps to time first treatment (blueberries, cherries)

-Non OP and/or non pyrethroid management programs

2017

-Using traps to time first treatment (blueberries, cherries)

-Comparison of programs with and without adjuvants

2016 Best Management Trials
NC Blackberry spray programs

Season long program	Trade Name	Active Ingredient	Class
Maximum modes of action	Mustang Max	zeta-cypermethrin	pyrethroid
	Malathion 8F	malathion	organophosphate
	Delegate	spinetoram	spinosyn
Non pyrethroid	Malathion 8F	malathion	organophosphate
	Delegate	spinteoram	spinosyn
Non organophosphate	Mustang Max	zeta-cypermethrin	pyrethroid
	Delegate	spinteoram	spinosyn

Infestation varied between crops, but not between treatments within a crop

Diepenbrock et al. 2017 Crop Protection

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NC COOPERATIVE EXTENSION

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2017 Best Management Trials
NC Blackberry

Rotation

Delegate & Malathion

+/- adjuvant NuFilm P

Floricane

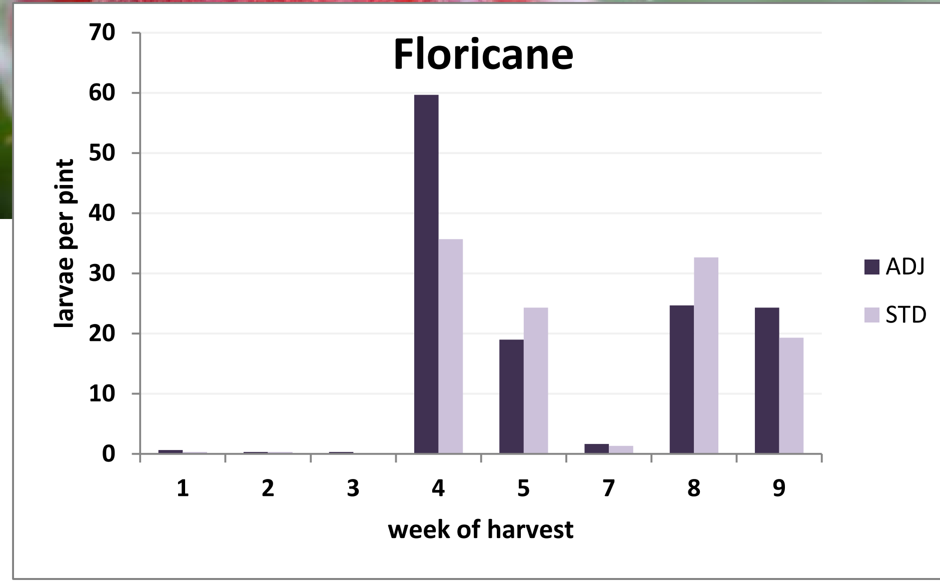
No difference in infestation

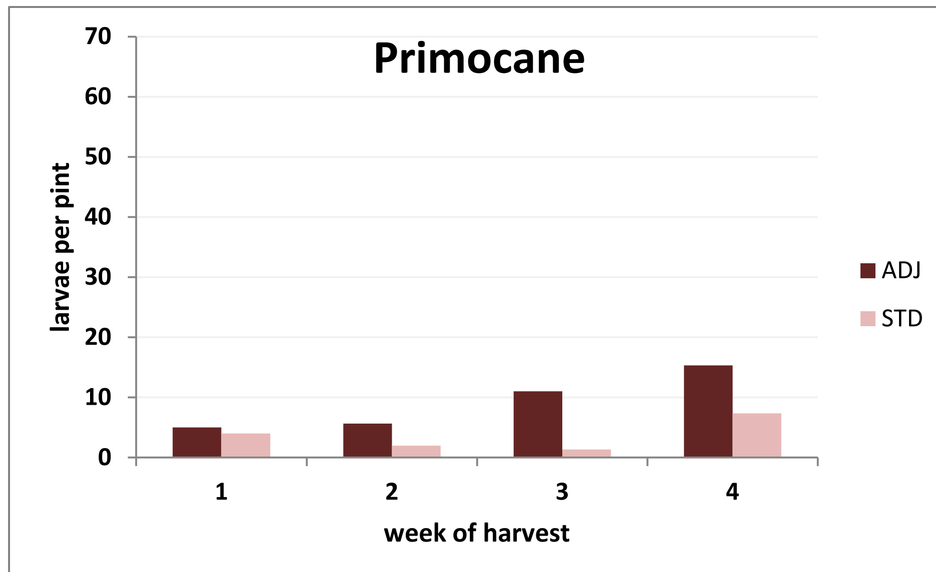
($F_{1,30}$ =0.16, p =0.693)

Primocane

More infestation in plots with adjuvant

($F_{1,14}$ = 6.72, p = 0.0213)





Objective 2.2: Determine sources of SWD populations between and during growing seasons

Lead: Greg Loeb, Joanna Chiu

Progress to date: Overwintering study conducted during 2016-2017. Spring food source experiments in NY and OR. High temperature tolerance in GA and OR.

39+ populations sequenced to assess long distance movement. Initial analysis suggests state level grouping which is promising for marker development

Future directions: Tools to track SWD movement and off season management strategies

Potential sources of early-season flies

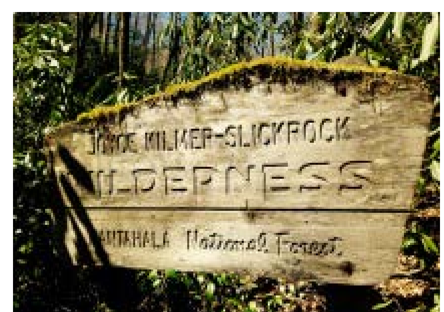
Fruit waste / Compost

Bal et al. 2017

Briem, F. et al. 2016. *J Pest Sci*

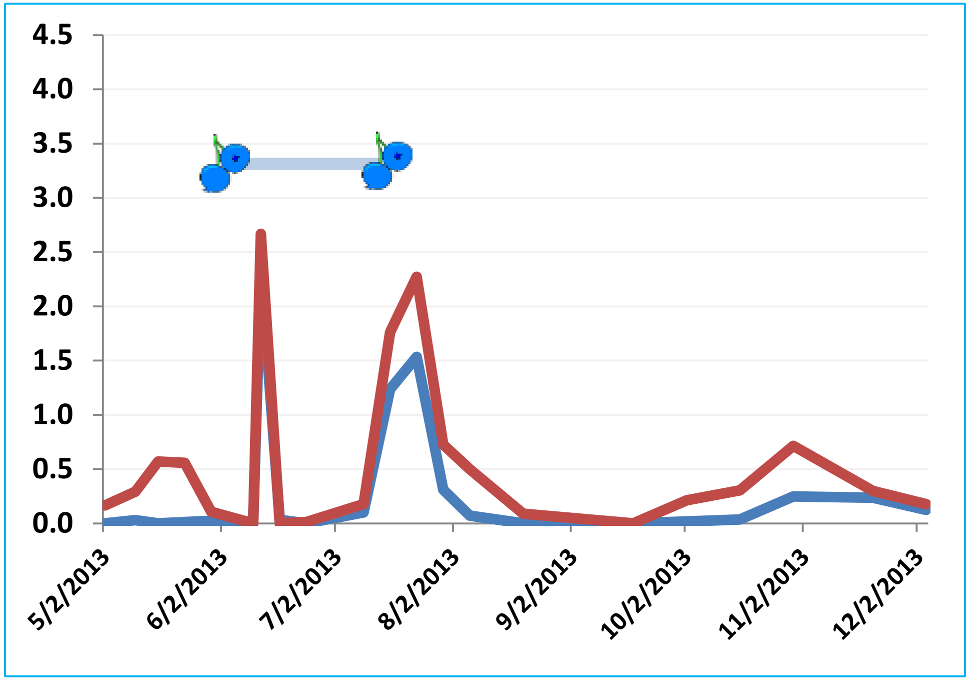
Winter fruits (mistletoe)

Wilderness areas



Elsensohn and Burrack *unpub.*

Potential sources of early-season flies: Do they survive local winter conditions?



NC Blueberry, 2013 *Unpub data*

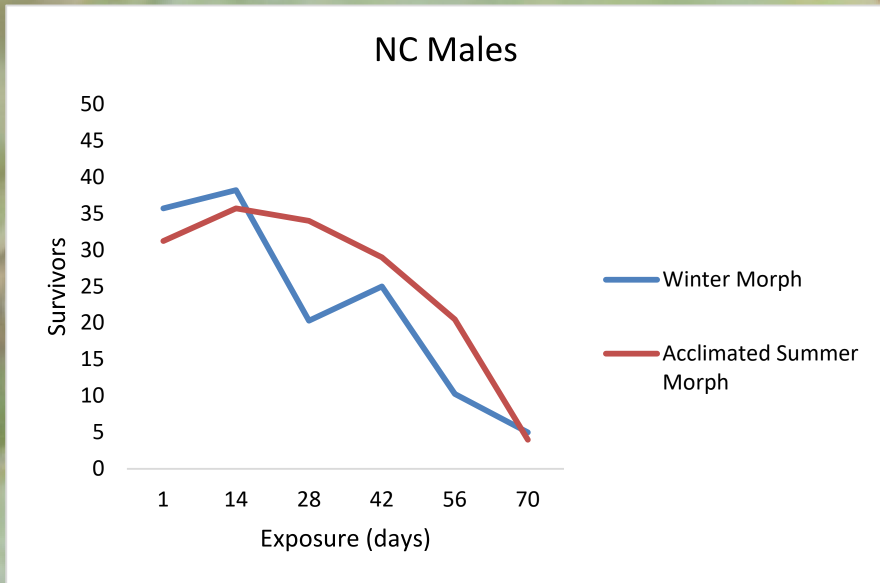
- -flies present after harvest
- -trapped throughout winter

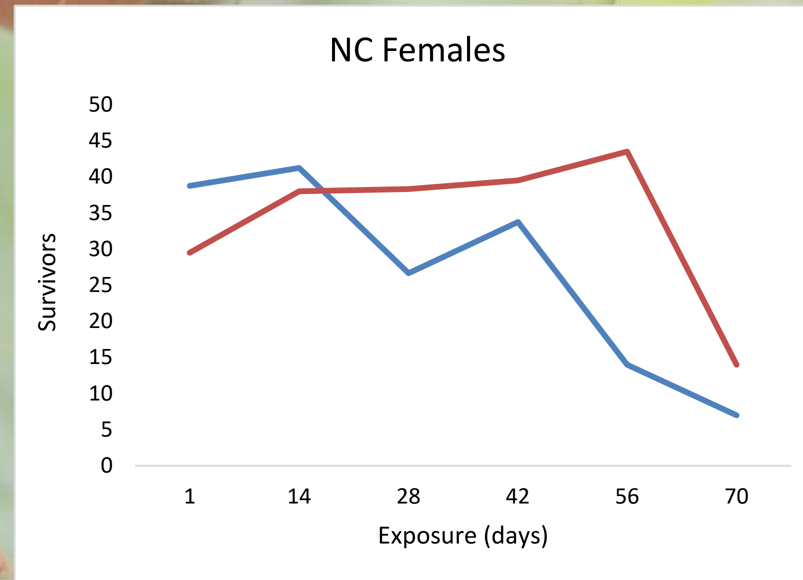
Potential sources of early-season flies: Do they survive local winter conditions?

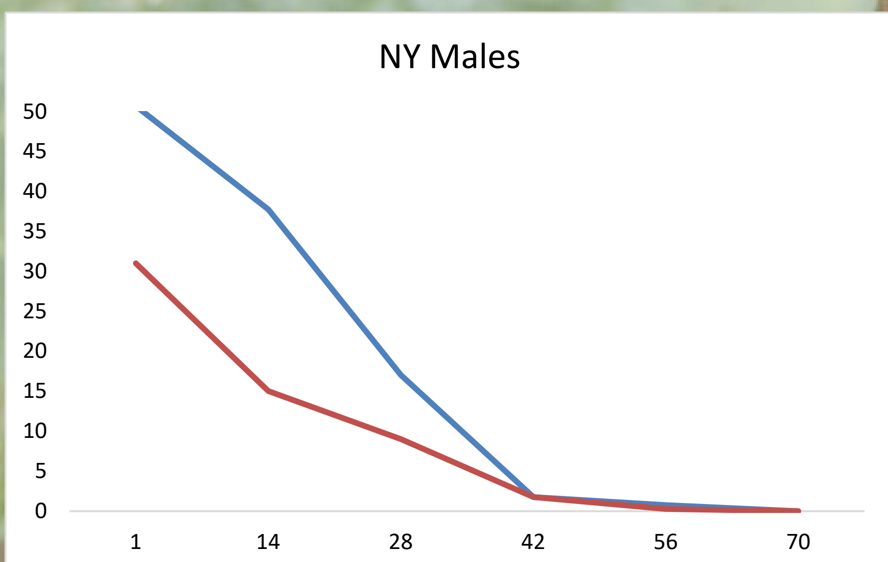
National overwintering study (Year 1)

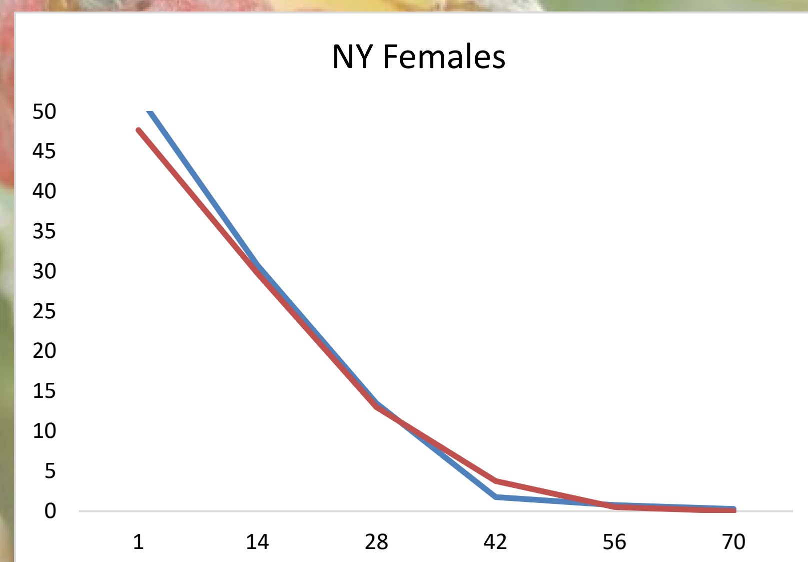
- Wild flies (lab-reared)
- Check survival every 2 weeks for 10 weeks
- Saw reproduction in 2016/17 in NC

2016-17 Overwintering Survival NC, NY









Wallingford et al. *Unpub data*

Objective 2.3: Develop monitoring tools that accurately estimate SWD populations

Lead: Cesar Rodriguez-Saona, Zain Syed, Larry Gut

Progress to date: Comparison of novel attractants conducted during two years in 7 states.

Methods to assess attraction of currently available traps developed in MI cherries suggest that one trap is effective over 7.5 acres. Mark-recapture experiments conducted in 3 additional states during 2017.

Future directions: Trap attraction experiments will be replicated in different crops and regions. Different, novel attractants will be tested.

Significant outputs: Hickner, et al. 2016. BMC Genomics.

SWD- specific lure development

Problems:

(1) Current traps/lures not specific

Yeast-Sugar-Water bait

Scentry lure bait

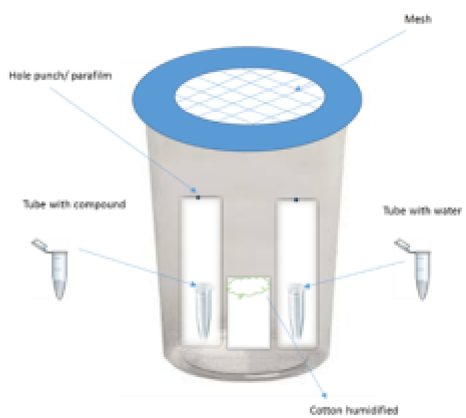
(2) Current lures not more attractive than fruit for laying eggs

What attracts SWD?
Novel attractant development

Tested previously identified fermentation, yeast, and leaf odors for attraction in the lab

Cha et al. 2012,2013, Scheidler et al. 2015, Keesey et al. 2015

Individual attraction tested with electro-antennography (EAG) ✓



Determine if both sexes are attracted ✓

Is a mix of compounds more attractive?

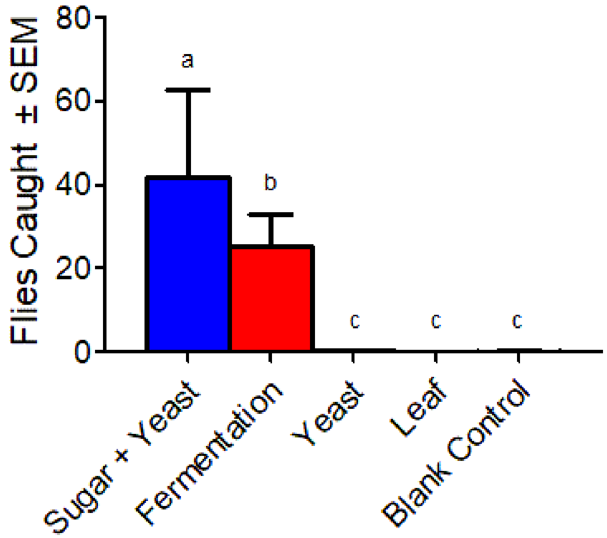
✓ Fermentation mix

Images from Cesar Rodrigues-Saona

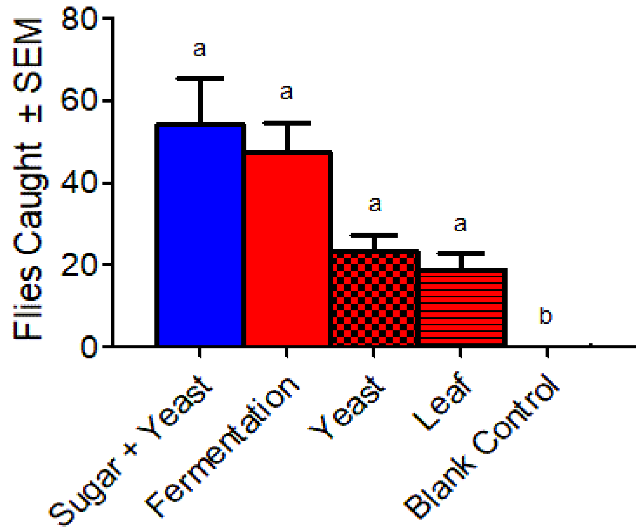
Novel attractant development: Field tests

2016-tested in blueberry, blackberry, cherry

In season



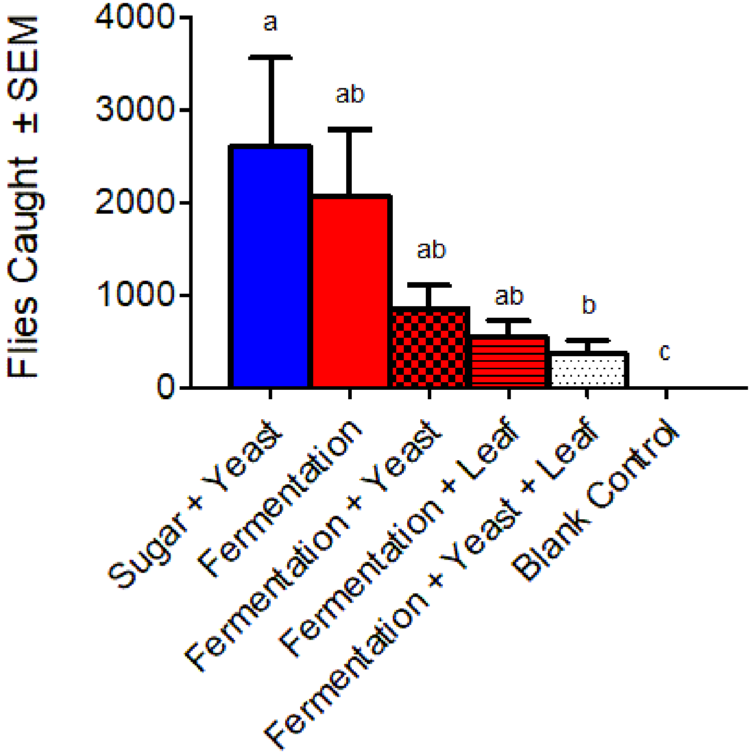
Off season



Flies are more attracted to the yeast and leaf lures when no fruit is available

Novel attractant development: Field tests

2017-tested in blueberry, blackberry, cherry, raspberry



Adding yeast and leaf volatiles to the fermentation lure significantly decreases fly catch

Journal of Integrated Pest Management, (2017) 8(1): 23; 1–7
doi: 10.1093/jipm/pmx019
Recommendations

OXFORD

A Filter Method for Improved Monitoring of *Drosophila suzukii* (Diptera: Drosophilidae) Larvae in Fruit

Steven Van Timmeren,[1] Lauren M. Diepenbrock,[2] Matthew A. Bertone,[2] Hannah J. Burrack,[2] and Rufus Isaacs[1,3]

https://academic.oup.com/jipm/article/8/1/23/4157137?searchresult=1

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Monitoring & risk assessment for *Drosophila suzukii*

Traps

- Traps indicate presence … adult flies
- Traps may be use… …g the start of treatments in some crop…
- No a… …g system has been demonstrated to … well with fruit infestation
- …standard lures; no lures more attractive than fruit yet

Traps are inefficient at predicting infestation

Hamby et al. 2014, Burrack et al. 2015

Need for an efficient larval assessment

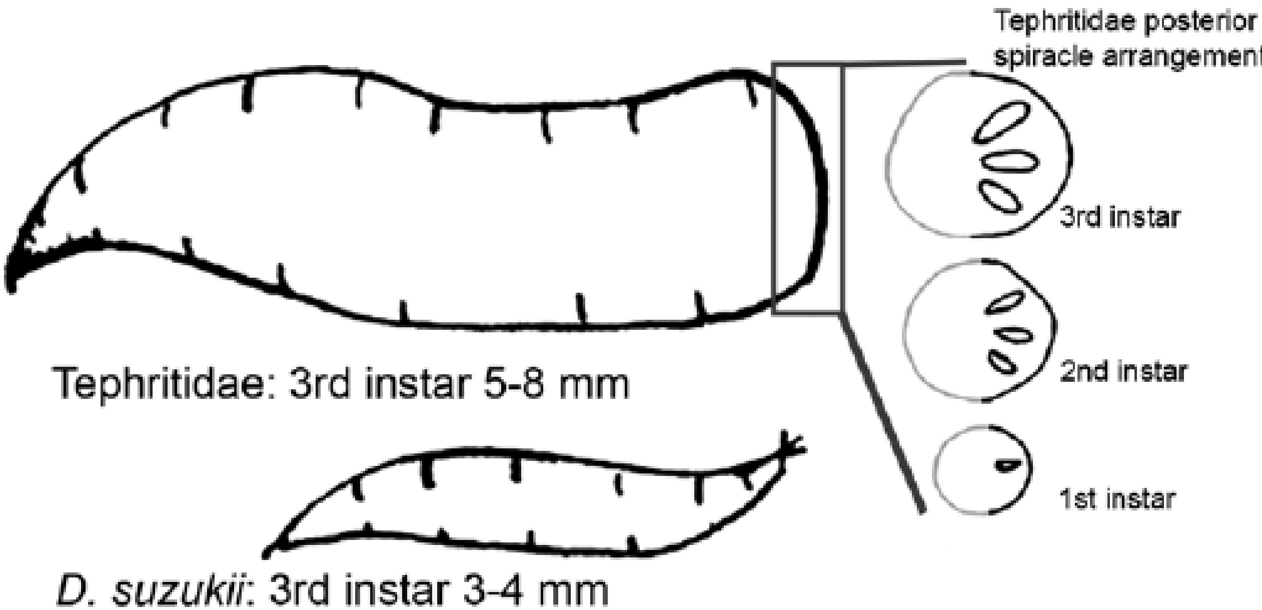
- **Research**
  - **Lack of consistency across research groups**
  - **Rearing is only way to detect eggs, small larvae, & ensure species identity**
- **Grower/Scout**
  - **Need easy tool that is cost efficient**
  - **Ability to detect infestation sooner can aide in management decisions**

Filter salt test methods

Maybe not the best for sampling strawberry…

Van Timmeren et al. 2017, Figure 1a

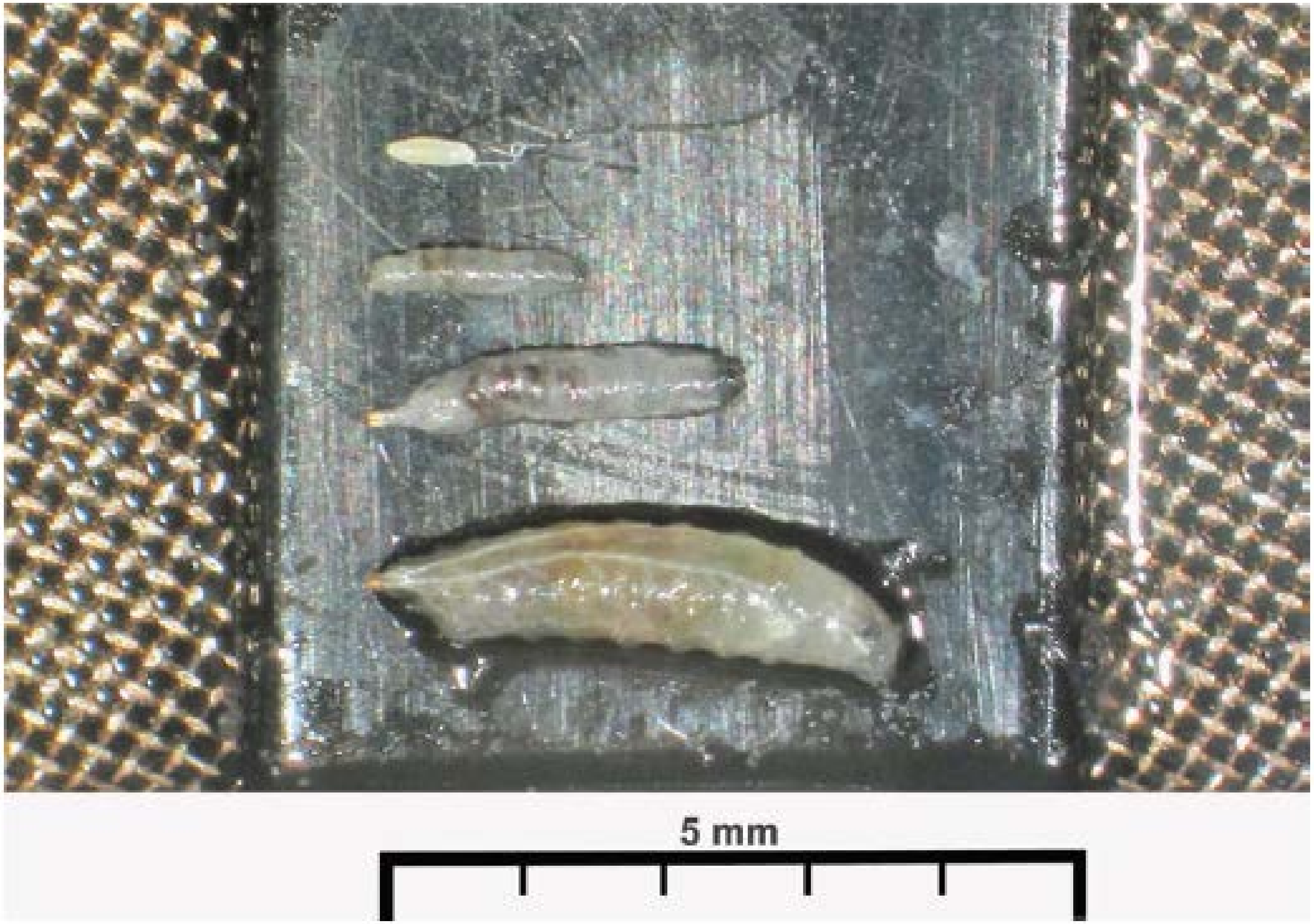
Larval ID: Tephritid vs Drosophilid



In blueberries only…

Van Timmeren et al. 2017, Fig. 3

Larval ID: Instars (Field ID)



Van Timmeren et al. 2017, Fig. 2

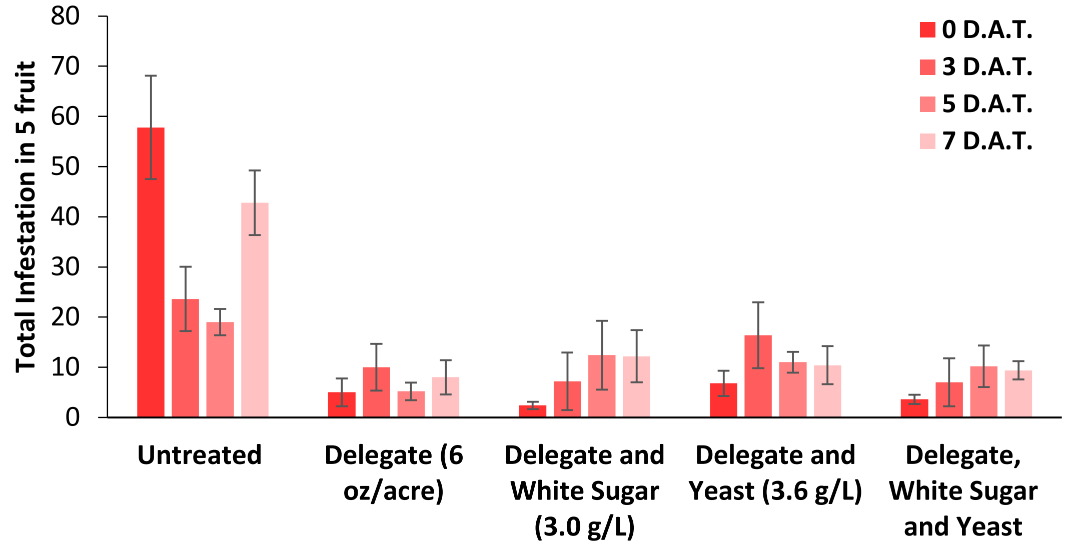
Objective 3.1: Reduce reliance on insecticides

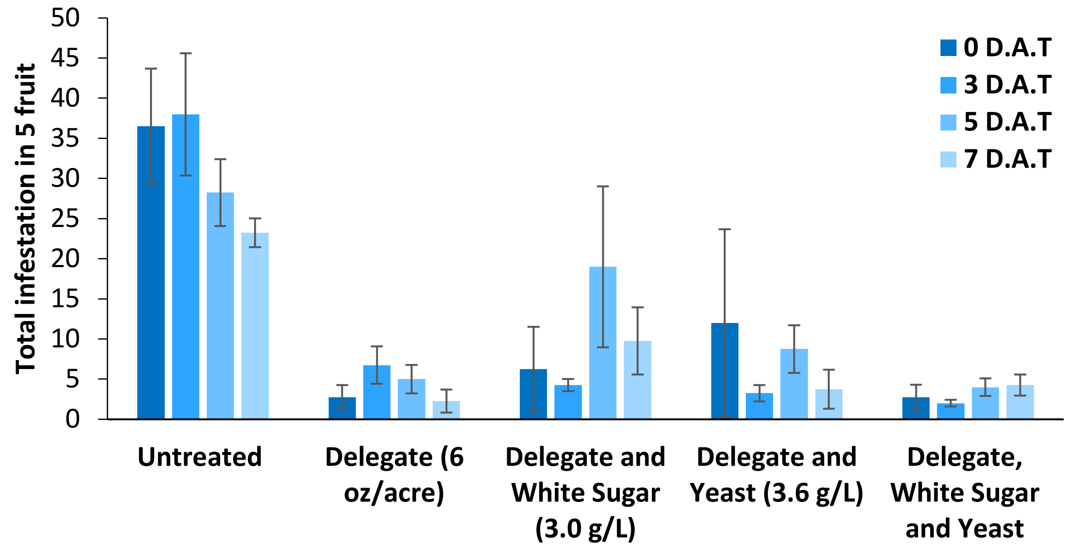
Lead: Rufus Isaacs

Progress to date: Conflicting results with other projects about the benefit of phagostimulants to improve insecticide efficacy. Results from our project suggest limited benefit in the field for high acute toxicity materials.

Future directions: Continue to identify materials and use patterns for reduced applications.

Phagostimulants– No benefit of sugar or yeast in semi-field assays

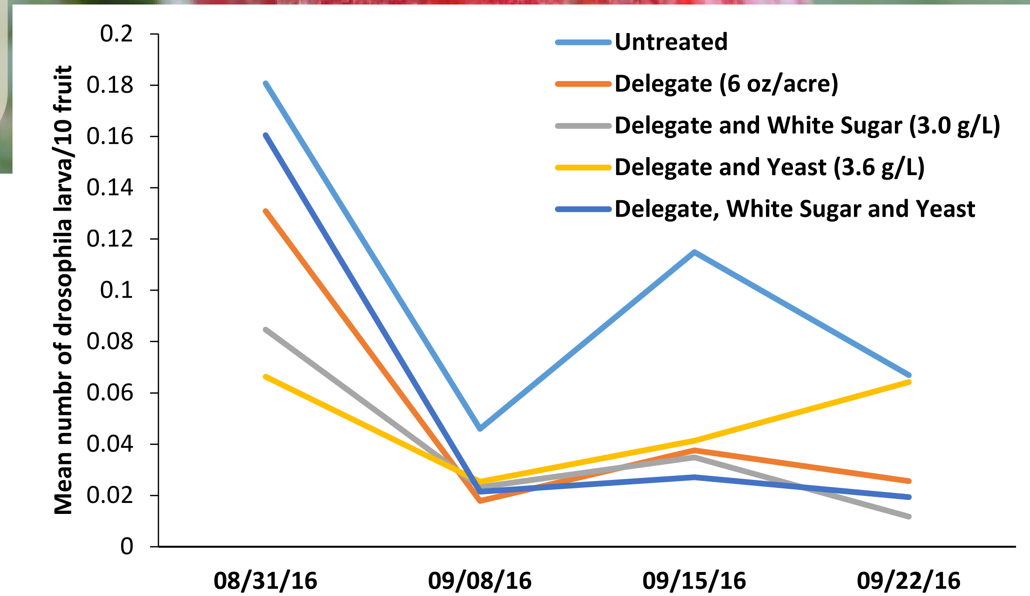


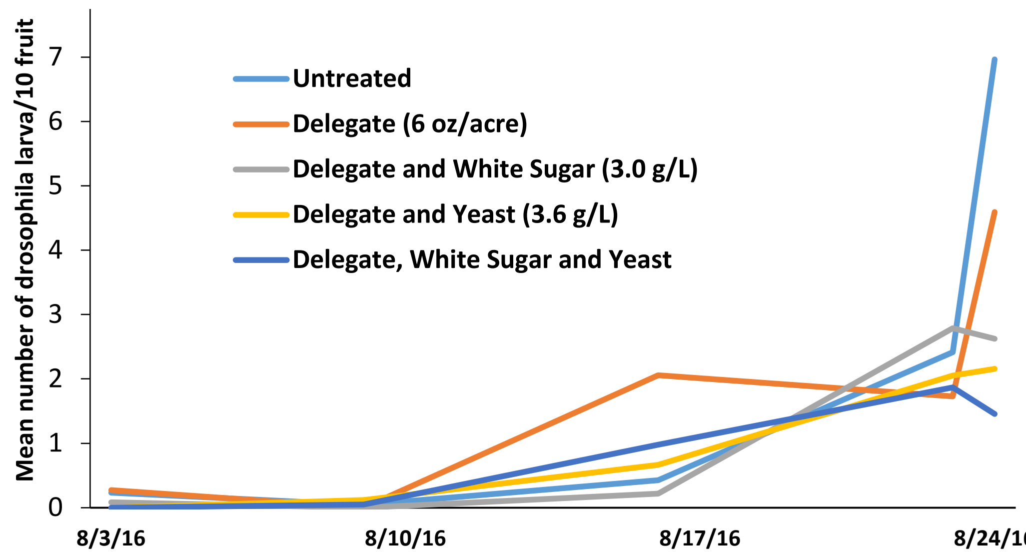


Isaacs lab, MSU
Frank Drummond, Maine

Phagostimulants– Limited benefit in the field

Isaacs lab, MSU
Frank Drummond, Maine





2017 Best Management Trials NC Blackberry

<u>Rotation</u>

Delegate & Malathion

+/- adjuvant NuFilm P

Floricane

No difference in infestation

($F_{1,30}$ =0.16, p =0.693)

Primocane

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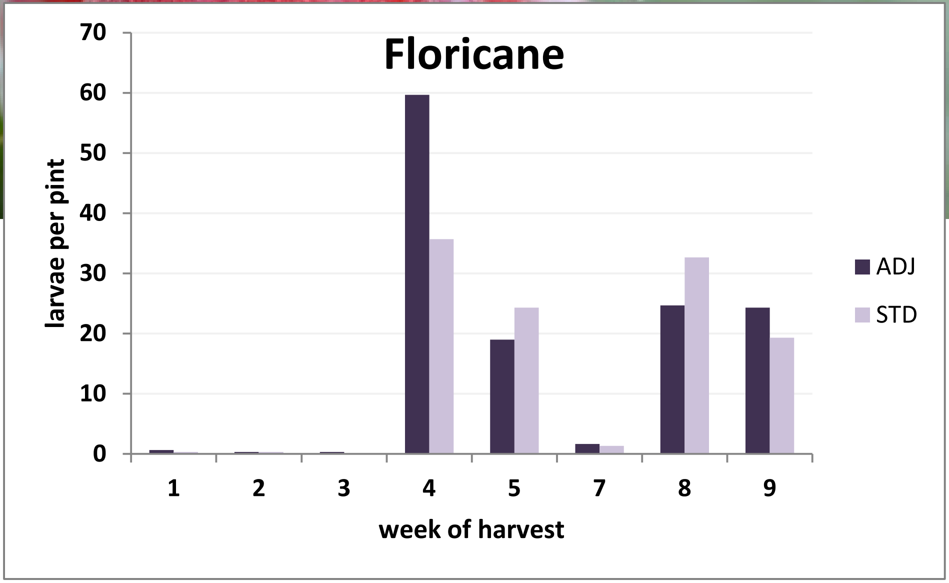
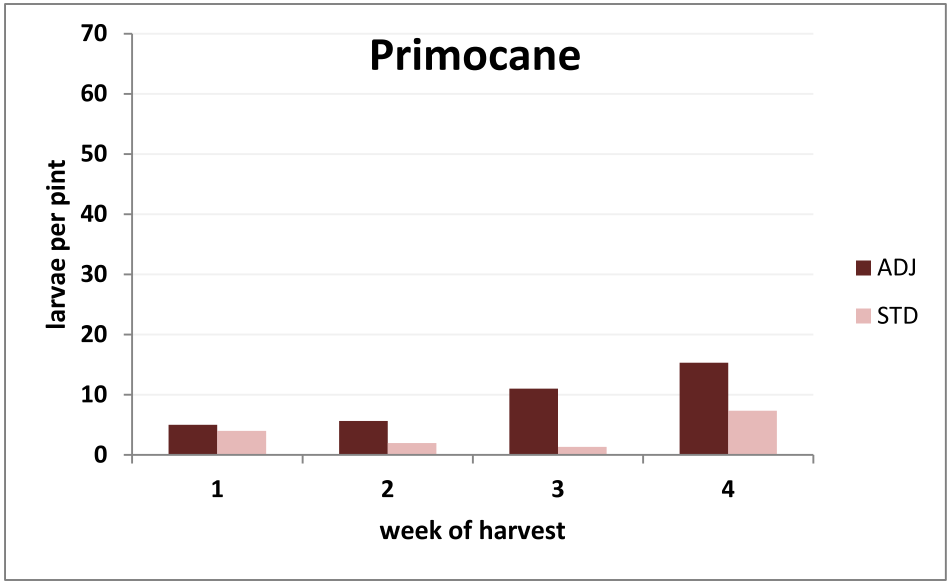




Objective 3.2: Insecticide resistance detection, minimization, and management

Lead: Ash Sial, Ke Dong, Zack Brown

Progress to date: Field population screening in MI and GA suggest very high susceptibility at rates far below field concentrations for key insecticides.

Standard glass vial assess developed, refined, and applied in multiple states during 2017.

Future directions: Resistance selection and mechanism targeting. Integration with population and economic models.

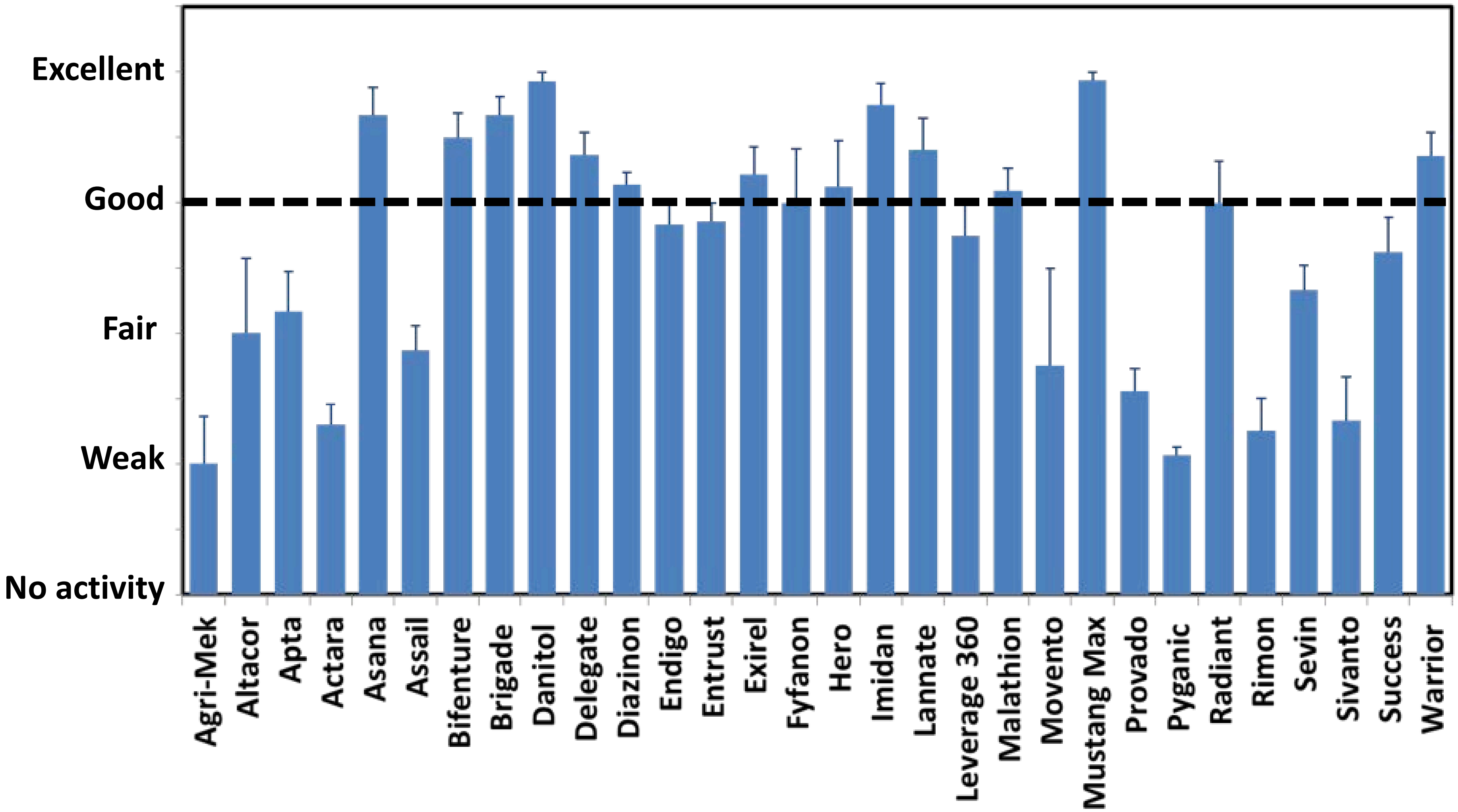
Significant outputs: Van Timmeren, et al. 2017. Pest Management Science.

Summary rankings of insecticide efficacy against *D. suzukii*

10 states, 20 state x crop combinations

CA, OR, WA, MI, ME, NY, NJ, NC, GA, FL

Rufus Isaacs
MSU



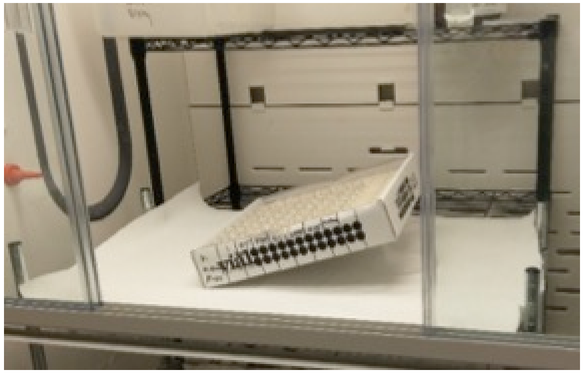
Efficacy of currently used insecticide tools

Rufus Isaacs
MSU

Ash Sial
U of GA

Glass vial assays

- Field collected populations from areas treated with target pesticides
- Assessed mortality of 5 male, 5 female *D. suzukii* after 6 h of exposure



Efficacy of currently used insecticide tools

Rufus Isaacs
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Ash Sial
U of GA

No resistance in field-collected flies in the Southeast!

Material	Location (# of populations	Estimated LC90	Fiel[illegible]
Zeta-cypermethrin	Michigan (12)	0.4[illegible]	[illegible]
Zeta-cypermethrin	Georgi[illegible]	[illegible]	[illegible] ppm
Malathio[illegible]	[illegible]	[illegible] ppm	2996 ppm
Malathion	[illegible]	5-10 ppm	2996 ppm
Spinetoram	[illegible]igan (14)	30-130 ppm	225 ppm
Spinetoram	Georgia (4)	2.5-30 ppm	225 ppm

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Objective 3.3: Discover natural enemies capable of reducing SWD populations

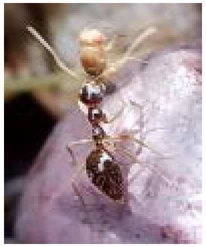
Lead: Kent Daane

Progress to date: Three international trips yielding 5 candidate species thus far. Host range and life table analysis conducted in quarantine. Two promising species (*Ganaspis brasiliensis* and *Leptopilina japonica*) in permit process for field trials.

Future directions: Make additional international trips earlier in the growing season when parasitism rates seem particularly high. Screen new collections. Conduct field trials of materials once permitted.

Significant outputs: Biondi, et al. 2017 Journal of Insect Behavior; Kacar, et al. 2017. PLoS One.

Good Bugs vs Bad:
Using biological controls in SWD management



A webinar presentation from the
Sustainable SWD Management SCRI Project

View recording at www.swdmanagement.org

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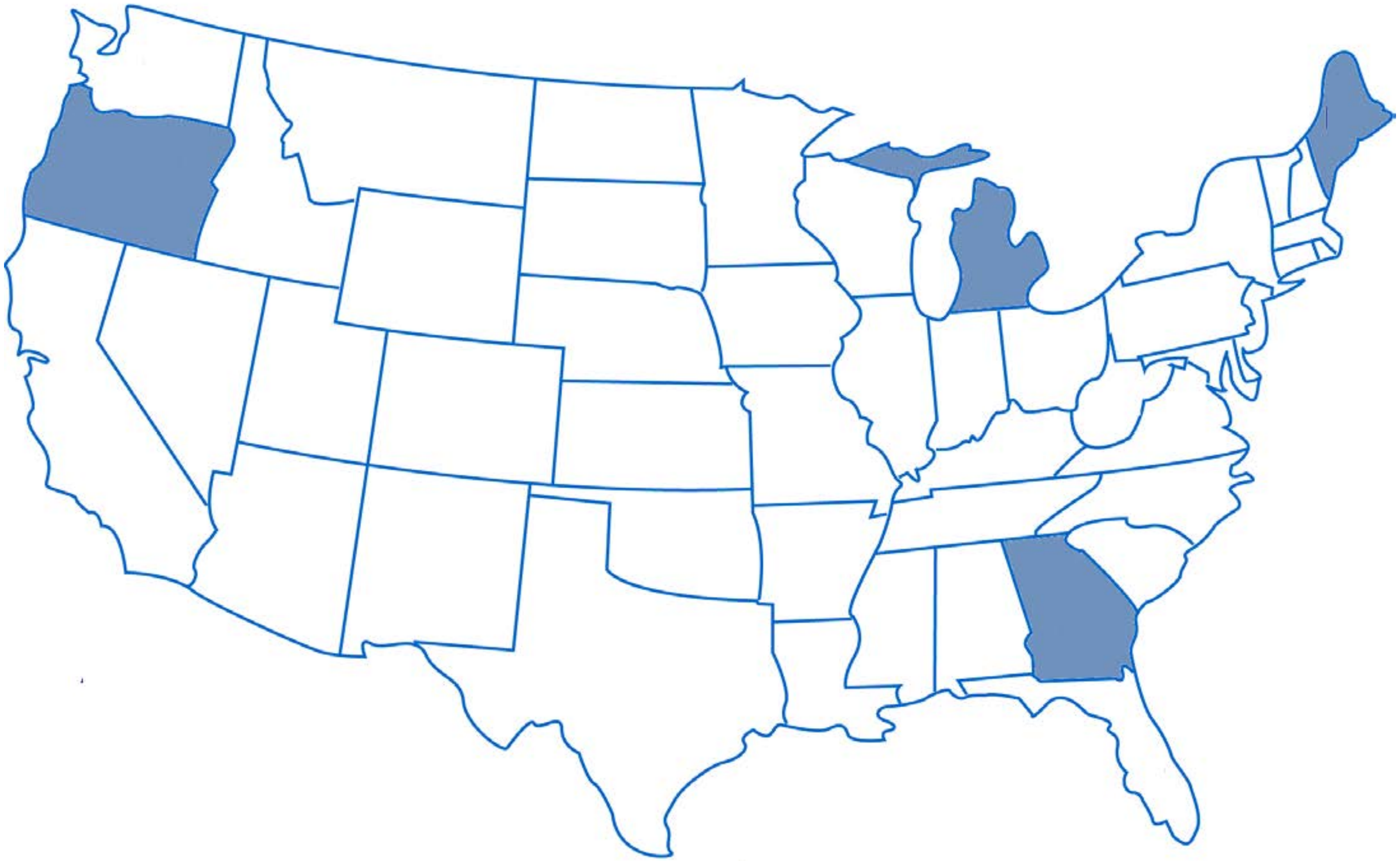
SWD predators assessed throughout the US

Heather Leach
MSU



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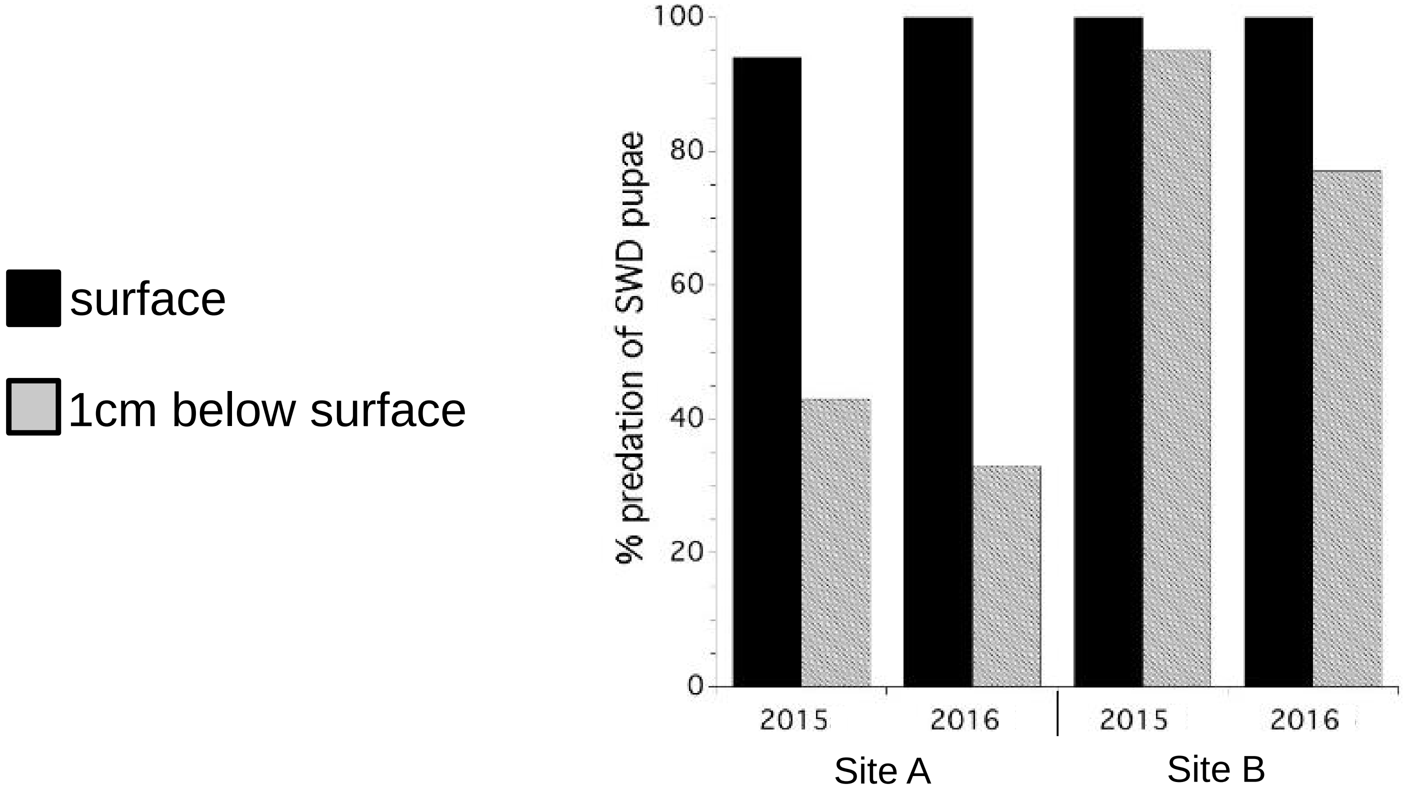
Higher predation levels when pupae are on soil surface

Heather Leach
MSU



Ballman ES, Collins JA, Drummond FA. 2017. Pupation behavior and predation on *Drosophila suzukii* (Diptera: Drosophilidae) pupae in Maine wild blueberry fields. J. Econ. Entoml. 110(6):2308-17.

Most common predators include ants, crickets, ground beetles, spiders

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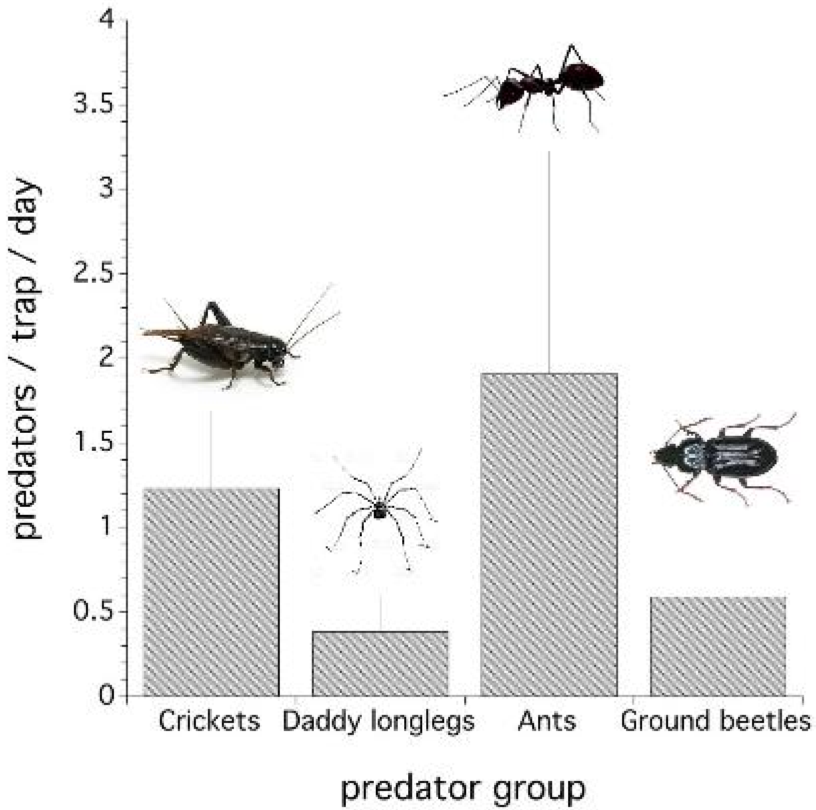

61-91% SWD pupae removed in blackberry and blueberry

From video recordings, ants dug up pupae and removed them on 39 occasions

Ballman ES, Collins JA, Drummond FA. 2017. Pupation behavior and predation on *Drosophila suzukii* (Diptera: Drosophilidae) pupae in Maine wild blueberry fields. J. Econ. Entomol. 110(6):2308-17, Woltz JM, Lee JC. 2017. Pupation behavior and larval and pupal biocontrol of *Drosophila suzukii* in the field. Biological Control, 110:62-9.

Mulching type does not effect level of predation

Heather Leach
MSU

>85% predation of pupae in all habitat types

Data provided by H. Leach & R. Isaacs, Michigan State University

Some predators prefer certain mulches

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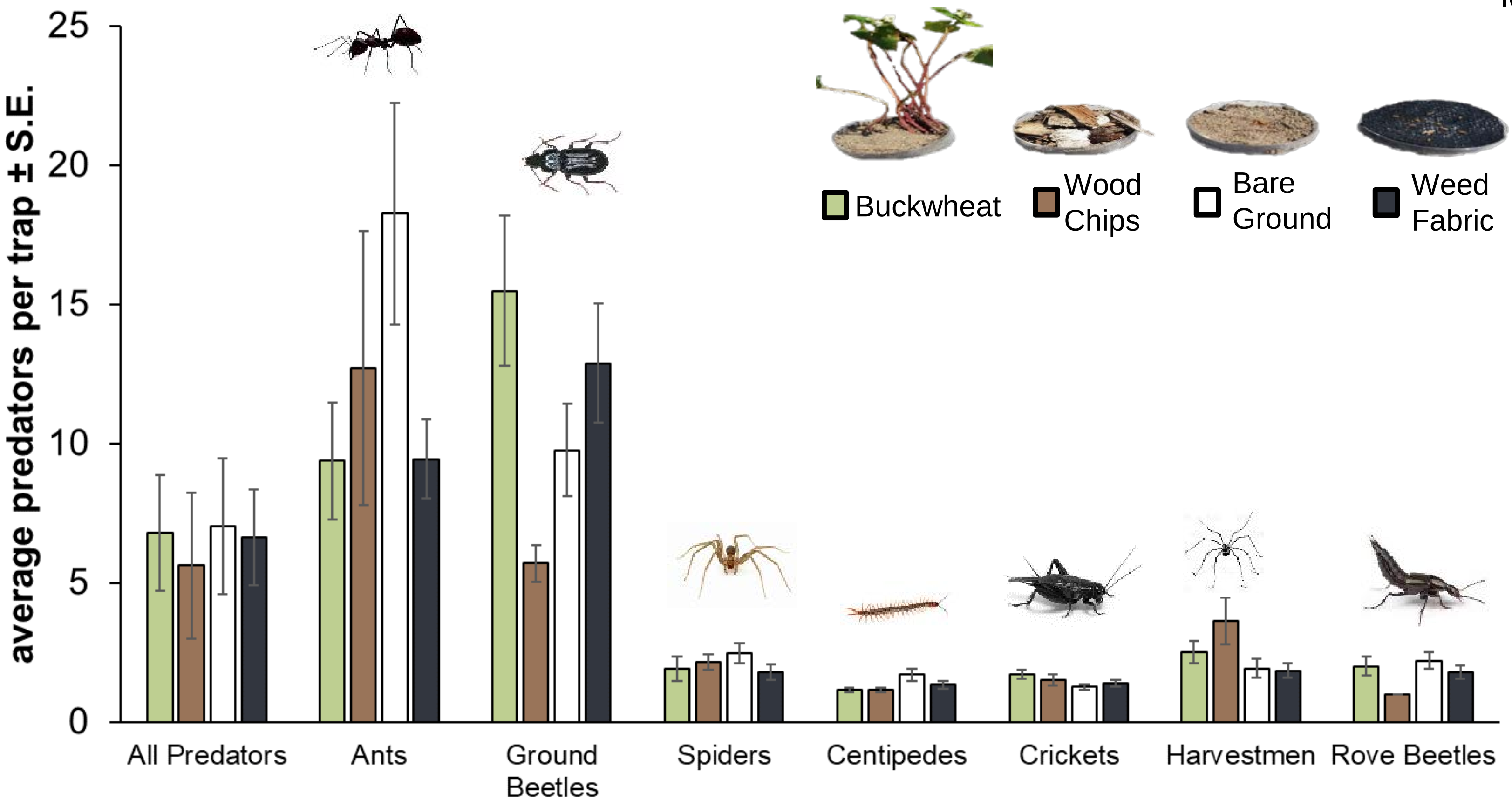
MSU



Data provided by H. Leach & R. Isaacs, Michigan State University

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High-input systems have lower numbers of natural enemies

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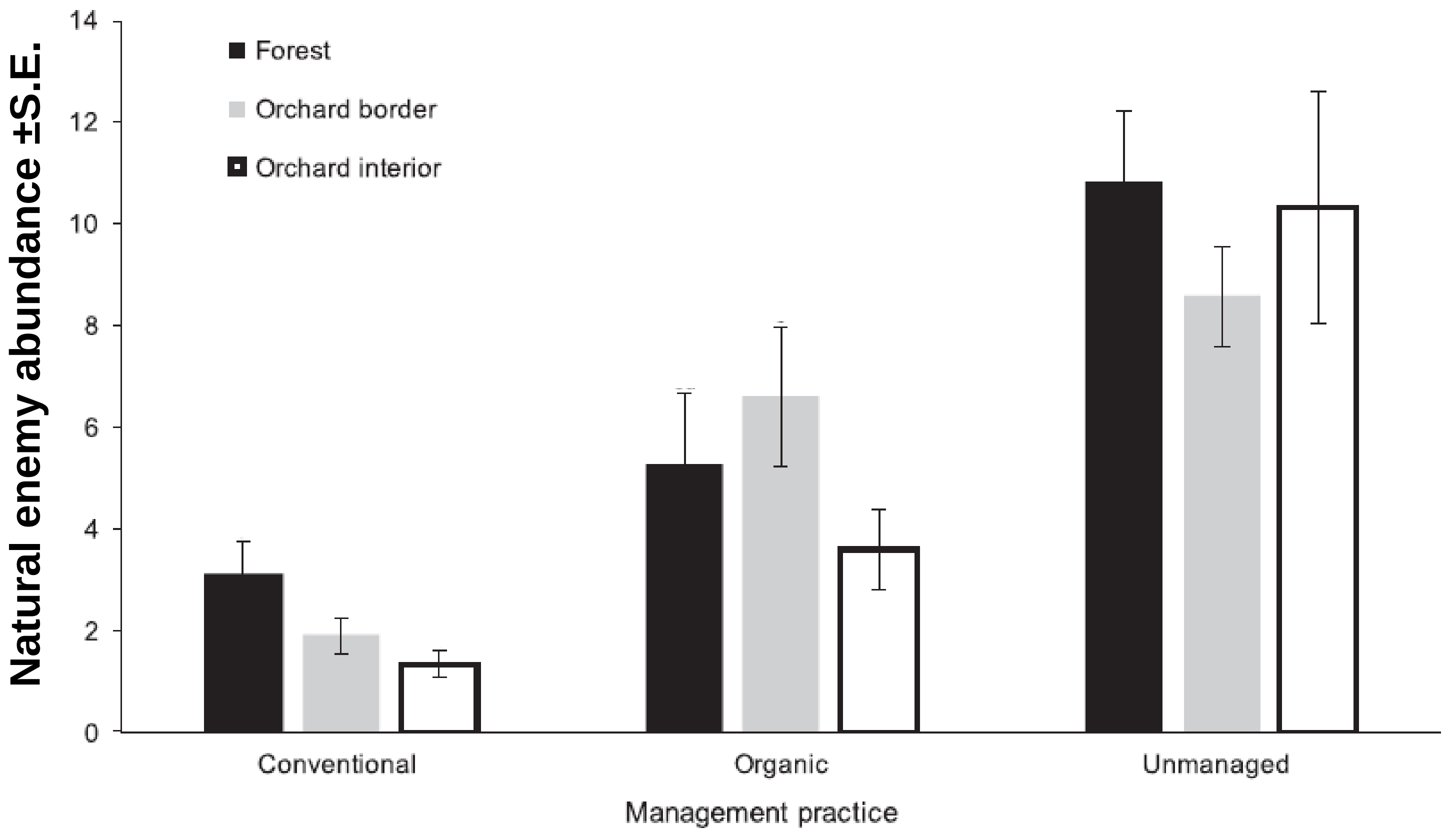

Whitehouse TS, AA Sial, and JM Schmidt. 2017. Natural enemy abundance in southeastern blueberry agroecosystems: distance to edge and impact of management practices. Environ Entomol, doi: 10.1093/ee/nvx188

Naturally occurring SWD parasitoids have been assessed throughout the US

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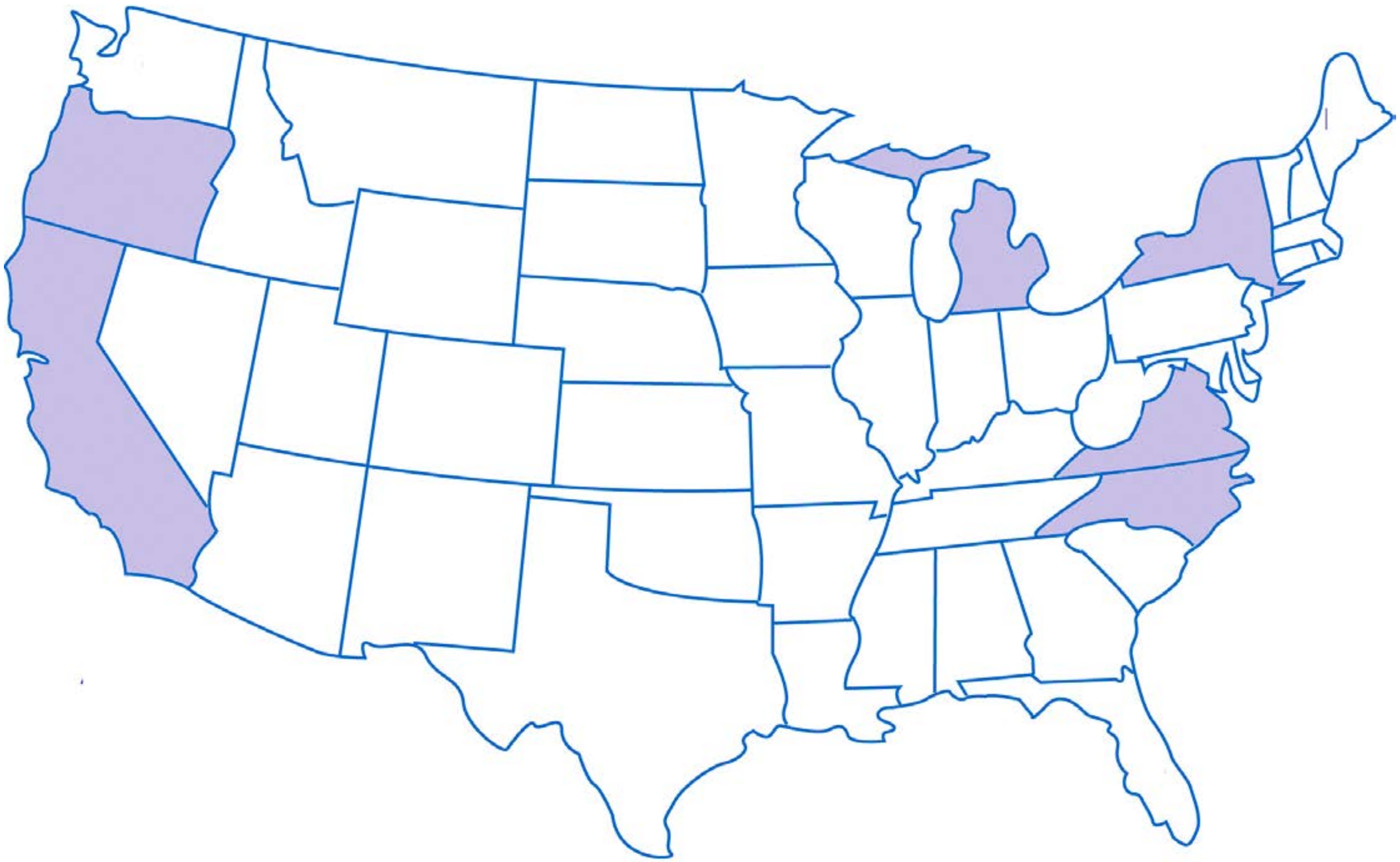

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Five naturally occurring parasitoids found in U.S.

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Leptopilina boulardi **[L]**

Leptopilina heterotoma **[L]**

Asobara tabida **[L]**

Pachycrepoideus vindemiae **[P]**

Trichopria drosophilae **[P]**

[L] = Larval parasitoid
[P] = Pupal parasitoid

Naturally occurring parasitoid community in North Carolina

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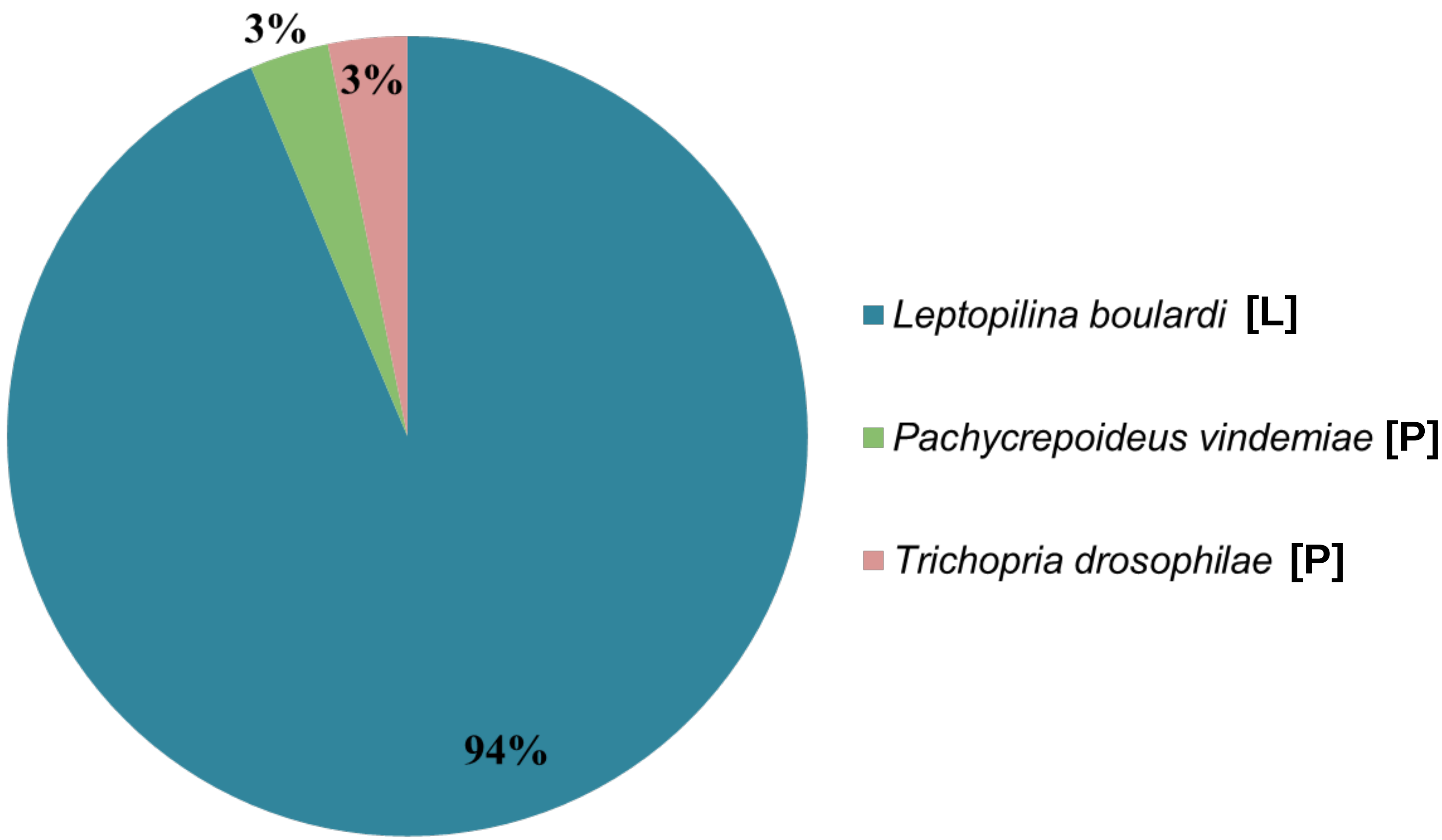

Data provided by Y. Zheng and H. Burrack, North Carolina State University

Abundance of parasitoids dependent on location

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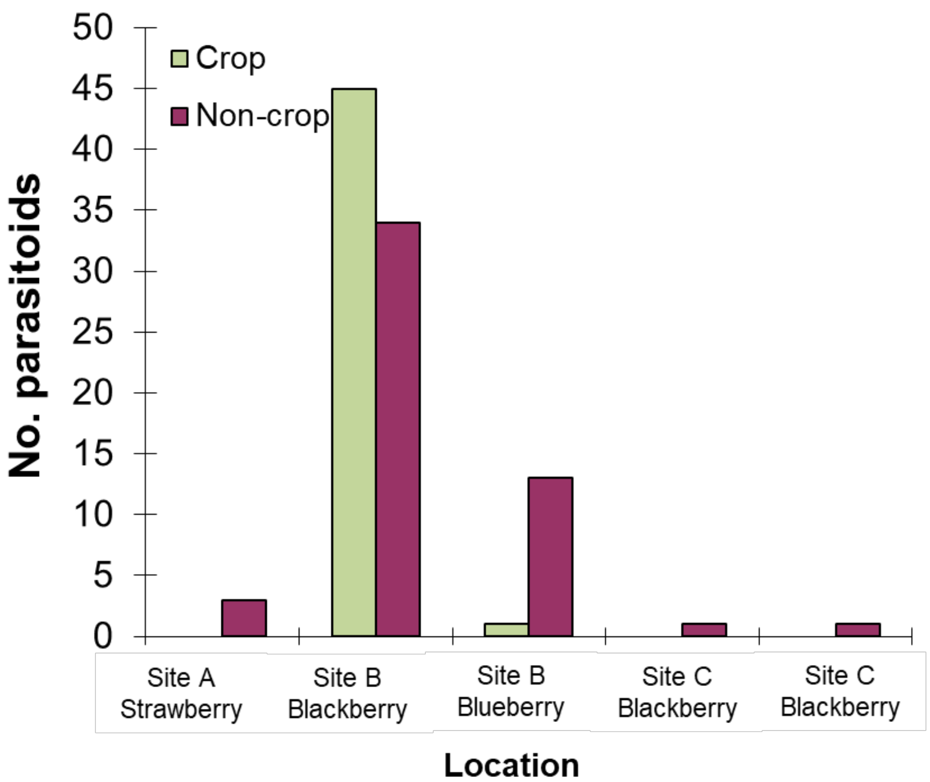
More sites with parasitoids found in non-crop habitats

Highest field parasitism levels only at 2.5%



Data provided by Y. Zheng and H. Burrack, North Carolina State University

Naturally occurring parasitoid community in Virginia

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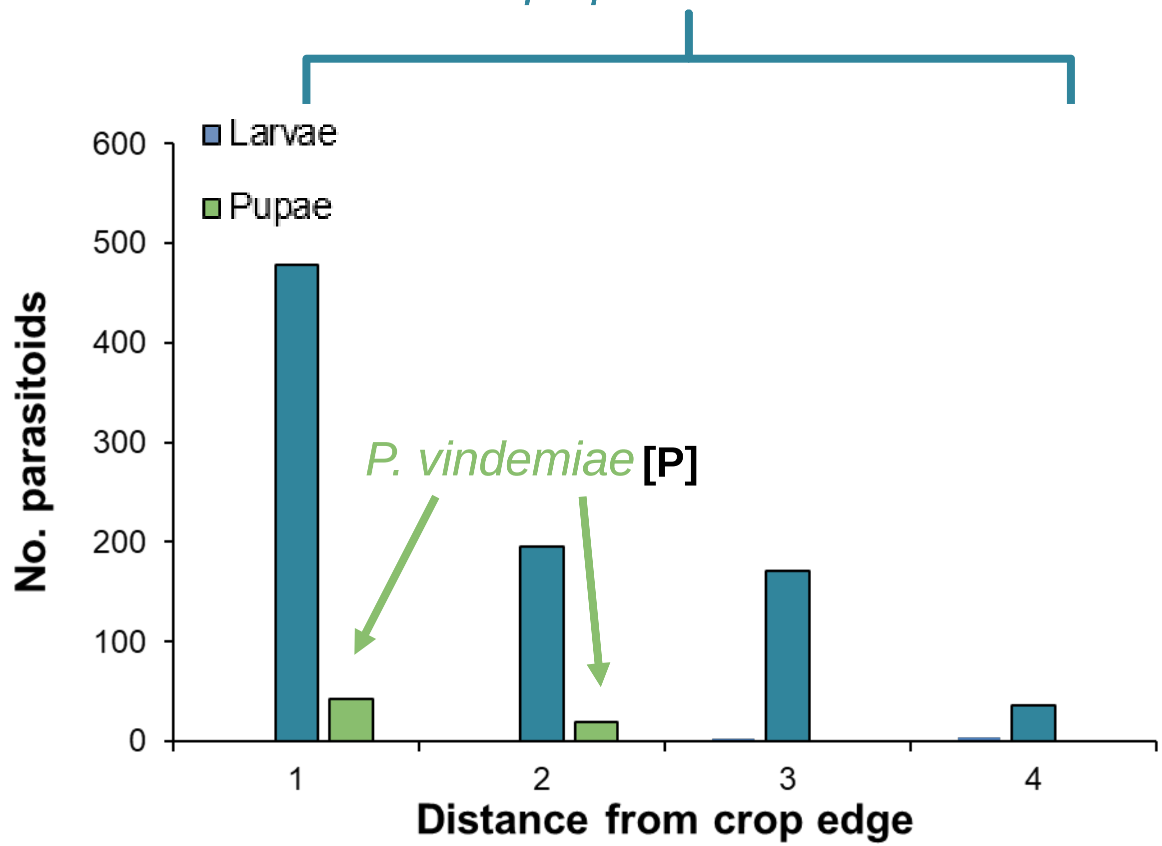
More parasitoids closer to the crop edge

Larval parasitoids more common than pupal parasitoids



Data provided by J. Wahls and D. Pfeiffer, Virginia Tech

Host-specificity of *T. drosophilae* and *P. vindemiae*

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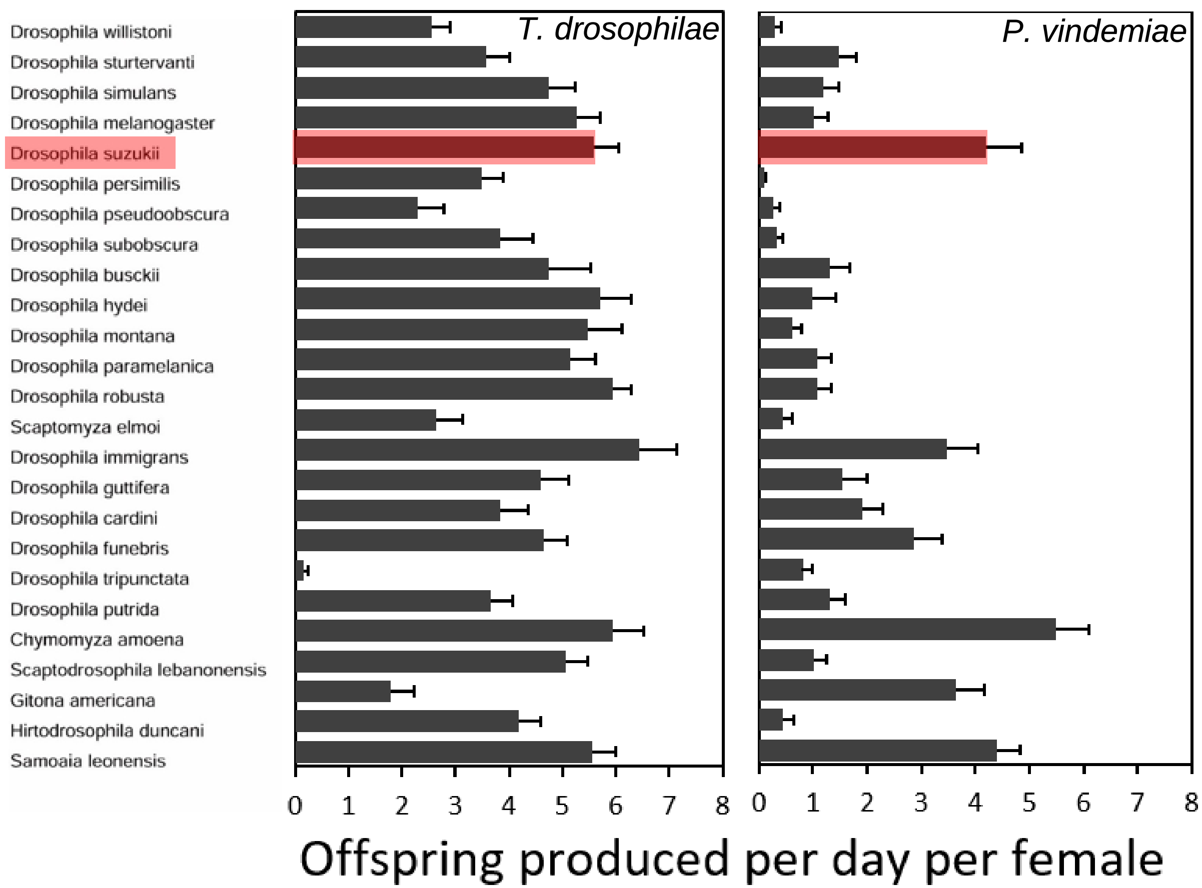
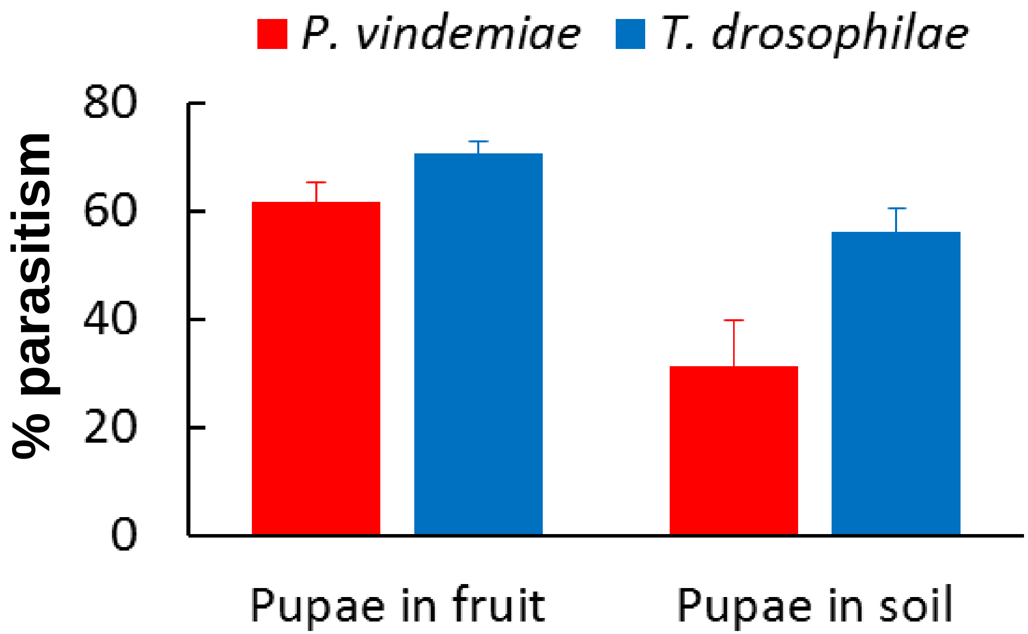


Data provided by X. Wang and K. Daane, UC-Berkeley

SWD parasitoids attack pupae in fruit and soil

Heather Leach
MSU



Both parasitoids can lay 6-7 eggs per day

Females decrease in egg production as they age

T. drosophiliae is more efficient than *P. vindemiae*

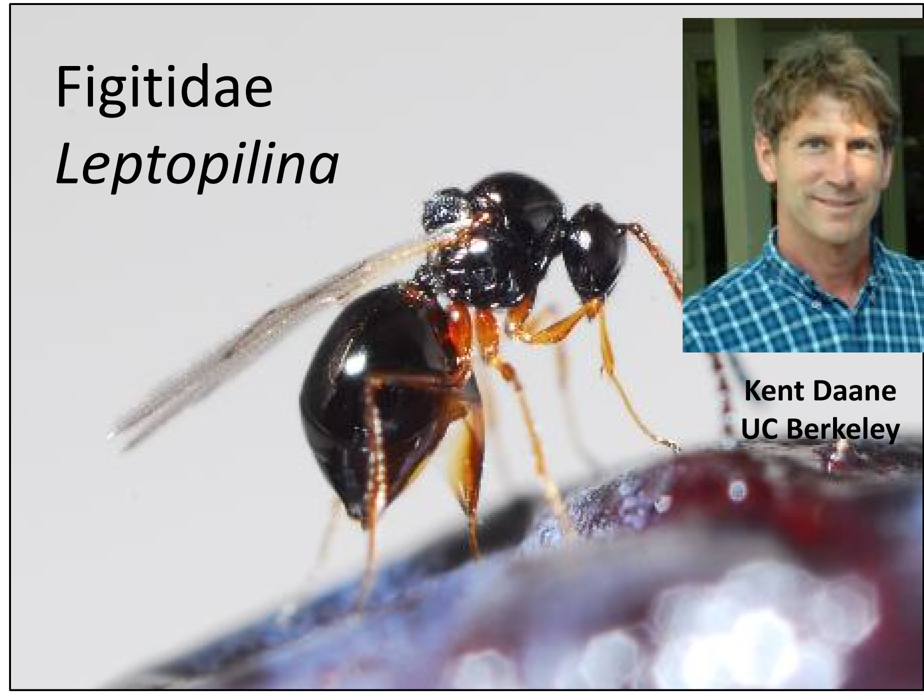
Data provided by X. Wang and K. Daane, UC-Berkeley

Collected parasitoids in South Korea and China

Larval parasitoids

Pupal parasitoids

Family	Parasitoid species	Host	Country
Braconidae	***Asobara japonica***	SWD, other drosophilids	SK, CHN
	Asobara leveri	SWD, other drosophilids	SK, CHN
	Asobara brevicauda	SWD	SK
	Asobara triangulata	SWD	SK
	Asobara mesocauda	SWD	SK, CHN
	Asobara unicolorata	SWD	CHN
	Asobara spp.	SWD	CHN
Figitidae	***Ganaspis brasiliensis***	SWD	SK, CHN
	Leptopilina japonica	SWD	SK, CHN
	Leptopilina formosana	SWD, other drosophilids	SK
	Leptopilina boulardi	Other drosophilids	SK
	Leptopilina spp.	SWD	CHN
Pteromalidae	*Pachycrepoideus vindemiae*	Other drosophilids	SK
Diapriidae	*Trichopria drosophilae*	SWD, other drosophilids	SK, CHN

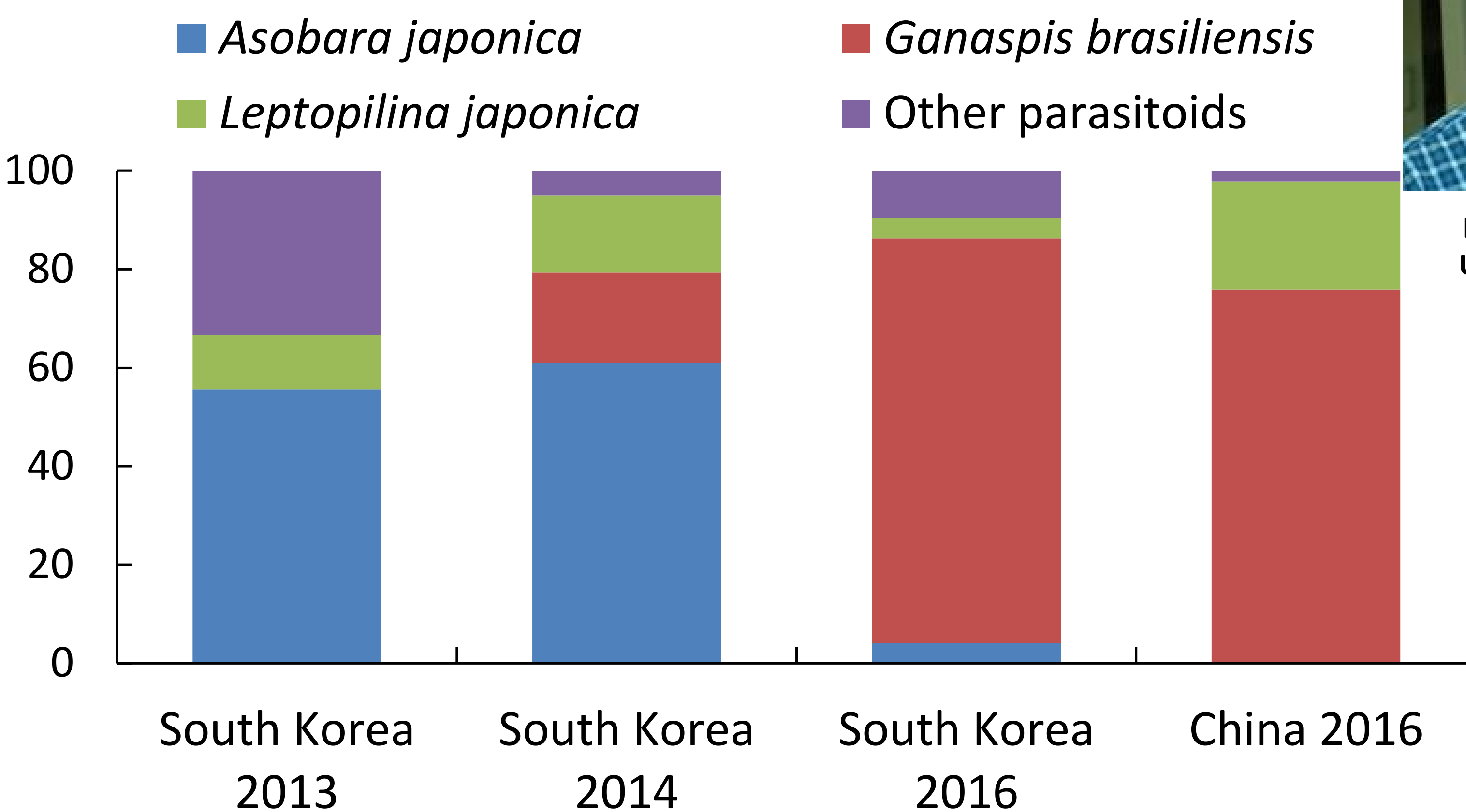


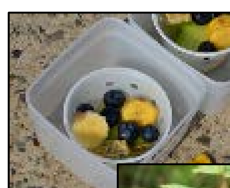
Asobara photo Tim Haye CABI

In both China and South Korea three important larval parasitoids attacked SWD: the 'figitids were more common in early fruit and the 'braconid' was more common later in the season.

Composition of larval SWD parasitoid species

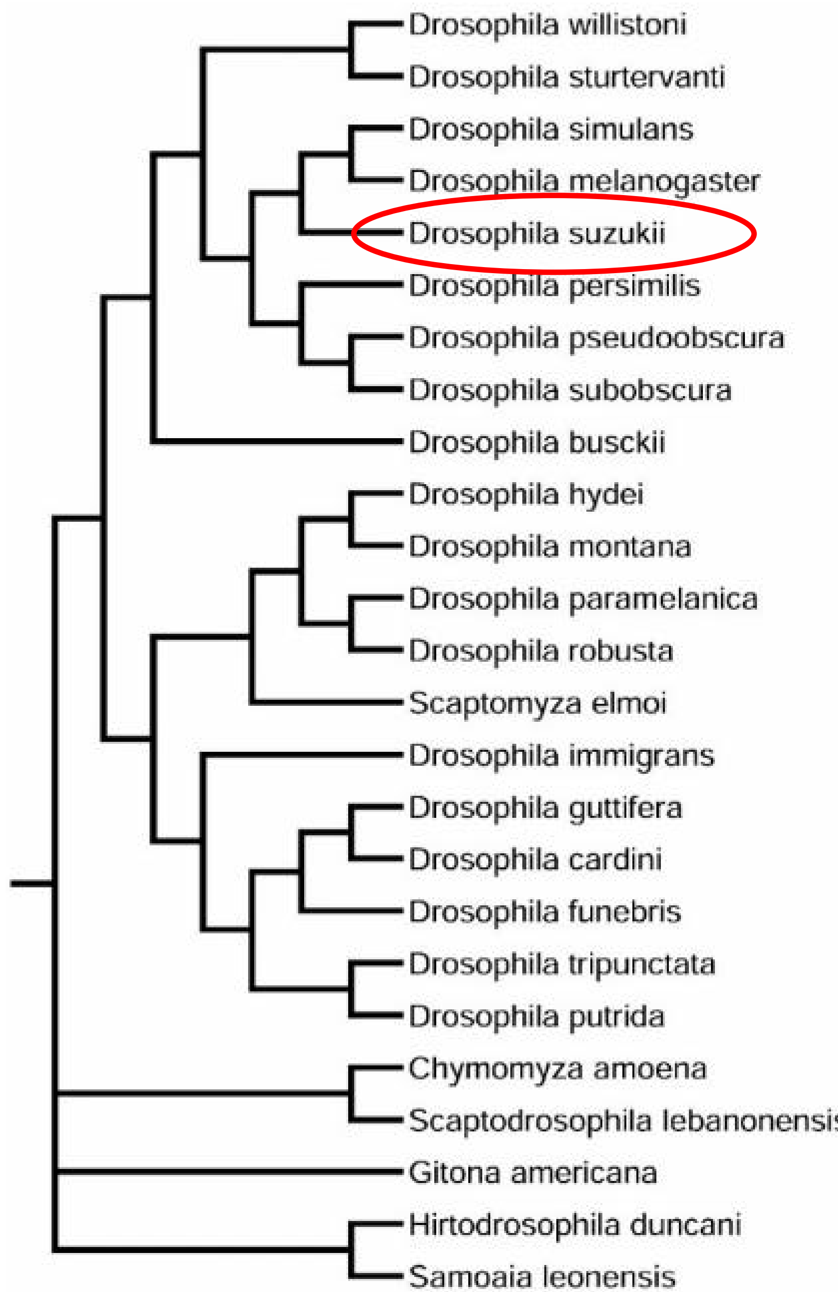
Kent Daane
UC Berkeley



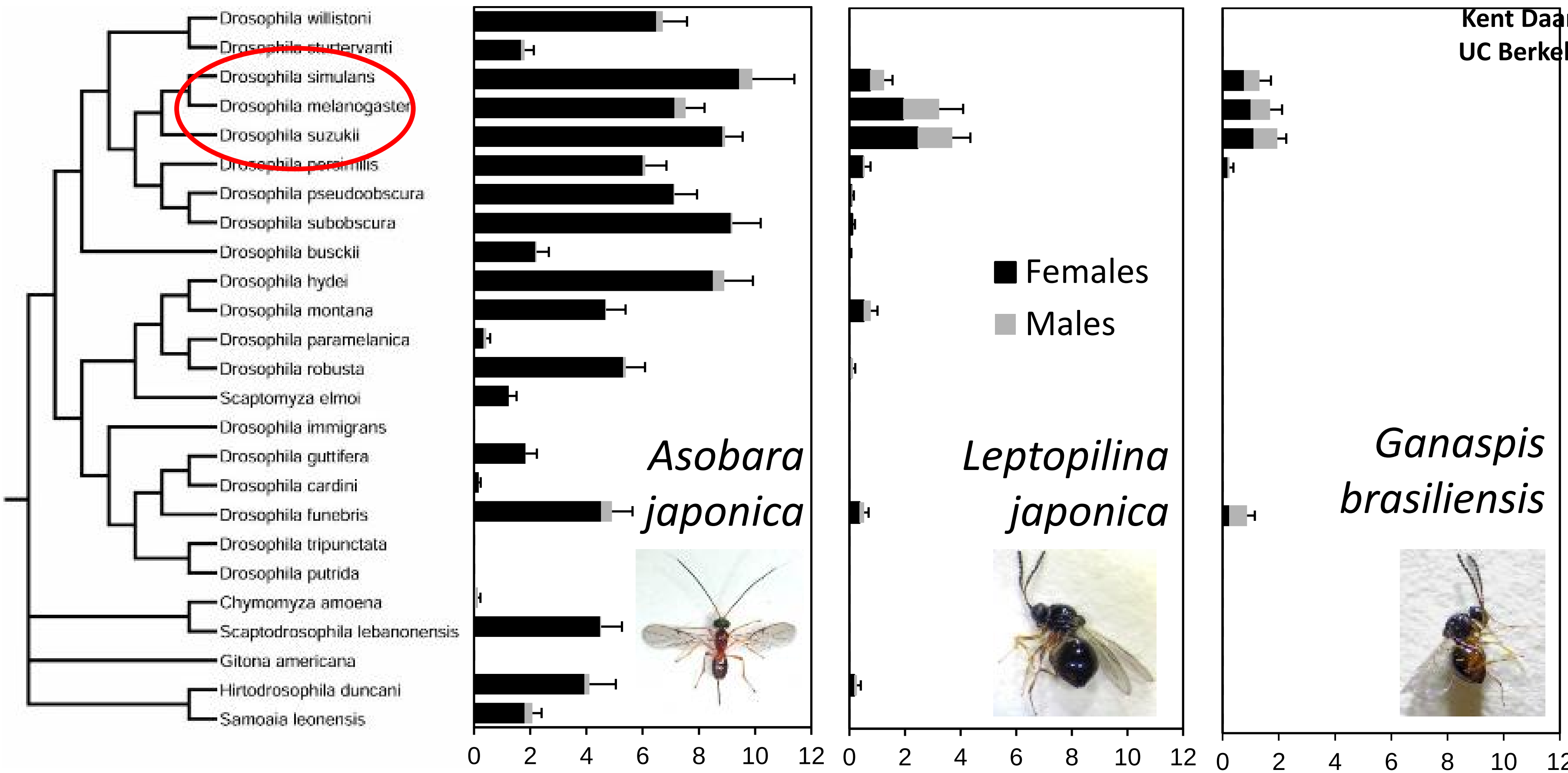

Host specificity test

- Phylogenetically related species
- 24 species (two subfamilies, 7 genera, 20 species groups)
- Breeding on fruits, mushrooms, woods, flowers or cactus



Kent Daane
UC Berkeley

Braconid is a "generalist" but Figitids are more like "Specialists"



NC STATE UNIVERSITY | MICHIGAN STATE UNIVERSITY | THE UNIVERSITY OF MAINE | RUTGERS | Oregon State University | Cornell University | USDA ARS | UNIVERSITY OF NOTRE DAME | The University of Georgia | Berkeley University of California | UC DAVIS UNIVERSITY OF CALIFORNIA

When will Imported Parasitoids be Released?

Kent Daane
UC Berkeley

SWD found in California

Insecticides are correctly the first control tools studied

2008

When will Imported Parasitoids be Released?

Kent Daane
UC Berkeley

Started looking at
SWD bio-control
in the USA

Walton (OSU)
Hoelmer (USDA)
Daane (UCB)
Burrack (NCSU)
Lee (USDA)
Isaacs (MSU)

2011 (2010-2014)

When will Imported Parasitoids be Released?

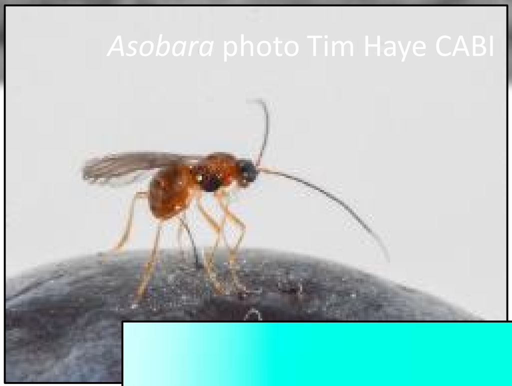
Kent Daane
UC Berkeley

First exploration in So. Korea for novel parasitoids.

Few parasitoids found and no parasitoids brought to USA.

2011

When will Imported Parasitoids be Released?


Asobara photo Tim Haye CABI

Kent Daane
UC Berkeley

Third exploration in So. Korea; first in China.

About 180 parasitoids brought to USA; including "specialized" Figitids

2014

When will Imported Parasitoids be Released?

Kent Daane
UC Berkeley

Quarantine work begins to obtain USDA APHIS permits for three imported species:

Asobara japonica
Ganaspis brasiliensis
Leptopilina japonica

2015

When will Imported Parasitoids be Released?

Kent Daane
UC Berkeley

Forth exploration in So. Korea; second in China.

More than 1,200 parasitoids brought to USA; including the more "specialized" Figitids and "new" species for taxonomists

2016

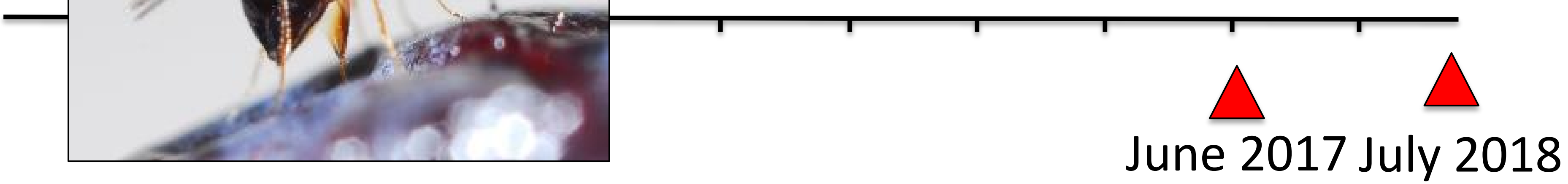
When will Imported Parasitoids be Released?

Kent Daane
UC Berkeley

USDA APHIS permit submitted in 2017 for *Ganaspis brasiliensis* and *Leptopilina japonica*

5 of 8 reviewers approved, requested additional information (climate matching, host specificity, parasitoid taxonomy)

Plan to resubmit in July 2018



Objective 3.4: Optimize post harvest practices

Lead: Hannah Burrack

Progress to date: Cold storage recommendations. Preliminary experiments with blueberry optical sorting indicate that fruit infested with second instar larvae are preferentially removed.

Future directions: Analyze optical characteristics of infested fruit to identify new means of detection.

Significant outputs: Aly et al. 2017 Journal of Economic Entomology

Post harvest cold storage

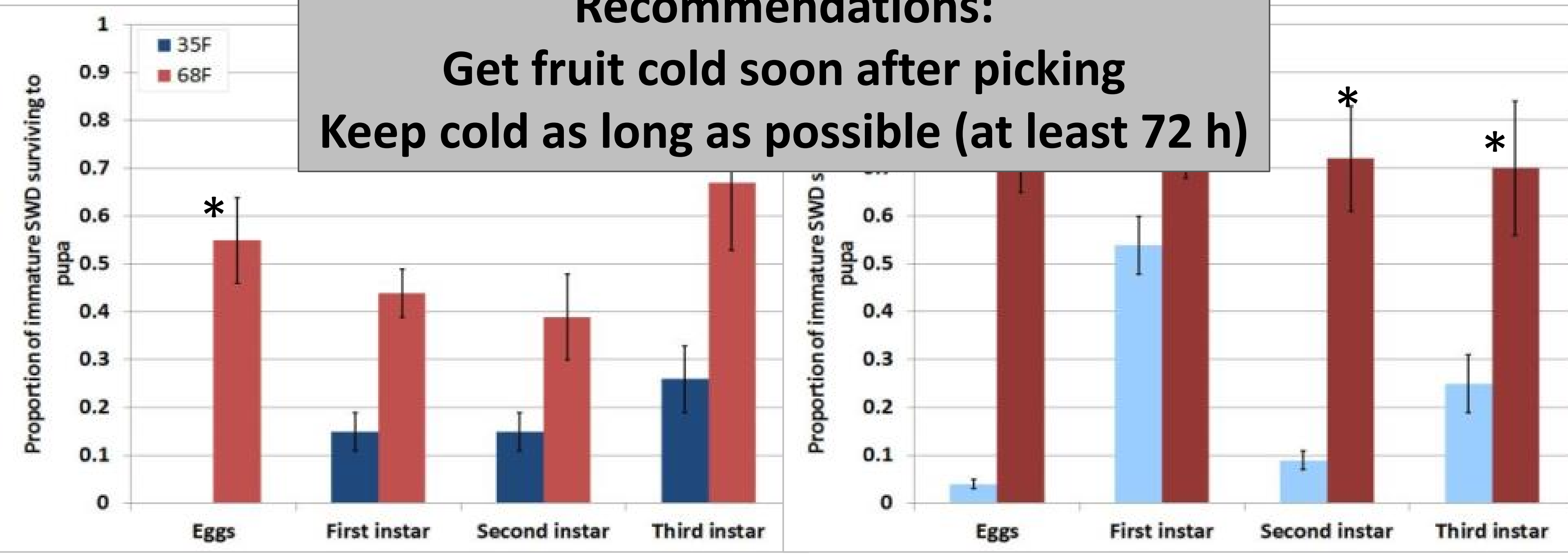
Cold Storage

35° F (1.7° C) slows larval development by at least 3 days

Blueberry: No eggs survive after 72 h, some larvae survived

Raspberry: 1st instars not impacted, survival of all other stages decreased

Recommendations:
Get fruit cold soon after picking
Keep cold as long as possible (at least 72 h)



Aly et al. 2017 J Econ Ent

Objective 3.5: Genetic control tactics

Lead: Max Scott, Zack Brown

Progress to date: Both “traditional” lethal and CRISPR cas9 lines under development.

Risk assessment of genetic controls underway.

Outputs: Completed risk assessment and use to guide future research activities. Optimize and assess fitness of genetically modified strains.

Gene drive work in CA cherries
(MIT Technology Review)


Rewriting Life

Farmers Seek to Deploy Powerful Gene Drive

A technology feared for its potential as a bioweapon is attracting interest from farmers as a way to control pests.

by Antonio Regalado December 12, 2017

- -Collaboration of Bruce Hays (Cal Tech), Omar Akbari (UC- Riverside) and the CA Cherry Board
- -NOT part of the SCRI program, but… we are talking with them!
- -Works well in the lab, not field tested yet

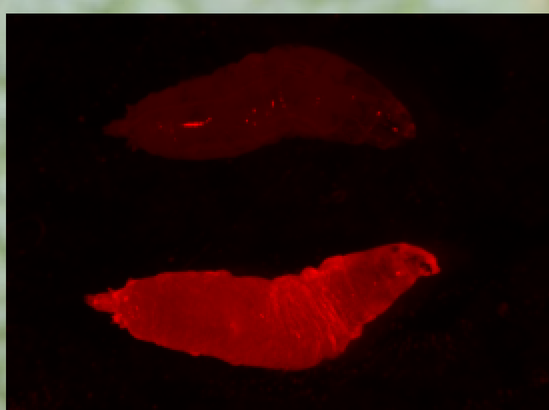


Image: Omar Akbari

Acknowledgements

USDA National Institute for Food and Agriculture (NIFA) Specialty Crops Research Initiative (SCRI) *Award number 2015-51181-24252*

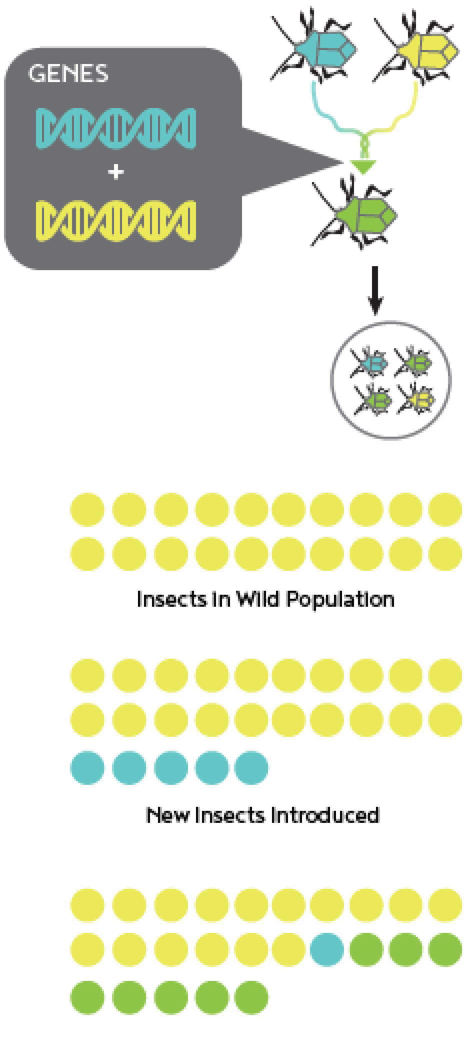
www.SWDManagement.org

- North Carolina Blueberry Council, Inc.
- Georgia Blueberry Growers Association
- Southern Region Small Fruit Consortium
- NC Agricultural Foundation, Inc.
- Project GREEEN
- MBG Marketing
- Michigan Blueberry Advisory Council
- Georgia Blueberry Commission
- Georgia Department of Agriculture

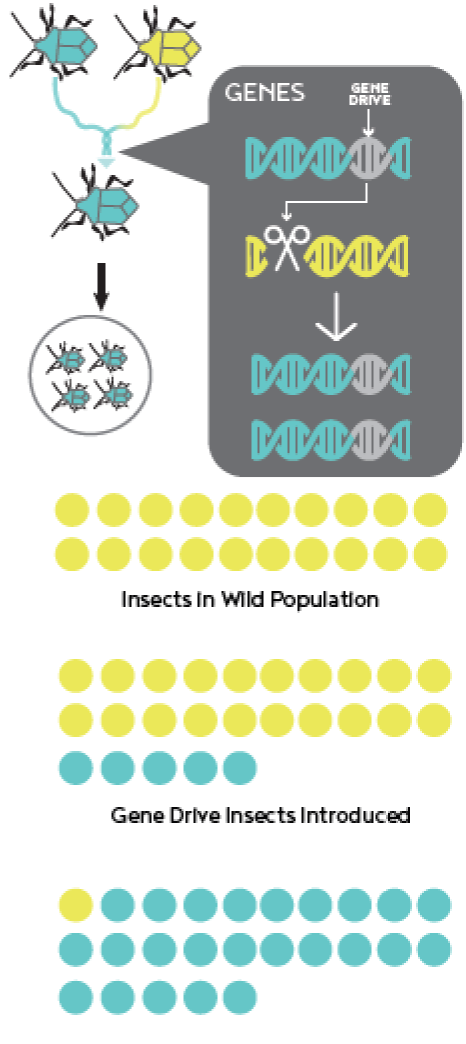
WHAT IS GENE DRIVE?

Gene drive is a method that enhances the inheritance of a modified [or preferred] trait in a specific species. The **goal** of the genetic modification may be to replace or reduce a pest population or to increase the prevalence of desirable traits in a beneficial species like silkworms or honey bees.

NORMAL INHERITANCE

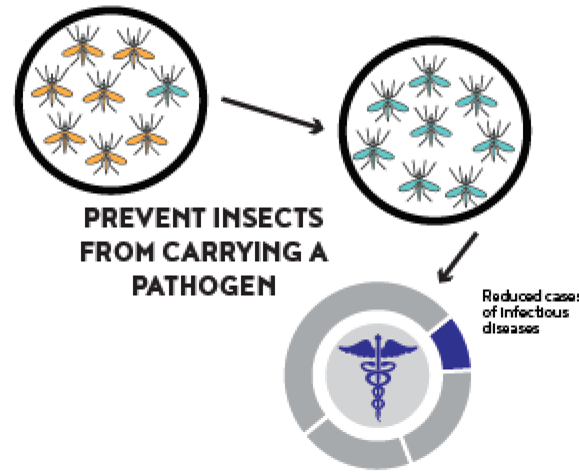


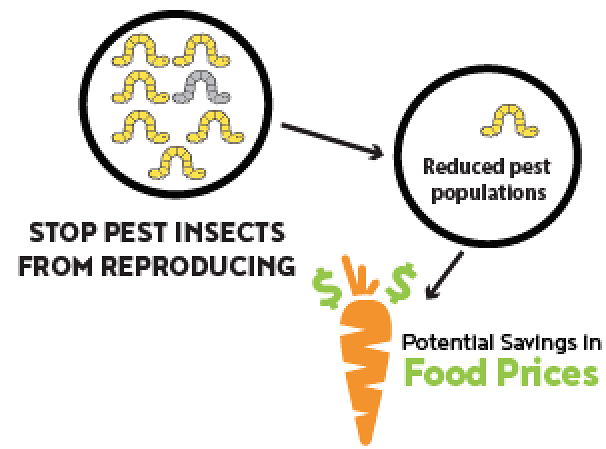
GENE DRIVE INHERITANCE



APPLICATIONS

Gene drive could be used to:





The Entomological Society of America is the largest organization in the world serving the needs of entomologists and other insect scientists. ESA stands as resource for policymakers and the general public who seek to understand the importance and diversity of earth's most diverse lifeform—insects. Learn mor