Research Update: Pest Management

December 10, 2015

Bob Curtis,
Almond Board

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David Haviland,
UCCE Entomologist

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Management of Arthropod Pests in the Lower San Joaquin Valley

David Haviland

UC Cooperative Extension, Kern Co.

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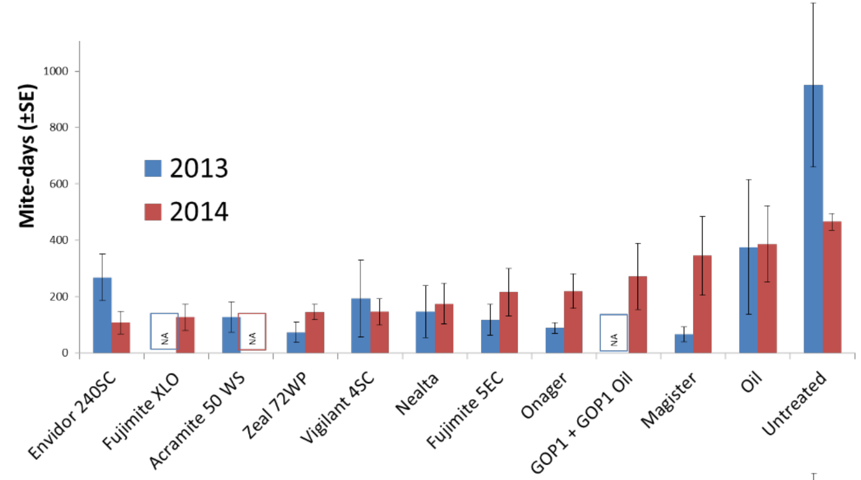
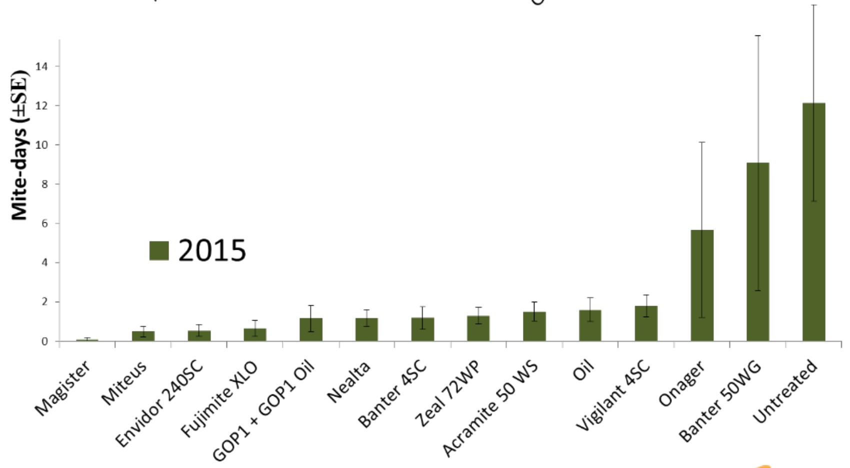
Spider mites- miticides

- Summer miticide trials
- Grower standards still effective
  - Acramite, Envidor, Fujimite, Onager, Vigilant, Zeal
- Fujimite formulations all effective
  - Past (5C), present (XLO), future (SC)(low odor, low VOC)
- New miticide Nealta is very effective
  - Excellent profile against beneficials
  - Similar uses/efficacy as Fujimite
  - Fast-acting contact miticide
- New products- Magister
- New formulations- bifenazate products



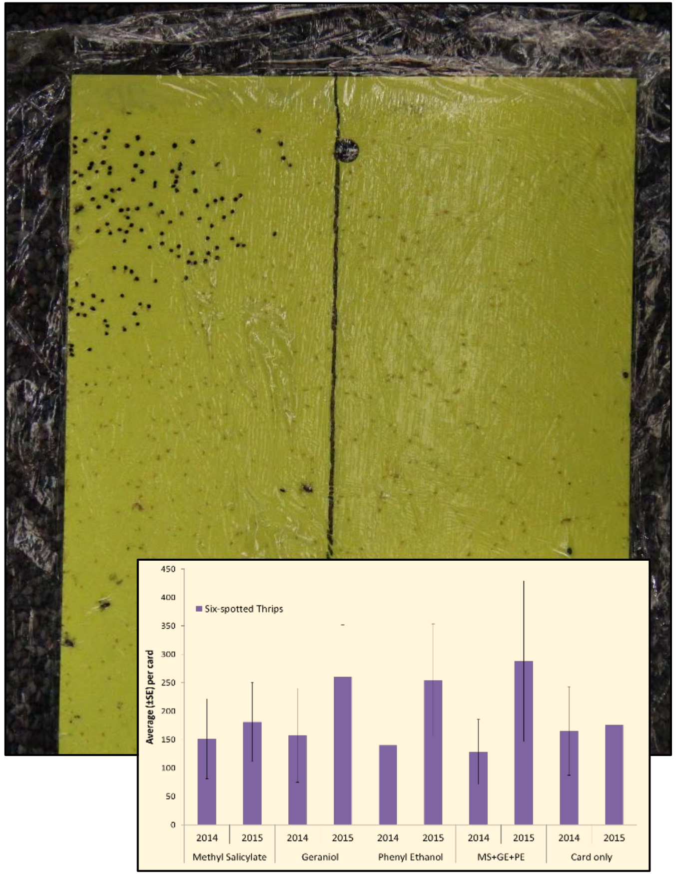


Spider mites- monitoring for beneficials

- Trees respond to herbivory by releasing chemicals into the air
  - Called "herbivore induced plant volatiles" (HIPVs)
  - Attractive to predatory insects
- HIPVs have been used in several studies
  - As lures for traps or general attractants
  - Studies on several predators, but not of spider mites
- Kern County study for last two years
  - Evaluate three lures by themselves and together
  - Attached to yellow sticky cards, ¼ acre plots
  - Replicated trial, 5 weeks, evaluated weekly
  - 4 key predators

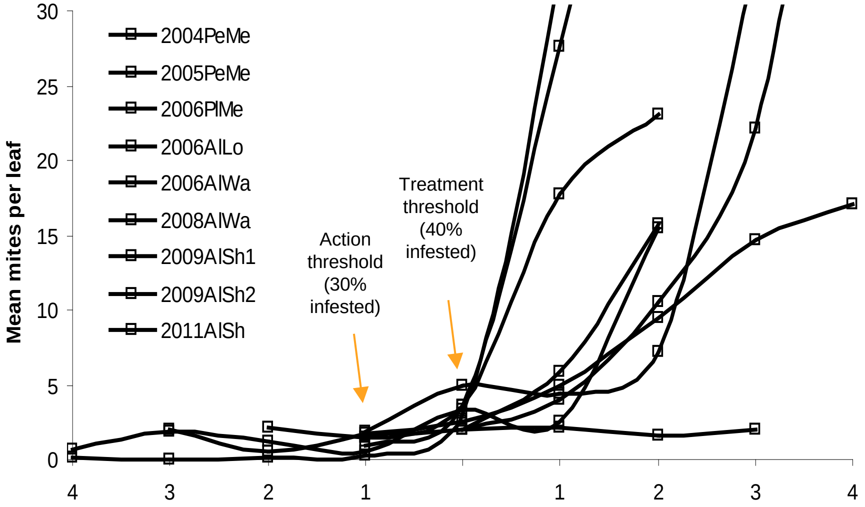
Spider mites- monitoring for beneficials

- Traps collected predators
  - No significant differences among treatments
- Numbers indicate something else might be going on
  - First week- 18 thrips per card
  - Second week- 221 thrips per card
  - Week 2 to 5 average- 286 per card
  - In 4 weeks in a 7-acre orchard we captured 5,709 thrips
    - 50 per tree
- Hypothesis: HIPVs attracted beneficials to the orchard
  - Predators may not use them for close-up searching



Spider mites- thresholds

- Advocate threshold-based miticide use
  - Preventative programs inhibit establishment of biocontrol
  - The primary miticide used in preventative programs kills sixspotted thrips
- Doing multi-year analysis of threshold data
- Evaluating PUR data to look at trends



Leaffooted bug management

- One year ago-
  - WARNING: Leaffooted bug populations in the southern San Joaquin Valley are at all-time highs
  - LFB completed an extra generation this year
  - Populations are comparable or higher than fall 2005
- This spring-
  - Warnings continued, monitoring levels at their highest
  - Treatments made as needed, overall damage low
- Spring treatments should be based on monitoring
  - Lorsban- industry standard
    - Excellent on contact, residual of 1 week
  - Pyrethroids- Brigade and Warrior II
    - Excellent on contact, residual of 4+ weeks
  - Abamectin- Agri-mek and others
    - Excellent on contact, no residual activity
  - Belay, Bexar, Sivanto, Beleaf, Exirel, Sequoia
    - Some contact activity, no residual activity

Brad Hanson,
UCCE Weed Specialist

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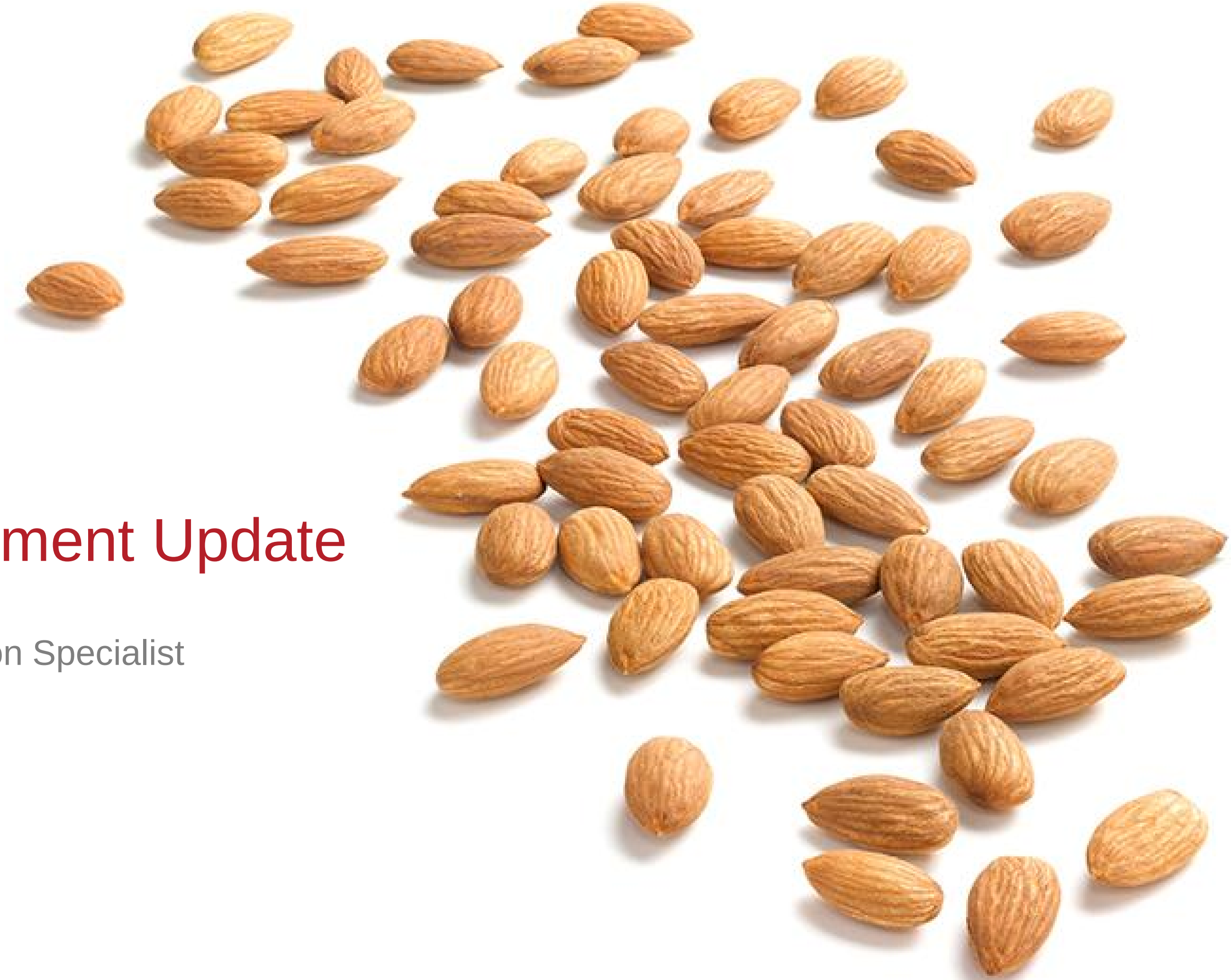

Weed Management Update

Brad Hanson
UC Cooperative Extension Specialist

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Weed research and extension focus

- Program focus is on orchards and vineyards, but provides applied weed management and herbicide support in annual crops
  - Herbicidal weed control efficacy
    - New products, label changes, tankmix partners, statewide performance, etc
  - Herbicide-resistant weeds
    - Management
    - Physiology, genetics, and mechanisms
  - Weed biology
    - reproduction and interactions with environment or management practices
  - Herbicide crop safety issues
    - Via foliar drift, soil uptake, other routes of exposure
  - Pesticide registration support
    - IR4 program and with crop protection industry partners

Epidemiology and control of foliar fungal and bacterial almond diseases

Brown rot, Jacket rot, Shot hole, Rust, Hull rot, Alternaria leaf spot, Scab, and Bacterial spot

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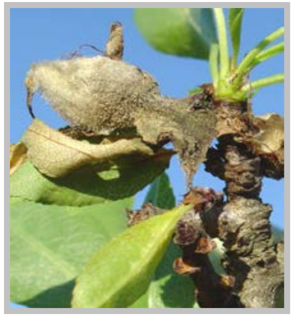
Foliar and fruit diseases of almond in California

Brown rot blossom blight



Green fruit rot/Jacket rot

Shot hole

Bacterial spot

Anthracnose

Scab

Alternaria leaf spot

Rust

Hull rot

Fungicides for Managing Almond Diseases

Inorganics and Conventional Synthetics

Inorganics — Copper, Sulfur — M1&2 — 1960s

Dithiocarbamates — Ziram, Manzate — M3 — 1940s

Phthalimides — Captan — M4 — 1950s

Isophthalonitriles — Bravo, Echo, Equus — M5 — 1960s

Guanidines — Syllit — U12 — 1960s

Benzimidazoles — Topsin-M, T-Methyl — 1 — 1970s

Dicarboximides — Rovral , Iprodione, Nevado, Meteor — 2 — 1980s

Sterol inhibitors (DMIs) — Rally, Indar, Tilt, Bumper, Quash, Inspire, Rhyme, Tebucon, Toledo — 3 — 1970s - 1980s

SDHIs — Xemium, Luna Privilege, Fontelis, Kenja — 7 — 1960s

Anilinopyrimidines — Vangard, Scala — 9 — 1990s

QoIs — Abound, Gem, Headline — 11 — 1990s

Hydroxyanilides — Elevate — 17 — 1990s

Polyoxins — Ph-D — 19 — 1960s

Phosphonates — ProPhyt, K-Phite, Fungi-phite, *Aliette, Linebacker (non-bearing)* — 33 — 1980s

Pre-Mixtures

- Inspire Super — 3+9
- Quadris Top, Quilt Xcel, — 3+11
- Pristine, Luna Sensation, Merivon — 7+11
- Luna Experience — 3+7
- Viathon — 3+33

New: Luna products, Merivon, Syllit (2014), Viathon, Kenja, (2015).

Pending: Rhyme, EXP-1, EXP-2, EXP-3: ongoing evaluation

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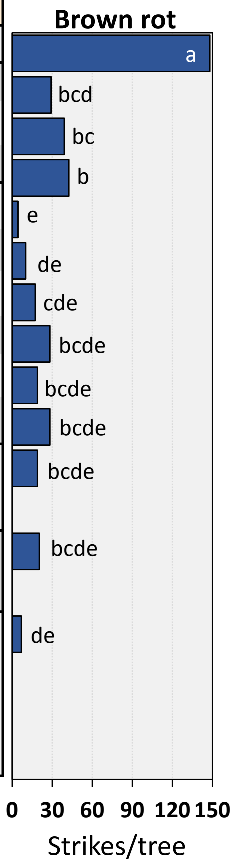
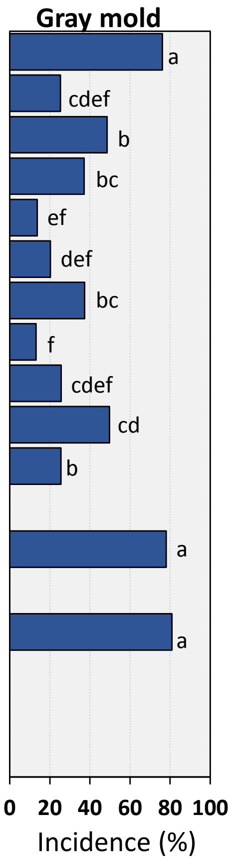
Brown rot blossom blight

No.	Treatment	Rate/A oz/ fl oz	PB	FB	PF	PF
1	Control	---	---	---	---	---
2	EXP-1	4	@	@	@	@
3	Fontelis	20	@	@	@	@
4	Kenja	13.7	@	@	@	@
5	Kenja + IB18220	10.3 + 6.9	@	@	@	@
7	Luna Experience + NIS	6	@	@	@	@
8	Luna Sensation + NIS	5	@	@	@	@
9	EXP-2	7	@	@	@	@
10	EXP-3	7	@	@	@	@
12	Merivon	5.5	@	@	@	@
13	Syllit	24	---	@	@	@
	Tebuconazole	4	@	@	@	@
15	Indar 2F + surf	6 + 16	@	@	---	---
	Dithane + surf	144 + 16	---	---	@	@
16	Vangard	5	@	---	---	---
	Quadris Top + Dyn.	14 + 16	---	@	---	---
	Bravo	64	---	---	@	---
	Inspire EC	7	---	---	---	@

Rotations (treatments 13–16)





- **Risk of infection is determined by environmental conditions**
- **Temperatures >58F**
- **Wetness**
- **Multiple highly effective fungicides are available**

Conventional Fungicides for Managing Brown Rot and Botrytis Blossom Blight

Registered Single AIs

Sterol inhibitors (DMIs)

Inspire, Tebucon, Toledo — 3

SDHIs

Fontelis, Kenja — 7

Guanidines

Syllit — U12

Registered Pre-Mixtures

Inspire Super — 3+9

Quadris Top — 3+11

Pristine, Luna Sensation, Merivon — 7+11

Luna Experience — 3+7

Viathon — 3+33

Experimentals: **Rhyme, EXP-1, EXP-2, EXP-3: ongoing evaluation**

Summary -

Single AIs and Pre-mixtures

- **Highly efficacious against brown rot blossom blight**

Pre-mixtures and tank mixtures

- **Improved performance against Botrytis blossom blight**
- **Resistance management**

Brown Rot - Timing of bloom applications

Determining factors	Delayed bloom application (30-40% bloom)	PB (5% bloom) <u>and</u> FB (80% bloom) applications
Environmental conditions (rain)	Less favorable	Highly favorable
Fungicide properties	Locally systemic action	With or without locally systemic action

- Many of the newer brown rot fungicides have some locally systemic activity and subsequently pre- and some post-infection activity.
- During less favorable environments **a single application at delayed bloom** (20-40% bloom) is sufficient for good disease control.
- During highly favorable conditions, a 2-spray program with applications at pink bud and full bloom is recommended.

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Almond Hull Rot

- Caused by *Rhizopus stolonifer* or by *Monilinia fructicola*
- Both pathogens infect fruit and cause dieback

Rhizopus stolonifer (left), *Monilinia fructicola* (right)

- For dieback of Rhizopus hull rot, fumaric acid production of the pathogen may be involved.
- The two pathogens require different management strategies

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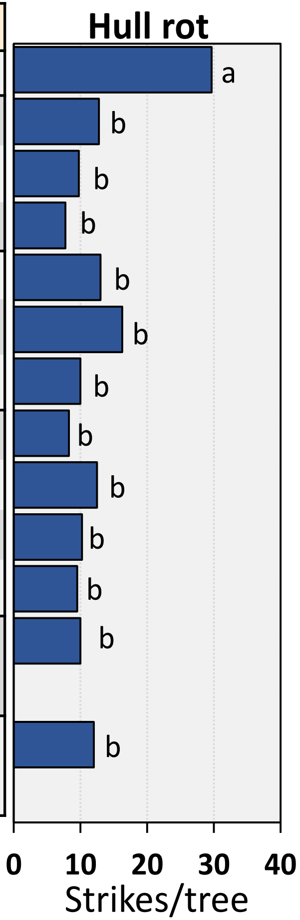
Almond Hull Rot – Alkaline treatments and fungicides

Treatment*	Rate/A (oz / fl oz)
Control	-----
Double OK 0-0-30	384/ 64*
Di-potassium phosphate	32 / 48**
Inspire	7
Quash + S-2200	3.36 + 3.36
Double OK 0-0-30 + Qu Top + Dyn.	384 / 64* + 14 + 16
Di-K phosphate + Qu Top + Dyn.	32 / 48** + 14 + 16
Quadris Top + Dyn.	14 + 16
Merivon	6.5
EXP-2	7
EXP-3	7
Ph-D + Quash + Nufilm P	6.2 + 3 + 8
Ph-D + Abound + Nufilm P	6.2 + 12 + 8
Luna Experience	6
Luna Sensation	5

Rotations

cv. Nonpareil, applications 6-12 and 7-14-15



Alkaline treatments were evaluated to possibly neutralize fumaric acid.

- Foliar applications of alkaline fertilizers were similarly effective as some of the fungicide treatments.
- However, no additive effect with fungicides tested.

Most **fungicides** performed similarly and significantly reduced the disease as compared to the control (FG 3+7, 3+9, 7+11, 3+11, 3+19).

Almond Hull Rot - Inoculum reduction treatments

Sub-plot appl.	6/12 7/14	Control Control		Luna Experience Luna Sensation		Quadris Top + Dyn Quadris Top + Dyn		Merivon Merivon		Inspire Inspire		Main plot Treatment Avg	
Main Plot	Appl. Date	Dis. Inc.^	LSD^^	Dis. Inc.	LSD	Dis. Inc.	LSD	Dis. Inc.	LSD	Dis. Inc.	LSD	Dis. Inc.	LSD
Control	---	22.6	A a	12.0	AB a	8.3	B a	12.5	AB a	7.8	B a	15.4	a
LLS 15 gal/A	5-7/6-3	23.5	A a	9.3	B a	6.8	B a	9.7	B a	9.7	B a	14.3	a
Sub-plot trt avg		23.1	A	10.4	B	7.4	B	10.8	B	8.9	B		

Statistical comparisons for values by column are with lower case letters, those by row are with upper case letters. Main plot treatment averages are values for treatments over all sub-plots and are statistically compared by column. Sub-plot averages are values for each of the main plots and are statistically compared within the row.

- **Soil treatments** with calcium sulfate or liquid lime sulfur to reduce soil inoculum of *R. stolonifer* were **not** effective.
- **For the most effective integrated management of hull rot**, fungicides should be integrated with proper water management (i.e., deficit irrigation) and restricted nitrogen fertilization.

Almond scab management

Effective management requires:

- **Knowledge** of the disease history of the orchard
- **Dormant treatments** – Applications to delay and reduce twig sporulation, synchronize disease management programs
  - Chlorothalonil-oil - 2EE Registration (Dec-Jan)
  - Copper – oil
- **Monitoring** for twig sporulation in the spring
- **In-season fungicide** applications at the beginning of twig sporulation (2 applications timed with Alternaria treatments if a dormant application is made)

Sporulating twig lesions and scab on fruit

Fusicladium carpophilum

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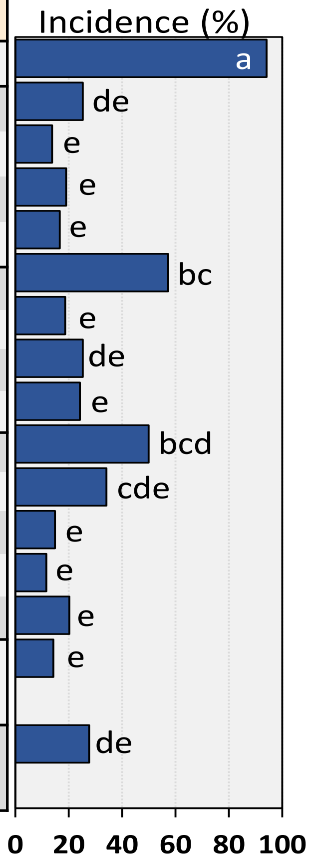
In-season treatments for scab

Treatment*	Rate/A oz/fl oz	4/21	5/12
Control	-----	-----	-----
Rhyme	7	@	@
Inspire	7	@	@
Quash	3.36	@	@
EXP-1	5.14	@	@
Kenja + IB18121	8.6 + 12.9	@	@
Ph-D + Tebucon 45 + NF-P	6.2 + 8 + 8	@	@
Quash + S2200	3.36 + 3.36	@	@
Fontelis + Tebucon 45	20 + 8	@	@
Luna Experience	6	@	@
Luna Sensation	5	@	@
EXP-2	7	@	@
EXP-3	7	@	@
Merivon	6.5	@	@
Ph-D + Quash + NF-P	6.2 + 3 + 8	@	---
Fontelis + Tebucon 45 + NF-P	20 + 8 + 8	---	@
Bravo WeatherStik	64	@	---
Quadris Top + DyneAmic	14 + 16	---	@

Rotations



cv. Monterey, Colusa Co., 2015, NF-P = Nufilm-P

Most effective newer fungicides:

Single: Chlorothalonil (high rates and extended PHI proposed), Quash, Inspire, EXP-1, Ph-D, Syllit,

Pre-mixtures: Quadris Top, Inspire Super, Luna Sensation, Merivon, EXP-2, EXP-3

Rotations: including Ph-D, Quash, Fontelis, Tebucon in tank mixtures

Multi-site fungicides with low resistance potential (chlorothalonil, mancozeb, captan, ziram) should be in rotations with the newer single-site and pre-mix fungicides.

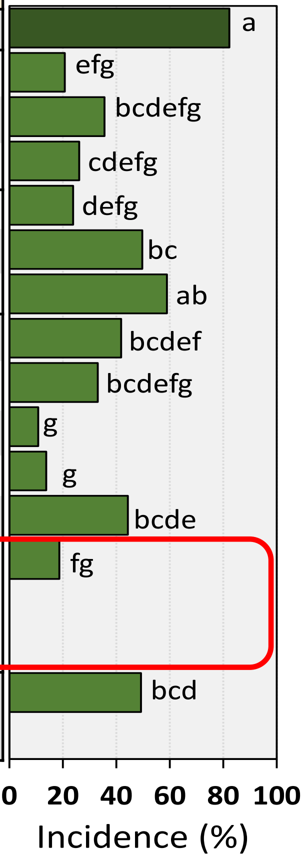
Alternaria leaf spot

Alternaria alternata,
A. arborescens,
A. tenuissima

- Inoculum is omnipresent in orchards.
- The disease is greatly influenced by microclimatic conditions.
- The DSV Model can be used to time applications based on infection periods in late spring/early summer.

Efficacy of Alternaria leaf spot treatments - 2015

Treatment*	Rate (/A)	4/29	5/20	7/7
Control	-----	---	---	---
Ph-D	6.2 oz	@	@	@
Inspire + Dyn.	7 + 16 fl oz	@	@	@
Fontelis	20 fl oz	@	@	@
Fontelis + Tebucon	20 + 8 fl/oz	@	@	@
Fontelis + Abound	20 + 12 fl oz	@	@	@
Kenja + IB18121	8.6 + 12.9 fl oz	@	@	@
Luna Experience	6 fl oz	@	@	@
Luna Sensation	5 fl oz	@	@	@
EXP-2	7 fl oz	@	@	@
EXP-3	7 fl oz	@	@	@
Merivon	6.5 fl oz	@	@	@
Rotations: Fontelis	20 fl oz	@	---	---
Quash	3 oz	---	@	---
Ph-D	6.2 oz	---	---	@
Bravo WeatherStik	64 fl oz	@	---	---
Quadris Top + Dyn.	14 + 16 fl oz	---	@	@



cv. Carmel Colusa Co.

- Two to three applications in late spring based on the DSV-model.
- **Most effective in 2015:** Ph-D, Fontelis, Inspire, Fontelis + Tebucon, EXP-2, EXP-3 - **have to be strictly used in rotations and/or mixtures for resistance management.**
- ***No detections of new resistance***
- Other components (e.g., irrigation schedule, water penetration, planting design, etc.) of an integrated approach in disease management are highly critical.

Management of Bacterial Spot

The pathogen *Xanthomonas arboricola* pv. *pruni* overwinters in fruit mummies on the tree. Isolates evaluated to date were all copper-sensitive.

High-disease years: Delayed dormant treatments with copper, copper-mancozeb, or copper-mancozeb-captan.

In-season treatments starting at full bloom/petal fall & timed around rain events and before temperatures start to rise.

Inorganics and Conventional Synthetics

Toxicants

- Inorganics: Copper (M1)
- Dithiocarbamates: Ziram, Manzate (M3)

Inhibitors

- Phosphonates: ProPhyt, K-Phite, Fungi-phite, *Aliette*, *Linebacker (non-bearing)* (33)

Natural Products and Biocontrols

Actinovate, Serenade Opti

Natural products/biocontrols with antibacterial or SAR characteristics for organic almond production

Experimental Products under Evaluation

Antibiotics

- Kasumin (24-D3)
- Oxytetra-cycline (41-D5)

Others

- Ceragenin (?)
- Quintec (13)
- ATD (?)

Multi-site mode of action | Single-site mode of action

Reduced-risk fungicides | FRAC group

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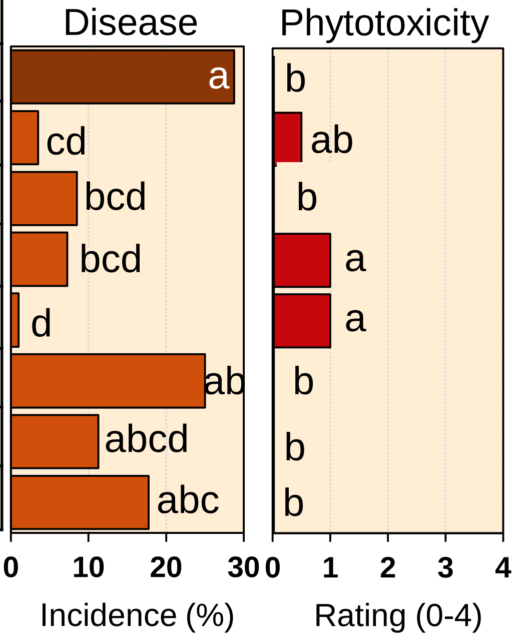
Management of Bacterial Spot – In-season treatments

Treatment	Rate(/A)
Control	---
Kasumin	64 fl oz
Mycoshield	12 oz
Kocide 3000 + Kasumin	8 oz + 64 fl oz
Kocide 3000 + Mycoshield	12 oz + 12 oz
Quintec	12 fl oz
Quintec + Manzate Max	12 + 96 fl oz
Ceragenin	5 fl oz



Cv. Fritz, Applications on 2-25, 3-6, 3-16, 3-26, 4-6, 4-24-15. Evaluation on 7-1-15.

Registration of Kasumin is on-going in IR-4 program

Most effective and consistent: copper (Kocide 3000, Badge, ChampION++) and copper mixed with mancozeb or Kasumin.

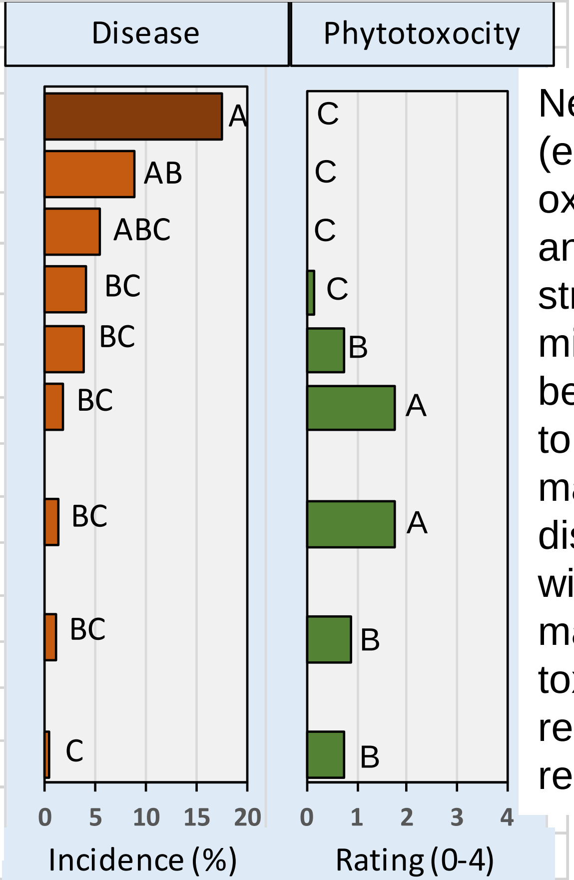
Experimentals: Kasumin, Fireline / Mycoshield, and USF2018A also effective.

Copper phytotoxicity on leaves after 4-5 applications even when copper rates were successively reduced. Minor leaf tip necrosis after $\geq$4 successive Kasumin applications.

Management of Bacterial Spot – in-season treatments

No.	Treatment*	Rate(/A)	PF 2/25	1-wk 3/6	3-wk 3/17	5-wk 3/26	7-wk 4/6
1	Control	---	---	---	---	---	---
2	Mycoshield	16 oz	@	@	@	@	@
3	ATD	13 oz	@	@	@	@	@
4	ATD + Kasumin	13 oz + 64 fl oz	@	@	@	@	@
5	Kasumin	64 fl oz	@	@	@	@	@
6	ChampION++	3.3 to 0.8 lb	3.3	1.6	0.8	0.8	0.8
	Mycoshield	16 oz	@	@	@	@	@
7	ChampION++	3.3 to 0.8 lb	3.3	1.6	0.8	0.8	0.8
	Kasumin	64 fl oz	@	@	@	@	@
8	ChampION++	3.3 to 0.8 lb	3.3	---	1.6	---	0.8
	Mycoshield	16 oz	@	@	@	@	@
	Manzate	4 lbs/A	---	@	---	@	---
9	ChampION++	3.3 to 0.8 lb	3.3	---	---	---	---
	Mycoshield	16 oz	@	@	@	@	@

Cv. Fritz, Copper rates were reduced with each treatment.



New compounds (e.g., ATD, oxytetracycline) and use strategies (e.g., mixtures) are being developed to effectively manage the disease with and without copper or mancozeb (phyto-toxicity or PHI restrictions, respectively).

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Thank you
Danke
Gracias
Merci
Cheers
谢谢
ありがとう
धन्यवाद
спасибо
شكرا

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Almond Bloom Disease Control Trials

By Brent A. Holtz, Ph.D.
UC Farm Advisor in San Joaquin County

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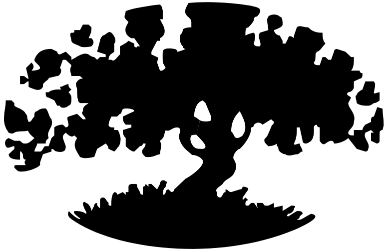
Almond Board of California

- When almond trees are blooming their flowers are susceptible to a number of plant pathogenic fungi capable of causing disease.

- Fungicides are usually applied during bloom to protect blossoms from becoming infected. Fungicides should be selected carefully to avoid resistance and to control the pathogens present.

Use this manual to avoid fungicide resistance!
www.ipm.ucdavis.edu

EFFICACY AND TIMING OF FUNGICIDES, BACTERICIDES, AND BIOLOGICALS
for
DECIDUOUS TREE FRUIT, NUT, STRAWBERRY, AND VINE CROPS
2009
(Updated June, 2009)



ALMOND	***PEACH/NECTARINE***
APPLE/PEAR	***PISTACHIO***
APRICOT	***PLUM***
CHERRY	***PRUNE***
GRAPE	***STRAWBERRY***
KIWIFRUIT	***WALNUT***

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UC Kearney Agricultural Center
www.uckac.edu/plantpath

Statewide IPM Program
www.ipm.ucdavis.edu

Almond Scab
Cladosporium carpophilum

Gray-black, oil-like soft looking spots form on leaves, fruit, and twigs.

Almond Scab
Cladosporium carpophilum

- Young lesions are indistinct small yellow specks, best seen by holding a leaf up to the light.
- Lesions usually are not visible until late spring or early summer.

Almond Scab
Cladosporium carpophilum

- The fungus survives in twig lesions, and spores are spread by wind or rain.
- Scab is favored by prolonged wet spring weather,

Almond Scab
Cladosporium carpophilum

- Severe scab infections can cause early defoliation
- If left uncontrolled for several years, infected trees become weakened.

Timing of Fungicide Treatments for Scab Control

Note: Not all indicated timings may be necessary for disease control.

		Bloom			Spring[1]		Summer	
Disease	**Dormant**	**Pink bud**	**Full bloom**	**Petal fall**	**2 weeks**	**5 weeks**	**May**	**June**
Scab[3]	++	---	---	++	+++	+++	+	---

Rating: +++ = most effective, ++ = moderately effective, + = least effective, and **----** = ineffective

[3] Early treatments (during bloom) have minimal effect on scab; the 5-week treatment usually is most effective. Treatments after 5 weeks are useful in northern areas where late spring and early summer rains occur. Dormant treatment with liquid lime sulfur improves efficacy of spring control programs.

Fungicide Timing for Scab

Disease	Dormant	Bloom			Spring		Summer	
		Pink bud	Full bloom	Petal fall	2 weeks	5 weeks	May	June
Scab[4]	M1+oil, M2[3]	----	----	1[2] 7/11[2] 11[2] M3 M4 M5	1[2] 7/11[2] 11[2] M3 M4 M5	3 7/11[2] 11[2] M2[3] M3 M4	M2[3] M4	----

Cladosporium has become resistant to strobilurin fungicides (QoI=quinone outside inhibitors, single site mode of action) in orchards of high use and disease pressure.

Use dormant treatments of copper and oil or liquid lime sulfur

Rotate groups for each application within a season and, if possible, use each group only once per season, except for multi-site mode of action materials or natural products/biological controls.

Carmel Variety

Treatment	Rates per acre	Incidence[a]	
6	Bravo (Chlorothalonil)[1] 4 pt, Quadris Top[2] 14 fl oz, Inspire Super[3] 20 fl oz	0.0	a
11	Rovral +oil +Topsin[1], 8 fl oz+1%v/v+10 fl oz, Quadris[2],14 fl oz, Captan[3], 5lbs	0.2	a
18	Microthiol Disperse[1,2,3] 20 lbs	0.4	a
3	Fontelis + Tebucon 45DF[1,2,3], 20 fl oz + 8 oz	0.6	a
17	Merivon SC[1,2,3] 6.5 fl oz	0.6	a
7	Quadris Top[1] 14 fl oz, Bravo (Chlorothalonil)[2] 4 pt, Inspire Super[3] 20 fl oz	0.8	a
12	Rovral +oil+Topsin[1], 11.4floz+1%v/v+14 floz, Quadris[2],14 floz,Captan[3], 5lbs	0.8	a
13	Luna Sensation SC[1,2,3], 6 fl oz	1.6	a
14	Luna Experience[1,2,3], 6 fl oz	1.8	a
15	Luna Experience[1,3], 6 fl oz, Gem+Serenade Optimum[2], 3.0 fl oz + 8 oz	2.8	ab
2	Fontelis + Bumper 3.6EC[1,2,3], 20 fl oz + 8 fl oz	2.8	ab
10	Rovral + oil + Topsin[1,2], 11.4 fl oz+1%v/v + 14 fl oz, Captan[3], 5 lbs	6.8	b
9	Rovral + oil + Topsin[1,2], 8 fl oz+1%v/v + 10 fl oz, Captan[3], 5 lbs	7.0	b
16	Pristine[1,2,3], 14.5 oz	16.6	c
5	Fontelis + Gem 4.05SC[1,2,3], 20 fl oz + 2.9 fl oz	21.0	cd
4	Fontelis + Abound 2.0 8F[1,2,3], 20 fl oz + 12 fl oz	24.2	d
8	Rovral + oil[1,2], 16 fl oz+1%v/v, Captan 80 WG[3], 5 lbs	24.6	de
1	Fontelis 1.67 SC[1,2,3], 20 fl oz	29.4	e
19	Untreated Control	35.0	f
20	Untreated Control	35.4	f

[a]Incidence = number of nuts that have scab lesions on 45 nuts randomly sampled per tree. Three people rated each tree (Cheryl, Scotty, and Stephen). Data was analyzed by ANOVA with means separated by Fisher's Protected LSD ($\alpha = 0.05$) test. Means followed by the same letter are not significantly different. The trial was rated on August 5th and 6th, 2014. All treatments significantly reduced the incidence of almond scab when compared to our two untreated controls.

The following trial applications are outlined above:

[1]First application was performed 2 weeks after petal fall (2WPF) on March 20th.

[2]Second application was performed 4 weeks after petal fall (4WPF) on April 3rd.

[3]Third application was performed was 8 weeks after petal fall (8WPF) on May 1st.

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Thank You!

Greg Browne,
USDA-ARS, Davis, California

Agricultural
Research
Service

Developing Improved Strategies for Management of Replant Problems

Greg Browne, Natalia Blackburn, Hossein Gouran, Gureet Brar, Brent Holtz, David Doll, Andreas Westphal, Amelie Gaudin

UC Davis, Department of Plant Pathology

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Key Objectives

- **Develop non-fumigant approaches for managing replant problems**

Fumigant performance summary
California Agric. 2013. 67:128-138

Alternatives ?

- **Develop better understanding of replant disease causes and prediction among fields**

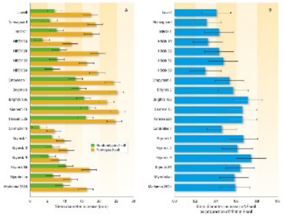
Soil bioassays, replant trials

High throughput DNA seq

Further resolution of RD

Predictive diagnostics?

- **Support development of improved rootstocks**

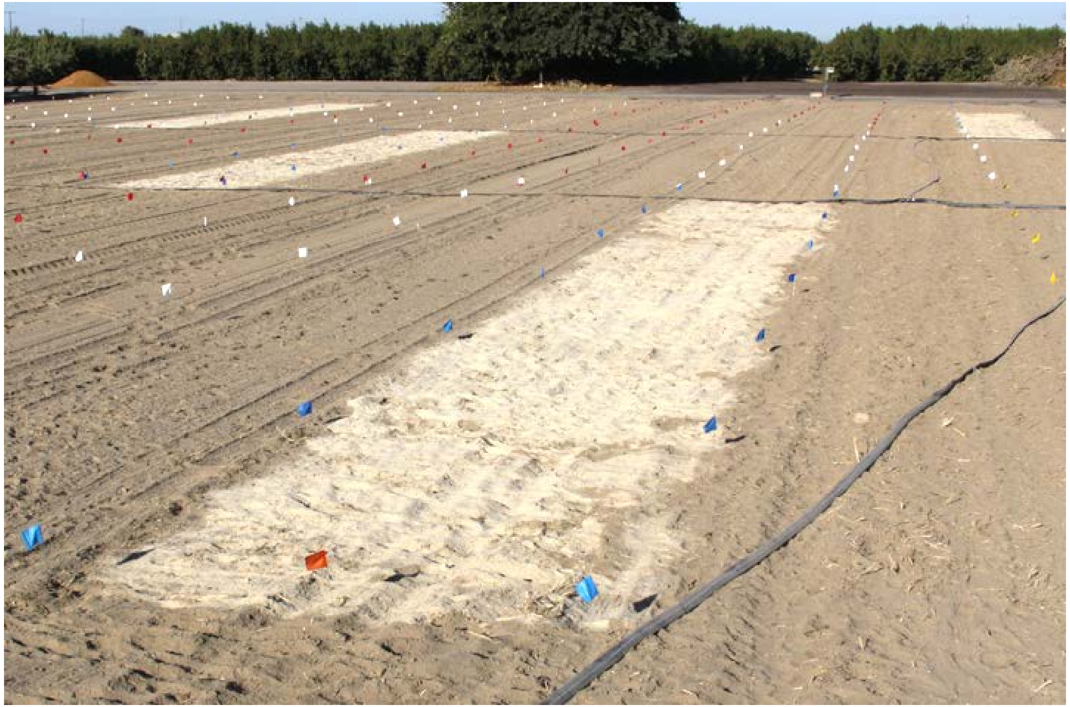


New hybrids vs. standards

RD resistance | ***Phytophthora* resistance**

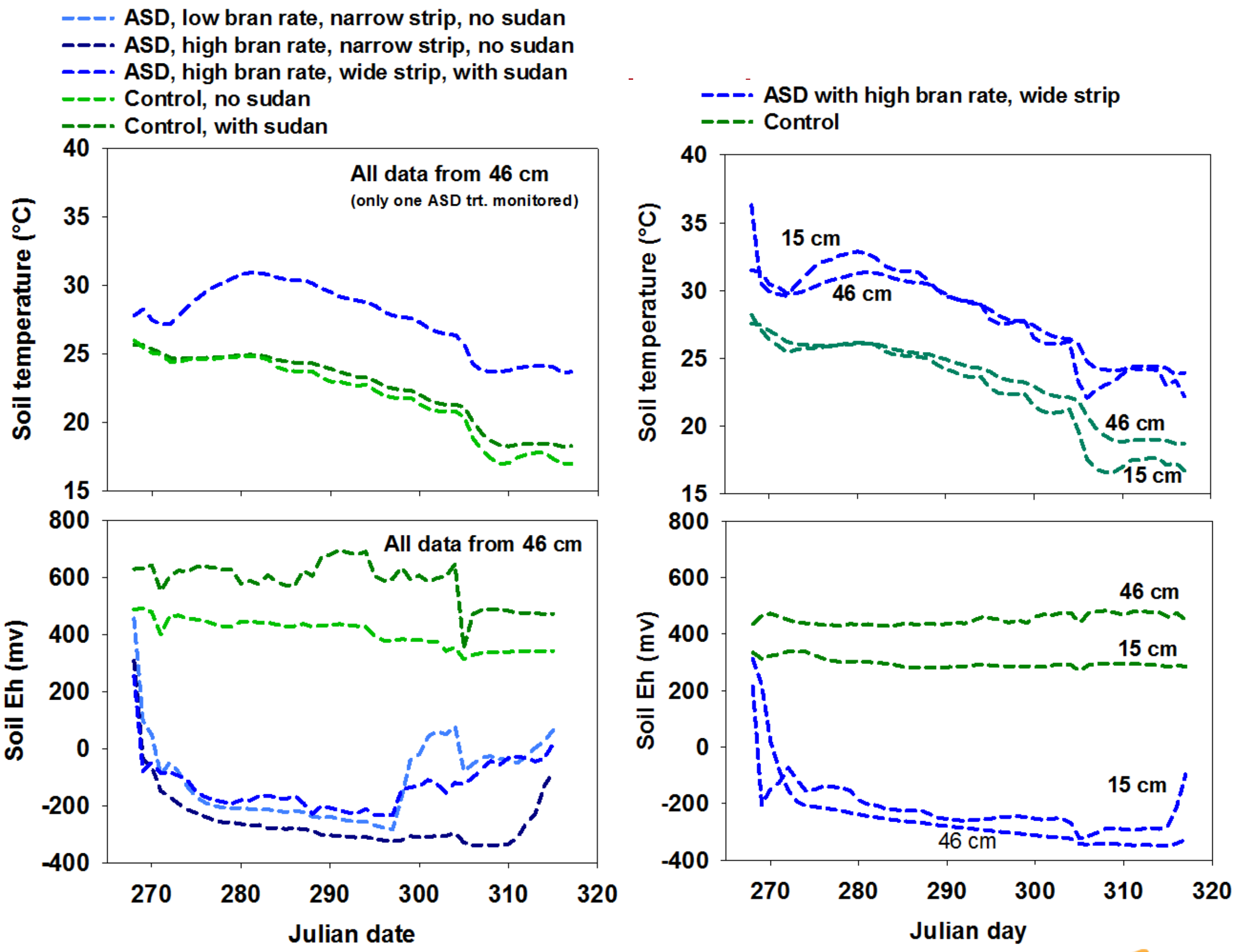
Non-fumigant method: Anaerobic soil disinfestation (ASD)

2 years of trials at Kearney Ag Center



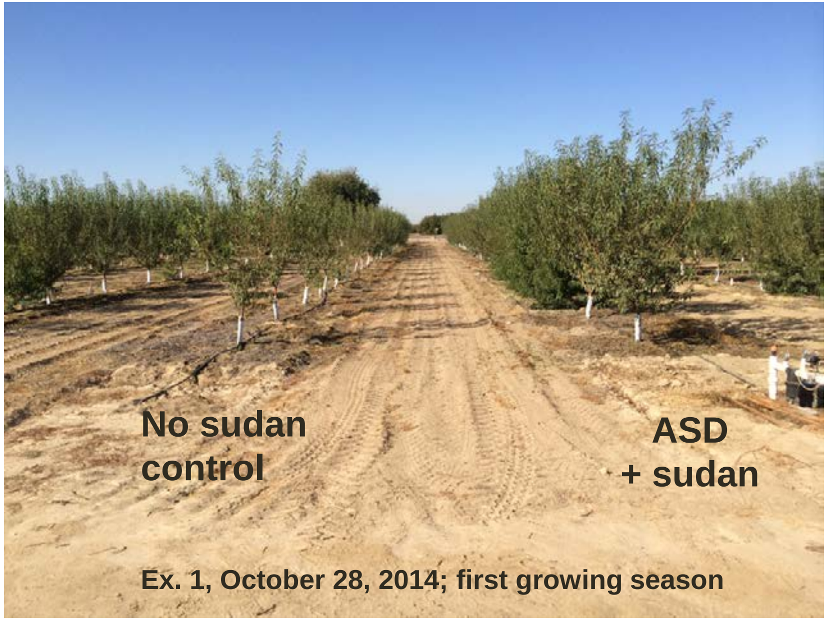
Impacts of ASD on temperature

Treatment period was late Sep through Nov

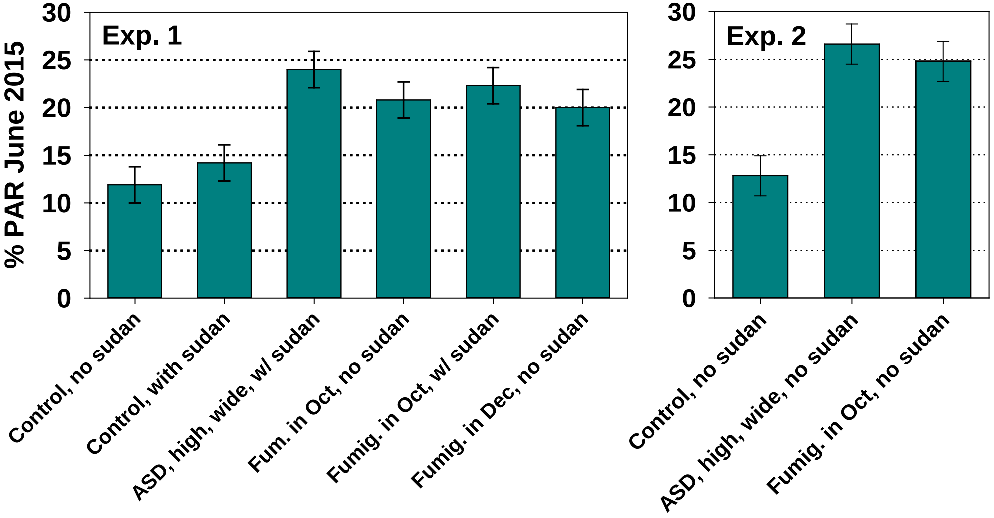


Non-fumigant method: Anaerobic soil disinfestation (ASD)

Response 1st growing season

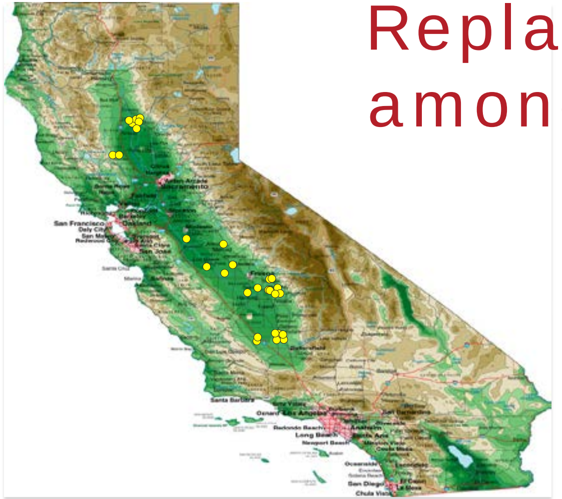


Response 2nd growing season



So, ASD "works" for RD, but questions now are econ. feasibility, general applicability…

Replant disease causes and prediction among fields



2015 soil number and code[a]	Nominal soil series	Selected properties							
		pH	CEC (meq/100g)	EC (dS/m)	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	SAR	exch. K (ppm)
1.Durham-Mea.Tri.CK.St	Edjobe silty clay	7.81	27.2	0.77	3.56	3.19	0.77	<1	179
2.Durham-Mtz.Tri.CK.St	Conejo clay loam	7.91	23.7	0.82	3.81	2.68	0.74	<1	276
3.Durham-Mtz.S.St	Conejo/Busacca clay loam	7.95	23.6	0.96	4.66	3.02	1.06	<1	119
4.Durham-Gilb.N.St	Almendra loam	7.08	31.8	0.70	2.90	2.70	0.85	<1	153
5.Durham-Gil.S.St	Conejo clay loam	6.95	37.1	0.55	2.24	1.99	0.73	<1	134
6.Arbuckle-Nic.Tri.CK.St	Arbuckle sandy loam	5.75	9.8	0.81	2.89	1.81	2.71	2	76
7.Arbuckle-Hen.St	Arbuckle-Hillgate complex	5.61	11.0	1.44	5.45	4.65	3.61	2	93
8.Delhi-Lit.Tri.CK.Cl	Delhi sand	6.34	3.2	1.07	5.50	2.38	1.65	<1	32
9.Delhi-Lit.Tri.C35.Cl	Delhi sand	6.80	2.8	0.50	2.63	1.00	0.83	<1	24
10.Firebaugh-WO.Tri.CK.St	Dinuba/El Peco fine sandy loam	7.85	6.0	2.98	14.39	2.39	16.00	6	254
11.Parlier-KAC.Vin.S.St	Hanford fine sandy loam	7.34	4.1	0.59	2.87	1.41	1.31	<1	52
12.Parlier-KAC.Vin.N.St	Hesperia fine sandy loam	7.57	6.5	0.60	2.74	1.21	1.75	1	63
13.Parlier-KAC2014.Tri.CK.Cl	Hanford fine sandy loam	7.55	6.0	1.81	7.54	3.73	5.80	2	50
14.Parlier-KAC2014.Tri.C35.Cl	Hanford fine sandy loam	7.12	5.8	1.69	7.72	3.93	4.15	2	51
15.Parlier-KAC2014.Tri.ASD.Cl	Hanford fine sandy loam	6.43	6.5	1.26	6.47	3.46	1.33	<1	64
16.Reedley-Klas.N.St	Hanford course sandy loam	6.80	6.7	1.04	5.48	2.76	1.56	<1	77
17.Reedley-Klas.S.St	Greenfield sandy loam	7.28	8.0	2.94	21.32	10.17	3.84	<1	65
18.Sanger-MG.Rep.St	Hanford sandy loam	6.79	7.1	1.62	6.66	7.13	2.08	<1	58
19.Sanger-LTB.Hc.Cl	Hanford sandy loam	6.18	4.5	1.02	4.70	3.12	1.55	<1	51
20.Sanger-LTB.Rc.Cl	Ramona loam	6.68	9.3	0.78	2.48	3.09	1.58	<1	92
21.Traver-Famt.St	Calgro complex	7.60	7.5	1.29	5.94	1.92	4.47	2	79
22.Shafter-3901.K&B.St	Wasco sandy loam	6.07	4.3	1.78	8.72	1.53	7.19	3	45
23.Shafter-WO.3010.S.St	Wasco sandy loam	7.57	6.3	1.99	7.16	1.08	12.24	6	117
24.Shafter-WO.3010.N.Stb	Driver coarse sandy loam	--	--	--	--	--	--	--	--
25.Belridge-WO.3540.196.St	Milham sandy loam	7.68	12.0	3.30	19.34	5.98	11.38	3	99
26.Belridge-WO.3580.211.St	Panoche clay loam	7.79	18.1	3.02	16.13	4.34	12.46	4	132

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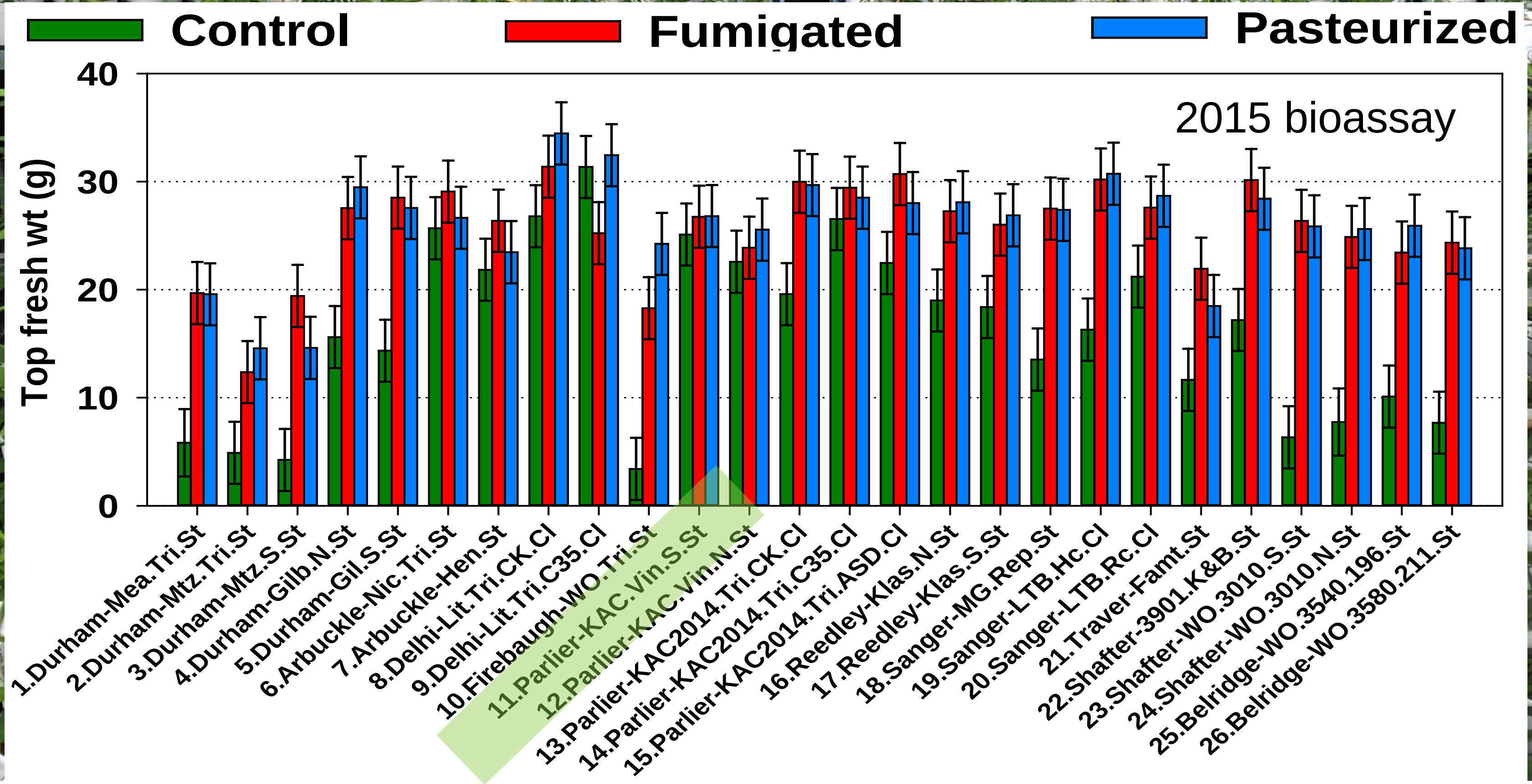
Varied incidence and severity of RD among soils



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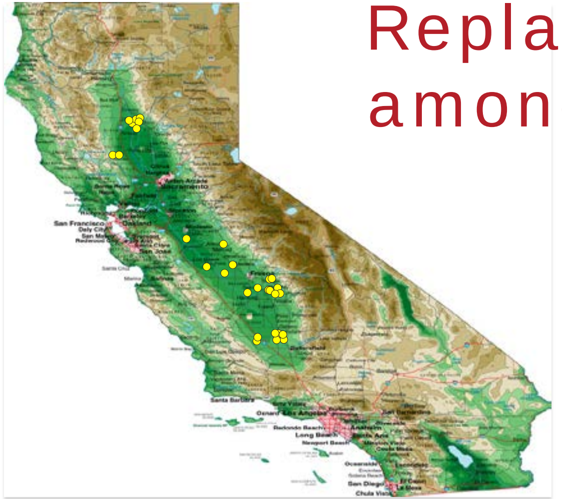
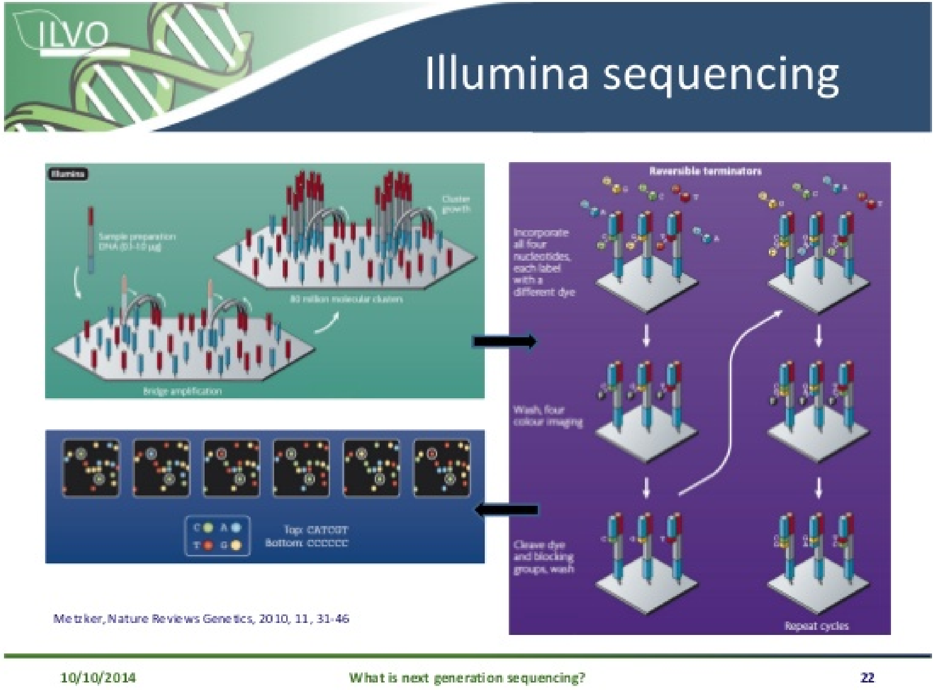
Replant disease causes and prediction among fields

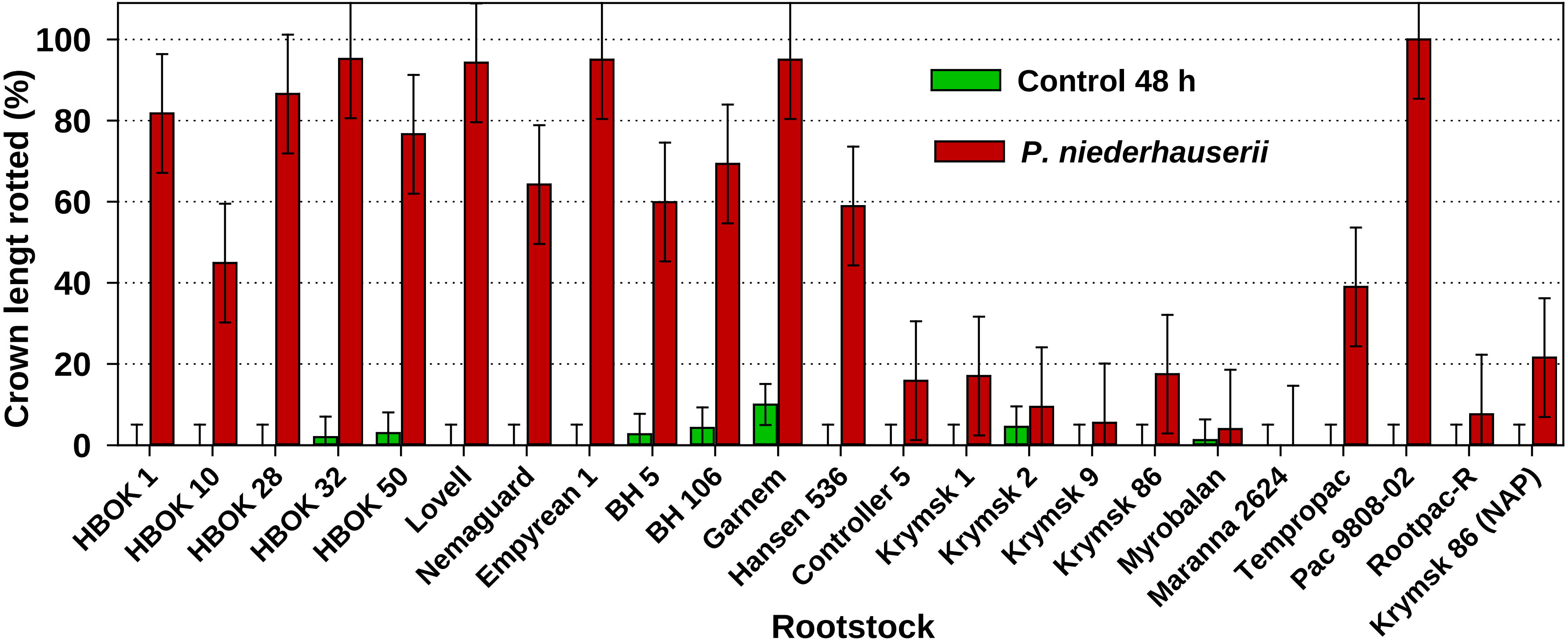


Roots, soil



Illumina amplicon and metagenomic (shotgun) sequencing underway

Rootstock resistance….visit poster?



gtbrowne@ucdavis.edu

Thank You!

Acknowledgements:

- **Almond Board of California**
- **Calif. Dept. Pesticide Regulation**
- **TriCal, Inc.**
- **Duarte Nursery, Inc.; Burchell Nursery, Inc.**

Roger Duncan,
UCCE – Stanislaus County

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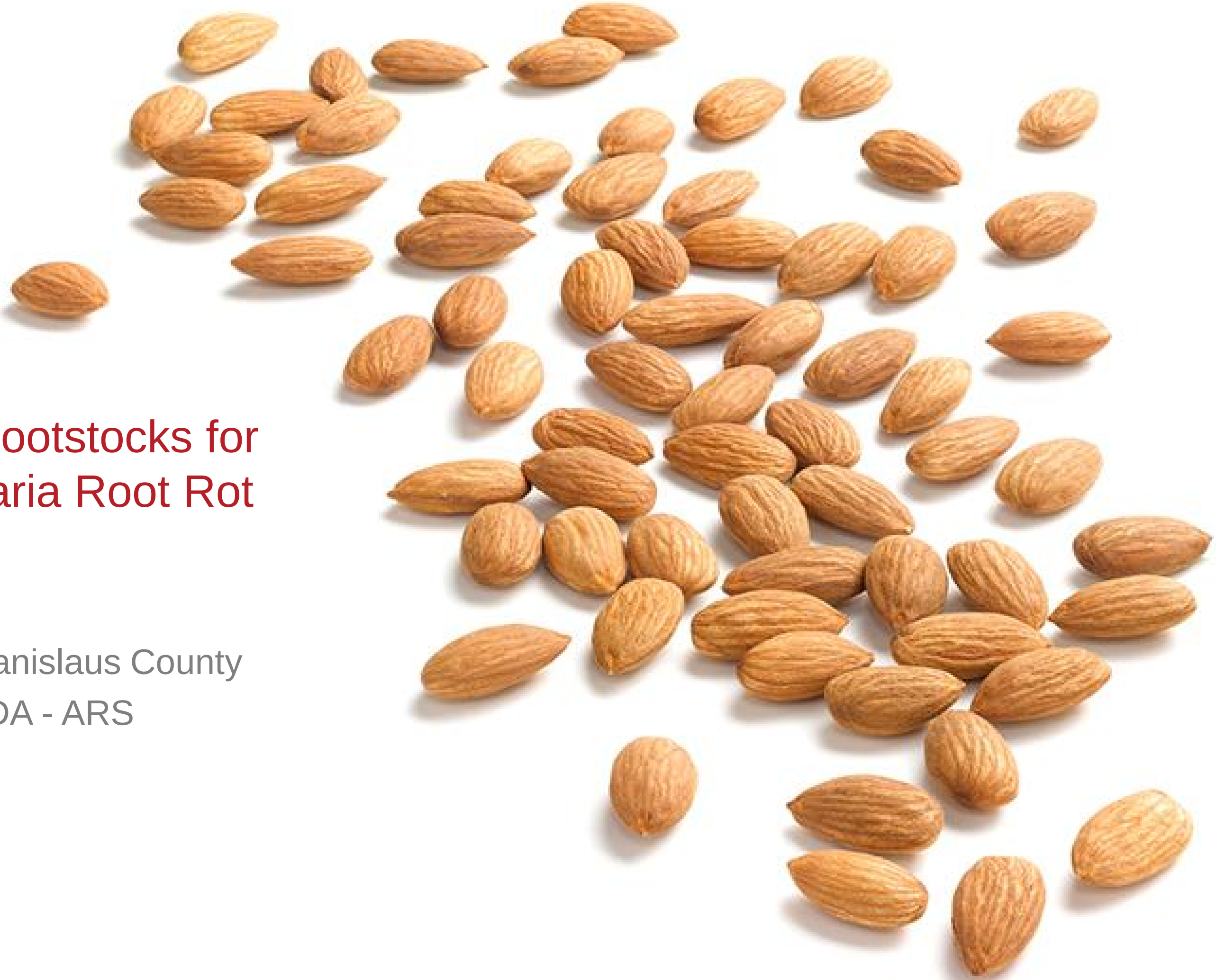

Screening Almond Rootstocks for Resistance to Armillaria Root Rot (Oak Root Fungus)

Roger Duncan, UCCE, Stanislaus County
Kendra Baumgartner, USDA - ARS

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Armillaria root rot (Oak Root Fungus) is a devastating disease that persists in the soil for many years and for which there is no cure

Recent Laboratory Rootstock Screening Effort by Baumgartner

Average Mortality of Rootstocks Inoculated with *Armillaria mellea*	
Krymsk 86	27.3 a
Krymsk 1	35.8 ab
Marianna 26-24	63.1 bc
Lovell	71.8 cd
Empyrean 1	77.8 cd
Nemaguard	84.5 d
Brights 5	87.2 d
Hansen 536	89.1 d

Next step: confirm laboratory results in potted tree experiment

Rootstocks tested:

1. Nemaguard
2. Marianna 26-24
3. Marianna 40
4. Krymsk 86
5. Citation
6. Rootpac R
7. Viking
8. Atlas
9. Empyrean 1
10. Hansen
11. Sam-1

Twenty – five replications of eleven rootstocks. October 2015.

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Each tree inoculated with peach wood colonized by Armillaria

- Monitor root infection and tree mortality over one year

Bob Johnson,
University of California, Davis

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Wood Decay Fungi

Bob Johnson

Almond Board of California

Objectives

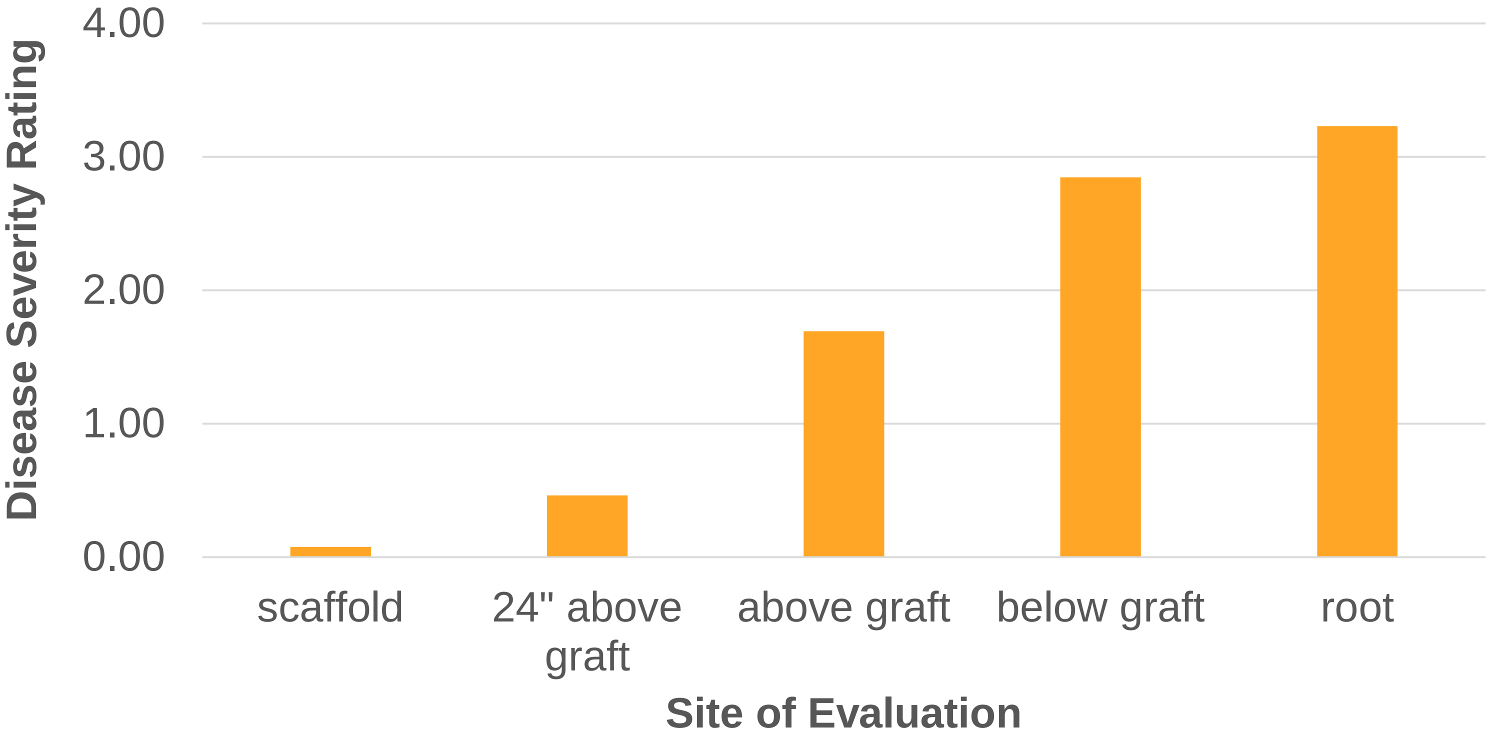
- Identify the main fungi associated with heart-rot diseases of almond in California

- Determine the infection process in orchards.

- Employ molecular techniques for early detection of decay fungi on standing trees.

- Removed Orchard
- Every 10th tree, Every 5th row
- Disease rating 1-4
- Collected samples

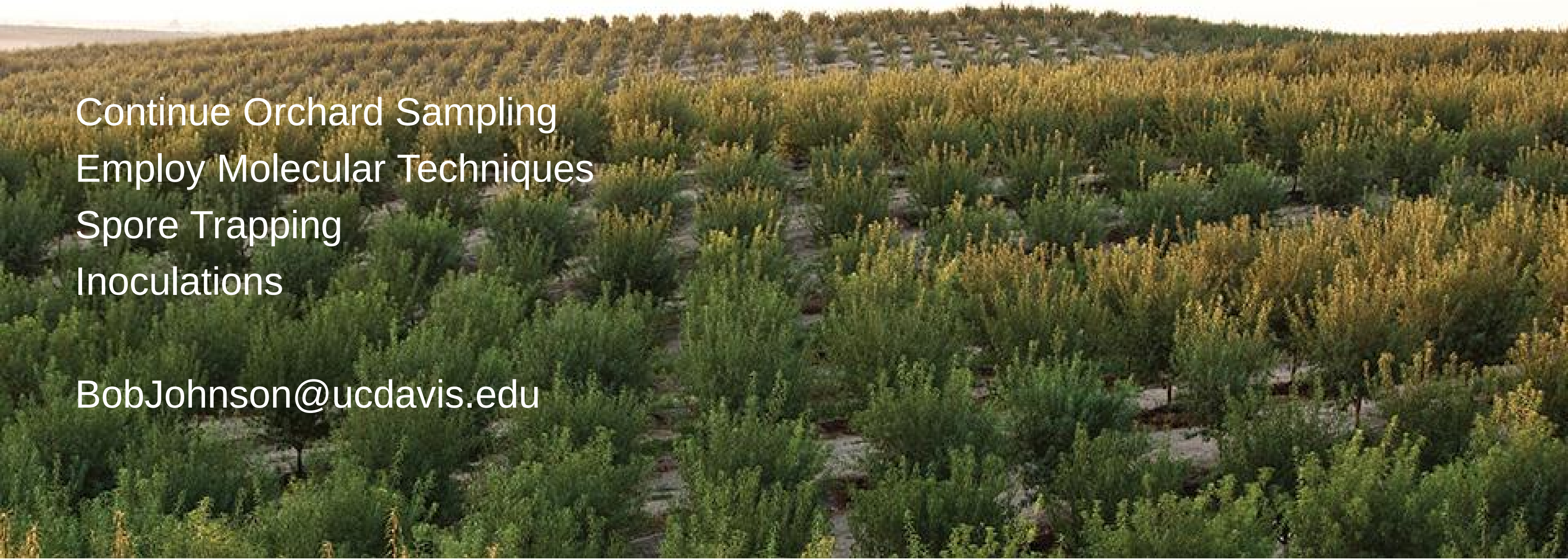
Severity and Incidence of Wood Decay



N=23

- *Punctularia sp.*
- *Trametes versicolor*
- *Psathyrella sp.*
- *'Hyphodontia sp.'*

Next Steps



Continue Orchard Sampling

Employ Molecular Techniques

Spore Trapping

Inoculations

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Dave Rizzo, UC Davis, Davis, CA

David Doll, UCCE Farm Advisor, Merced County

Franz Niederholzer, UCCE Farm Advisor, Yuba/Sutter/Colusa Counties

Florent P Trouillas, UCCE Plant Pathology Specialist, Kearney Ag Center

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Luke Milliron, UCCE Intern, Yuba/Sutter/Colusa Counties

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Insect and Mite Research

Frank Zalom
Department of Entomology and Nematology
University of California, Davis

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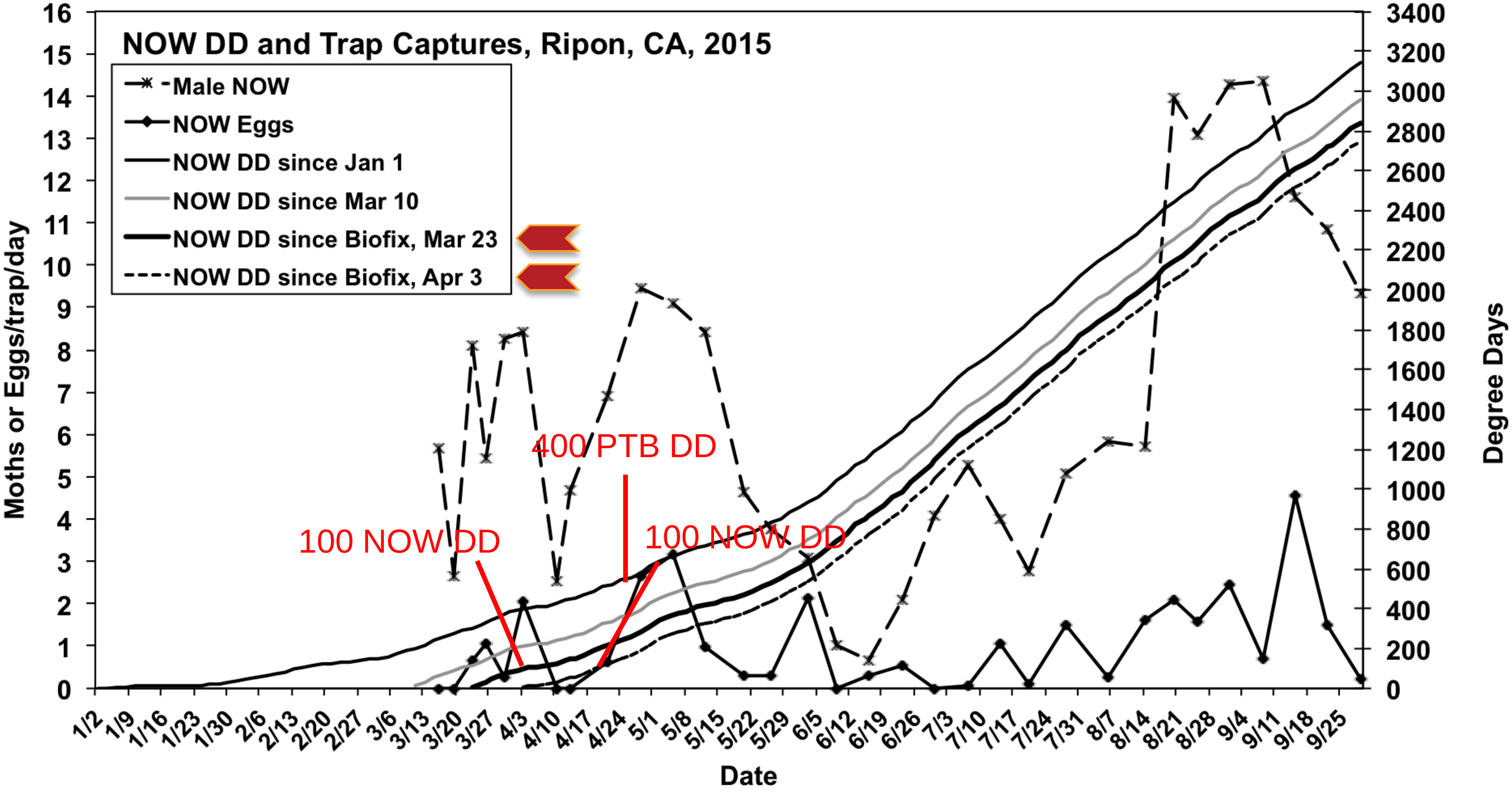
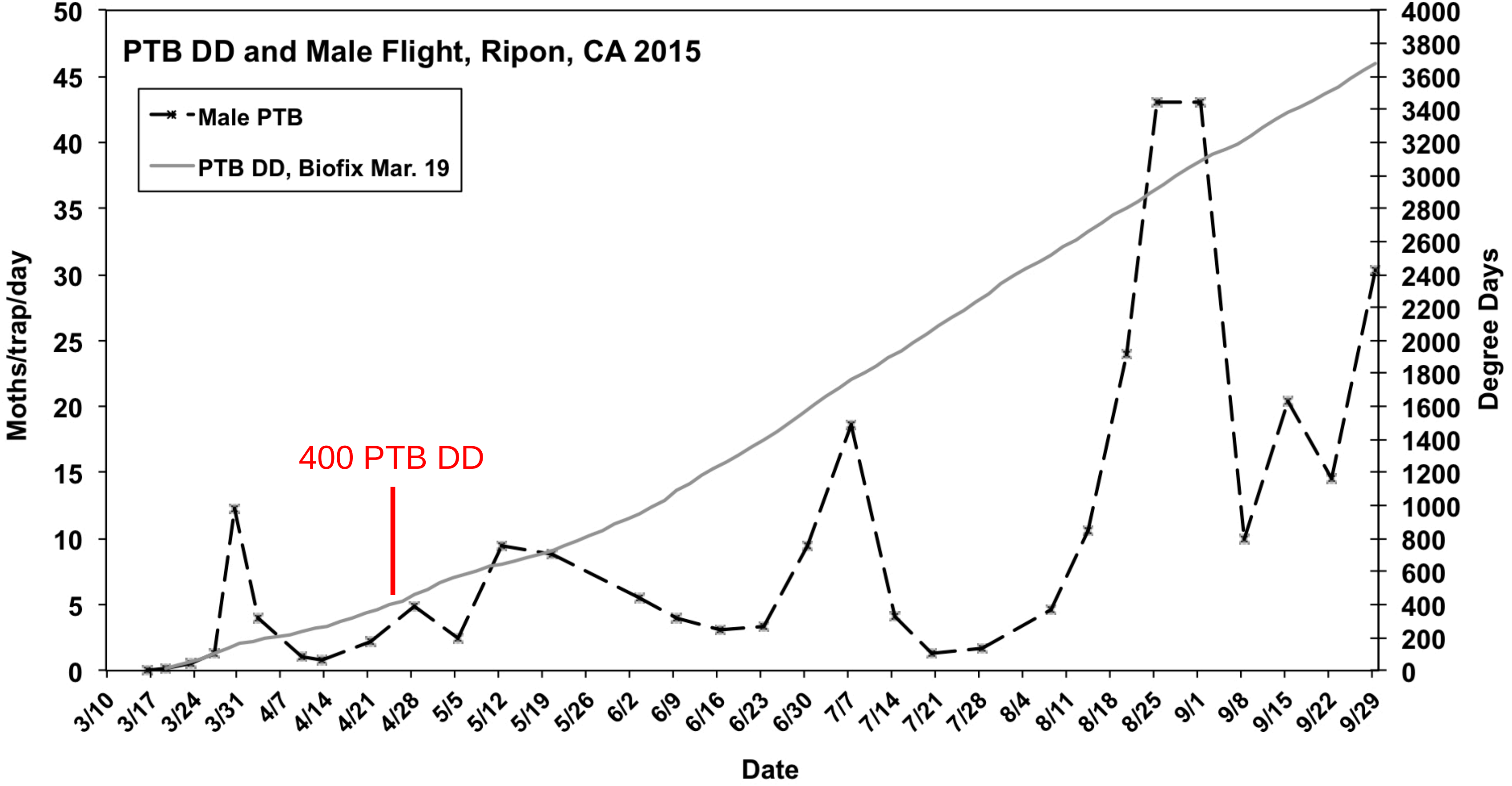
2014-15 NOW Studies

- Spring treatment timing ★
- Residual activity
- Effects of low temperatures on activity ★
- Infestation of pre-infested nuts


NOW DD and Trap Captures, Ripon, CA, 2015
Male NOW
NOW Eggs
NOW DD since Jan 1
NOW DD since Mar 10
NOW DD since Biofix, Mar 23
NOW DD since Biofix, Apr 3
400 PTB DD
100 NOW DD
100 NOW DD
Moths or Eggs/trap/day
Degree Days
Date



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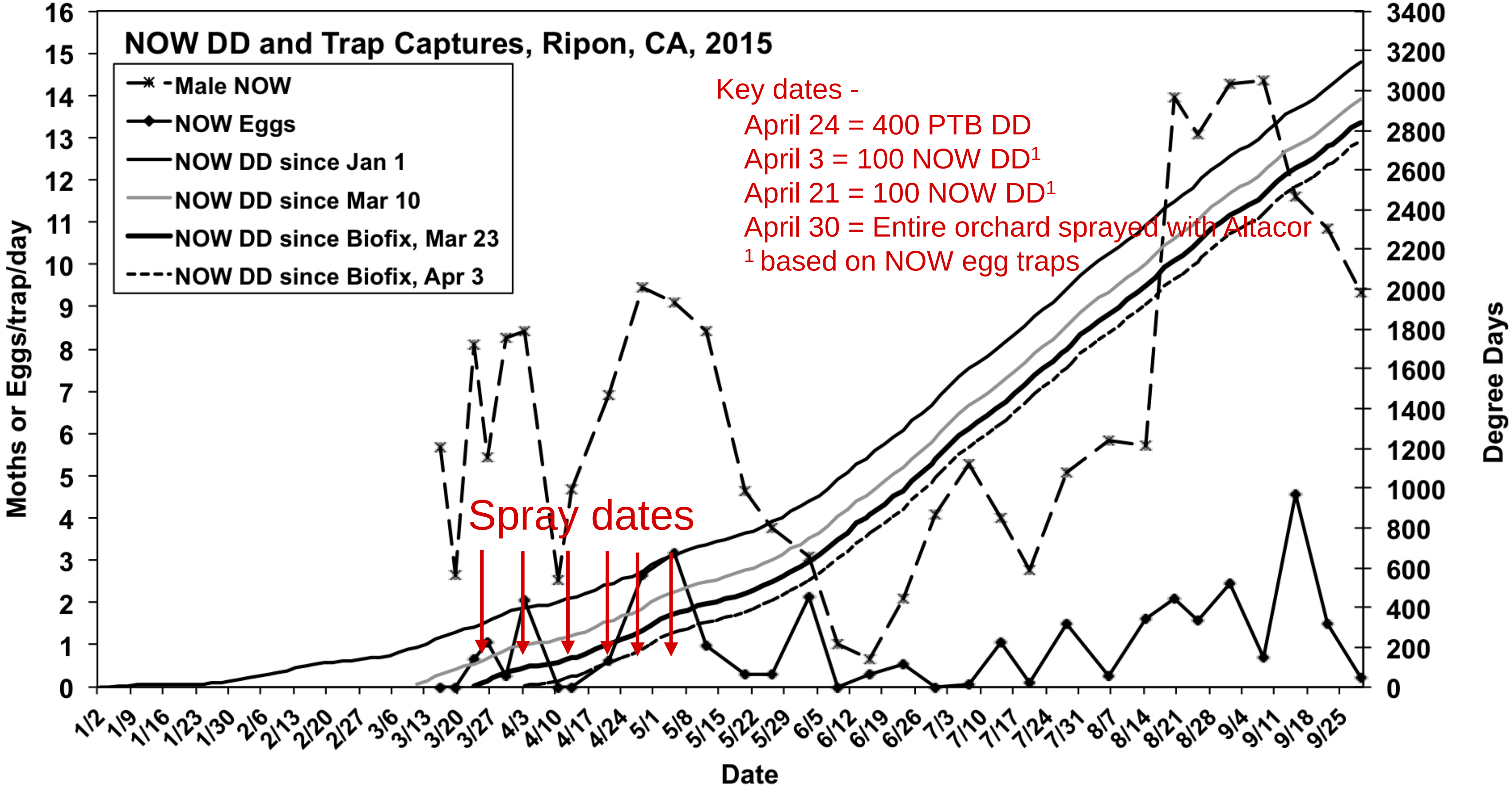

NOW DD and Trap Captures, Ripon, CA, 2015
Male NOW
NOW Eggs
NOW DD since Jan 1
NOW DD since Mar 10
NOW DD since Biofix, Mar 23
NOW DD since Biofix, Apr 3
Key dates -
April 24 = 400 PTB DD
April 3 = 100 NOW DD1
April 21 = 100 NOW DD1
April 30 = Entire orchard sprayed with Altacor
1 based on NOW egg traps
Spray dates
Moths or Eggs/trap/day
Degree Days
Date
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1/2
1/9
1/16
1/23
1/30
2/6
2/13
2/20
2/27
3/6
3/13
3/20
3/27
4/3
4/10
4/17
4/24
5/1
5/8
5/15
5/22
5/29
6/5
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
9/25

Spring treatment timing

Infestation and damage of almond mummies treated with different registered insecticides at weekly intervals starting at the initiation of oviposition of the overwintering flight of navel orangeworm at Ripon, 2015.

Mean % infestation includes nuts with larvae and/or pupae
Mean % damage includes nuts with larvae and/or pupae and nuts with some frass or webbing but no larvae present

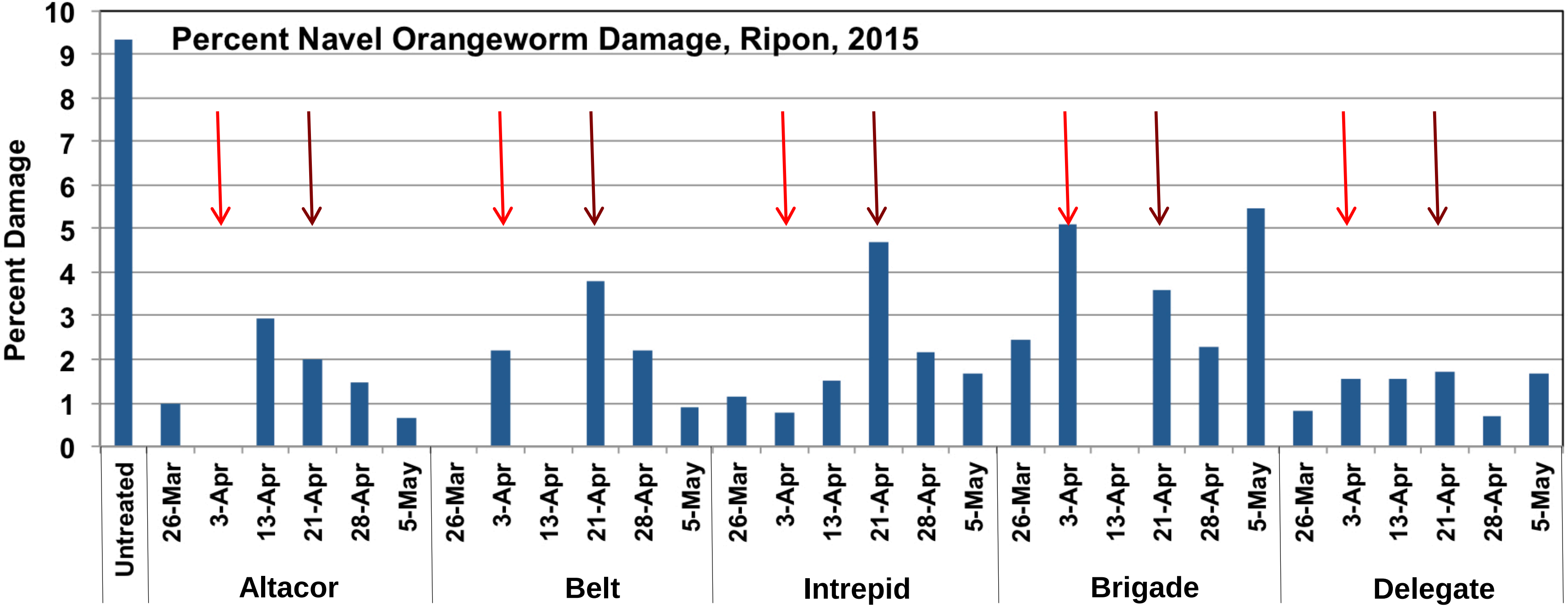
Key dates -

April 24 = 400 PTB DD
April 3 = 100 NOW DD[1]
April 21 = 100 NOW DD[1]
April 30 = Entire orchard sprayed with Altacor
[1] based on NOW egg traps

Treatment	Spray date	Rate/ac	Mean + SD[1,2] % infestation				Mean + SD[1,3] % damage			
Control	n/a	n/a	2.01	±	3.39	A	9.35	±	10.72	A
Altacor	3/26	4 oz.	0.00	±	0.00	B	0.96	±	2.72	BCD
Altacor	4/3	4 oz.	0.00	±	0.00	B	0.00	±	0.00	D
Altacor	4/13	4 oz.	1.48	±	2.74	AB	2.95	±	5.48	BCD
Altacor	4/21	4 oz.	0.63	±	1.77	AB	2.02	±	2.80	BCD
Altacor	4/28	4 oz.	0.00	±	0.00	B	1.48	±	2.74	BCD
Altacor	5/5	4 oz.	0.00	±	0.00	B	0.66	±	1.86	CD
Belt	3/26	4 oz.	0.00	±	0.00	B	0.00	±	0.00	D
Belt	4/3	4 oz.	0.00	±	0.00	B	2.22	±	4.54	BCD
Belt	4/13	4 oz.	0.00	±	0.00	B	0.00	±	0.00	D
Belt	4/21	4 oz.	0.83	±	2.36	AB	3.81	±	3.26	BCD
Belt	4/28	4 oz.	0.00	±	0.00	B	2.22	±	3.08	BCD
Belt	5/5	4 oz.	0.00	±	0.00	B	0.89	±	2.53	BCD
Intrepid	3/26	16 oz.	0.00	±	0.00	B	1.14	±	3.21	BCD
Intrepid	4/3	16 oz.	0.00	±	0.00	B	0.78	±	2.21	BCD
Intrepid	4/13	16 oz.	0.00	±	0.00	B	1.52	±	2.81	BCD
Intrepid	4/21	16 oz.	0.00	±	0.00	B	4.71	±	5.27	BCD
Intrepid	4/28	16 oz.	0.00	±	0.00	B	2.17	±	4.34	BCD
Intrepid	5/5	16 oz.	0.83	±	2.36	AB	1.67	±	4.71	BCD
Brigade	3/26	16 oz.	1.67	±	3.11	AB	2.46	±	3.40	BCD
Brigade	4/3	16 oz.	1.25	±	3.54	AB	5.10	±	5.25	BC
Brigade	4/13	16 oz.	0.00	±	0.00	B	0.00	±	0.00	D
Brigade	4/21	16 oz.	1.32	±	2.44	AB	3.59	±	5.04	BCD
Brigade	4/28	16 oz.	1.59	±	2.97	AB	2.28	±	3.19	BCD
Brigade	5/5	16 oz.	2.30	±	4.48	A	5.46	±	5.27	B
Delegate	3/26	17 oz.	0.00	±	0.00	B	0.83	±	2.36	BCD
Delegate	4/3	17 oz.	0.71	±	1.89	AB	1.55	±	2.67	BCD
Delegate	4/13	17 oz.	0.00	±	0.00	B	1.56	±	2.89	BCD
Delegate	4/21	17 oz.	0.00	±	0.00	B	1.73	±	3.20	BCD
Delegate	4/28	17 oz.	0.00	±	0.00	B	0.69	±	1.96	CD
Delegate	5/5	17 oz.	0.00	±	0.00	B	1.67	±	4.71	BCD

[1] Means followed by the same letter do not differ significantly at *P*=0.05 by Student's t-test
[2] F=1.4936, df=30,265 p<0.0541
[3] F=2.6559, df=30,265 p<0.0001

Percent damage of almond mummies treated with different registered insecticides at weekly intervals starting at the initiation of oviposition of the overwintering flight of navel orangeworm at Ripon, 2015.



ANOVA statistics, F=2.6559, df=30,265 P<0.0001

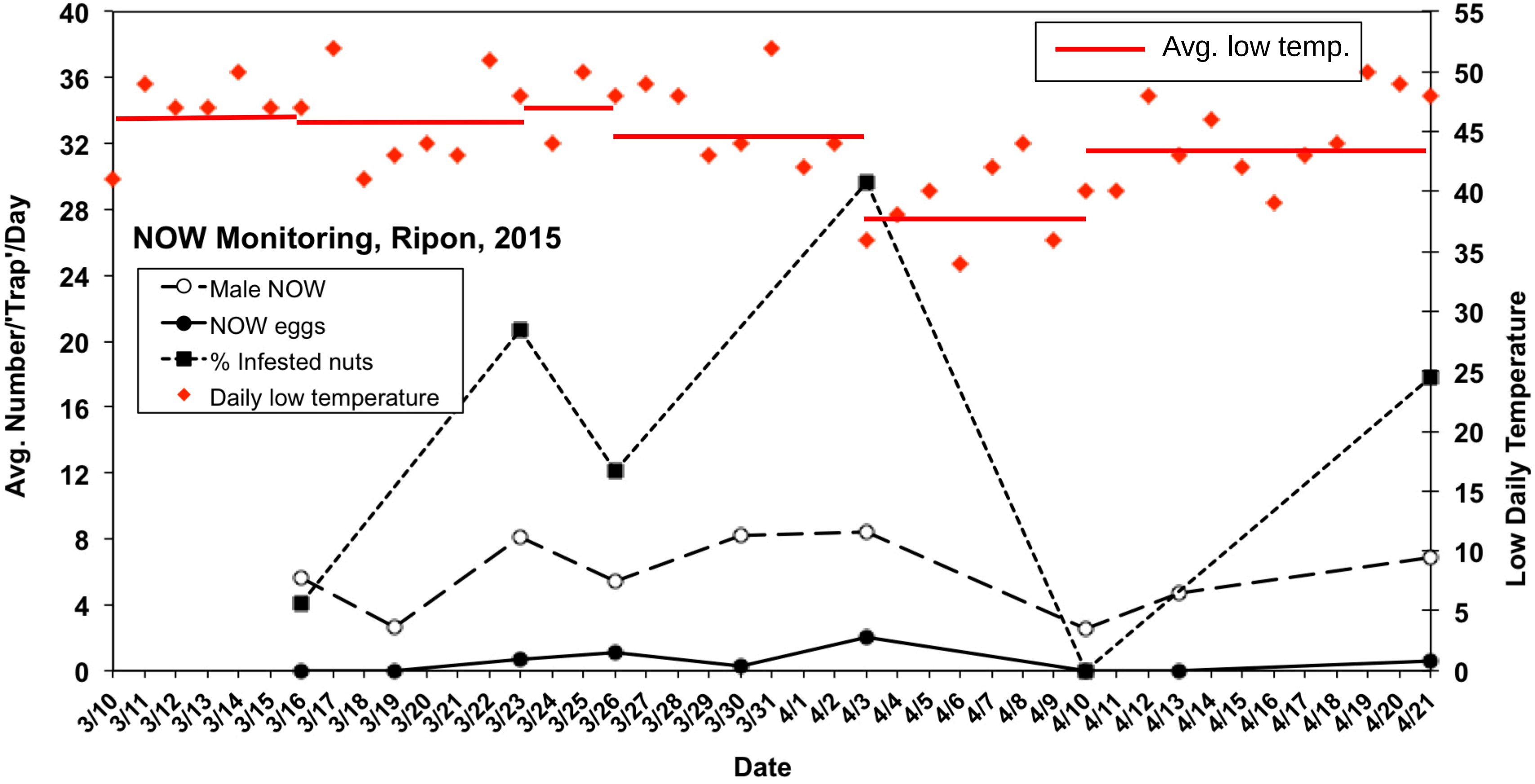
Effects of low temperatures on activity

Almond strand method

Effects of low temperatures on activity

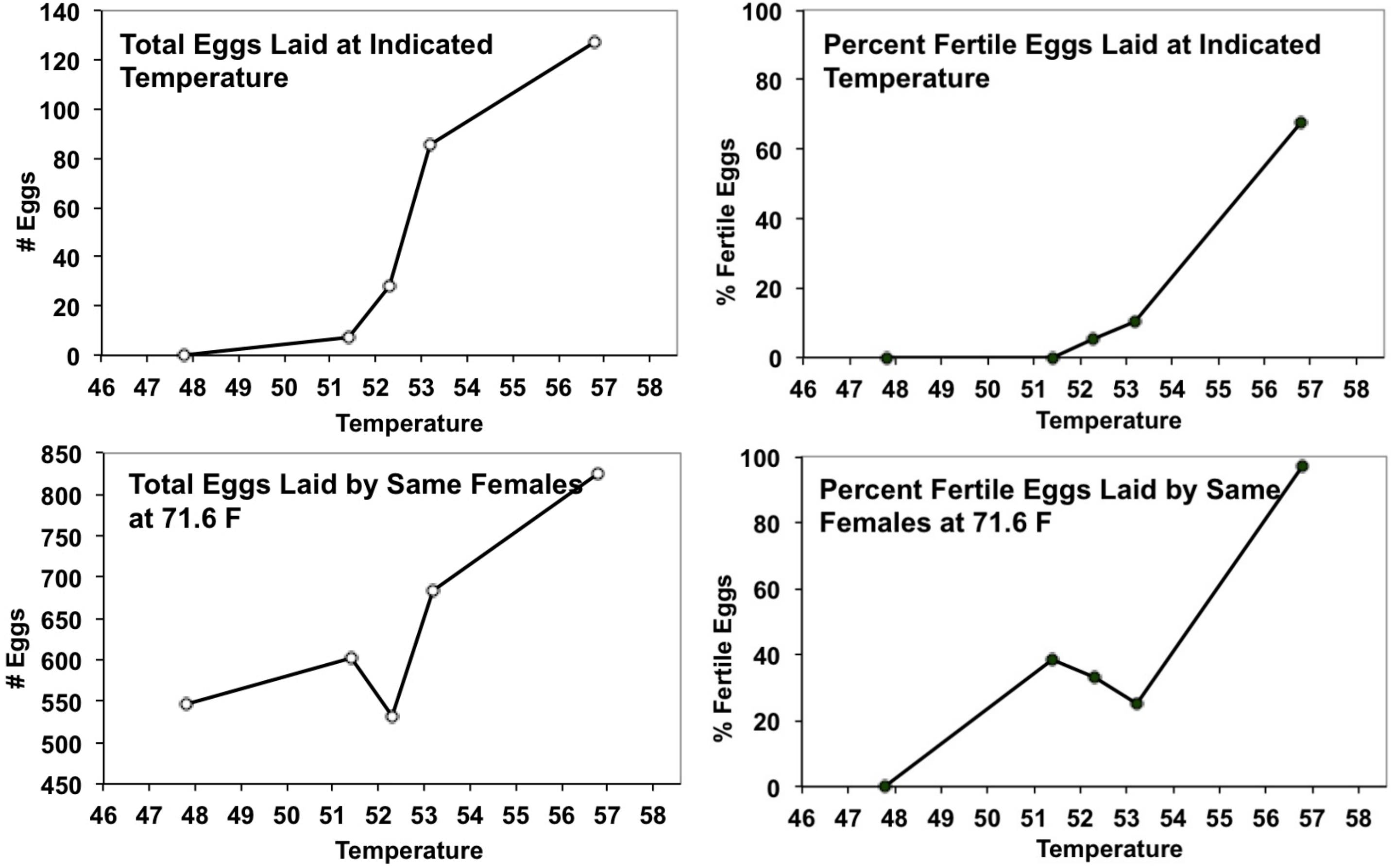
Almond strand hung during specific periods in spring, then removed

	March 10-15	March 16-22	March 23-25	March 26 -April 1	April 3-9	April 10-20
Avg. larvae/strand/day	1.5	7.4	8.0	9.1	0.0	3.5
Avg. % infested nuts/strand/day	4.1	20.7	12.1	29.6	0.0	17.8
Avg. low temperature	46.8	45.9	47.3	46.3	38.6	44.0
Avg. high temperature	78.2	75.6	71.7	78.0	67.6	76.7
Accumulated DD	56.3	56.1	19.5	74.1	26.2	91.1
Avg. DD	9.4	8.0	6.5	9.3	3.7	8.3
# of strands	10	10	9	10	9	10

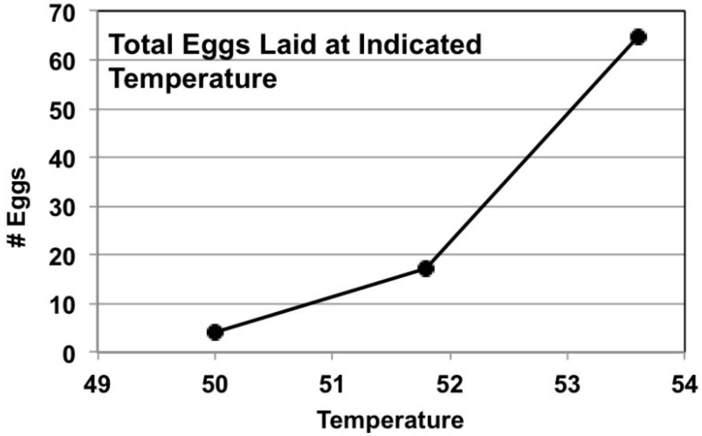


NOW Monitoring, Ripon, 2015
Avg. low temp.
Male NOW
NOW eggs
% Infested nuts
Daily low temperature
Avg. Number/'Trap'/Day
Low Daily Temperature
Date
40
36
32
28
24
20
16
12
8
4
0
55
50
45
40
35
30
25
20
15
10
5
0
3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3 4/4 4/5 4/6 4/7 4/8 4/9 4/10 4/11 4/12 4/13 4/14 4/15 4/16 4/17 4/18 4/19 4/20 4/21

Lab virgin females, constant temperature

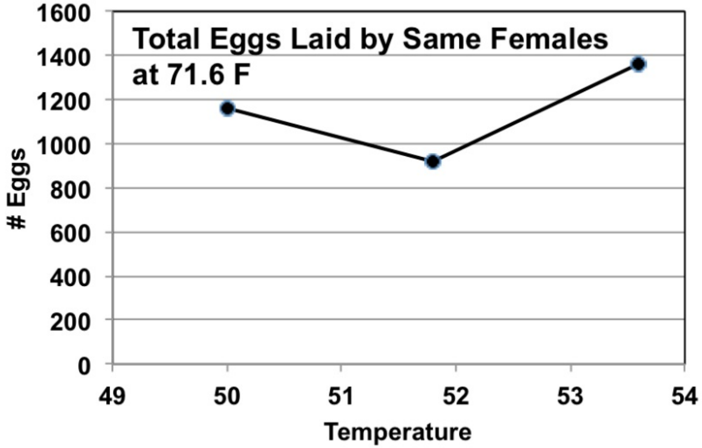


Wild virgin females, constant temperature



Females held at constant temperatures for 72 hours		
Temp (°F)	Total Eggs Mean ± SD[1,2]	% Fertility Mean ± SD
50.0	4.0 ± 5.2	0.0 ± 0.0
51.8	17.3 ± 14.4	0.0 ± 0.0
53.6	64.7 ± 16.9	0.0 ± 0.0

[2] F=17.5361, df=2, 8, P<0.0031



Females transferred to 71.6°C for 48 hours		
Pre-Temp (°F)	Total Eggs Mean ± SD[1,3]	% Fertility Mean ± SD[1,4]
50.0	1164.0 ± 191.3	3.9 ± 5.0
51.8	918.7 ± 418.6	4.4 ± 7.5
53.6	1360.7 ± 510.9	0.4 ± 0.7

[3] F=0.9333, df=2, 8, P<0.4437

[4] F=0.508, df=2, 8, P<0.625

Total eggs laid during the first 72 hours after placing 20 virgin females and males from F1 offspring of lab colony or wild collected NOW larvae in containers at 3 variable temperatures, and percent fertility of those eggs held at 71.6ºF.

Wild virgin females, variable temperature

Max./Min. Temp (ºF)	Total Eggs Mean ± SD[1]	% Fertility Mean ± SD[2]
60.8/41.0	171.3 ± 107.2	15.1 ± 10.2
64.4/44.6	173.0 ± 74.6	32.6 ± 14.5
68.0/48.2	347.3 ± 41.2	62.6 ± 12.5

[1] F=4.9098, df=2, 8, P<0.0546

[2] F=11.0423, df=2, 8, P<0.0098

Lab virgin females, variable temperature

Max./Min. Temp (ºF)	Total Eggs Mean ± SD[1]	% Fertility Mean ± SD[2]
60.8/41.0	489.0 ± 198.5	33.7 ± 9.5
64.4/44.6	535.0 ± 125.0	41.1 ± 20.8
68.0/48.2	764.3 ± 250.1	54.4 ± 7.4

[1] F=1.6653, df=2, 8, P<0.2659

[2] F=1.7190, df=2, 8, P<0.2569

Mark Demkovich, University of Illinois

Detoxification of insecticides by navel orangeworm (NOW)

Mark Demkovich,University of Illinois at Urbana-Champaign

Vikram Bagchi,University of Illinois at Urbana-Champaign

Joel Siegel,USDA-ARS, Parlier, CA

Spencer Walse, USDA-ARS, Parlier, CA

May Berenbaum, University of Illinois at Urbana-Champaign

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Research Objectives

1. Using our bifenthrin-resistant (R347) and susceptible (CPQ) navel orangeworm colonies, conduct neonate feeding assays to calculate median-lethal concentrations of pesticides (chlorantraniliprole, methoxyfenozide, flubendiamide) and phytochemicals (furanocoumarins, chlorogenic acid).

2. Apply synergists piperonyl butoxide (PBO), diethyl maleate (DEM), and S,S,S-tributyl phosphorotrithioate (DEF) with an LC_{50} dose of each insecticide to determine if cytochrome P450s, GSTs, and/or esterases, respectively, are involved in detoxification

3. Use the Parlier USDA-ARS spray tower to test effects of adjuvants on pesticide toxicity to eggs and sublethal effects on survivors from R347 and CPQ colonies.

4. With the newly available NOW genome, compare our susceptible CPQ strain with the R347 resistant strain by deep-sequencing transcriptomes, mapping the cDNA reads to the reference genome, and identifying differences in detoxification loci that distinguish the strains

Insecticides and Adjuvants Tested

Diamide Insecticides (IRAC Group 28)

- Chlorantraniliprole (Altacor®)
- Flubendiamide (Belt®)

Methylated Seed Oils (Penetrators)

- Dyne-Amic™
- FastStrike™

Wetter-Spreader

- Induce™

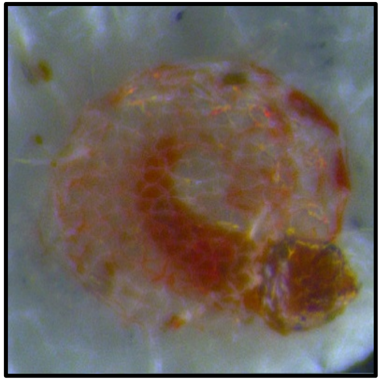
Spreader-Sticker

- Cohere™
- Latron B-1956™

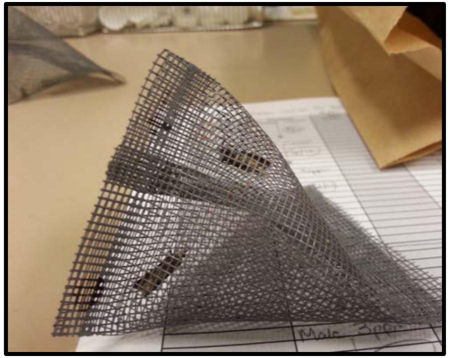
Methods

<u>Adjuvant Application Rates:</u>

- Dyne-Amic: 8 oz/100 gal
- FastStrike: 64 oz/100 gal
- Induce: 8 oz/100 gal
- Cohere: 8 oz/100 gal
- Latron B-1956: 3.5 oz/100 gal



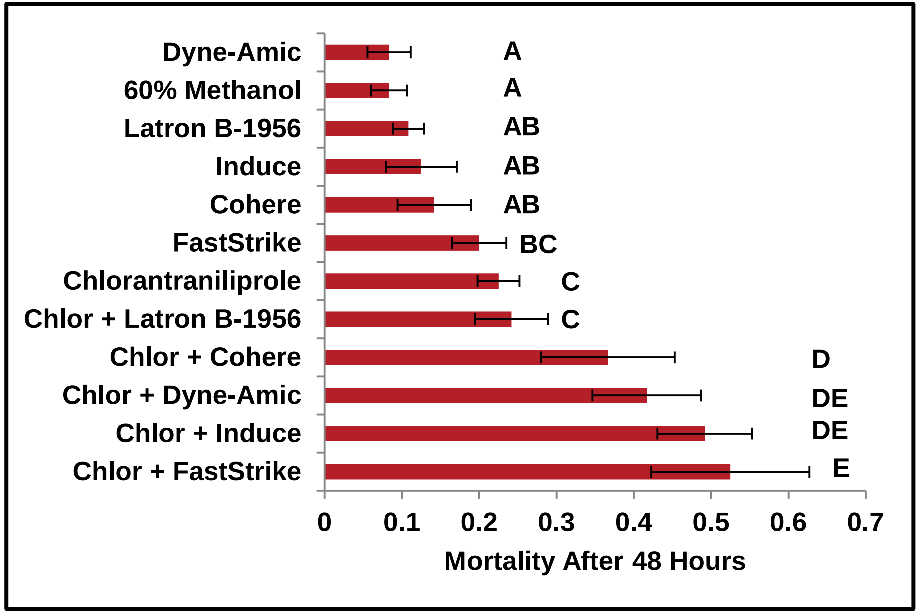
10 ml Sprays of Chlorantraniliprole and Flubendiamide at 125 ppm + Adjuvants in 60% Methanol



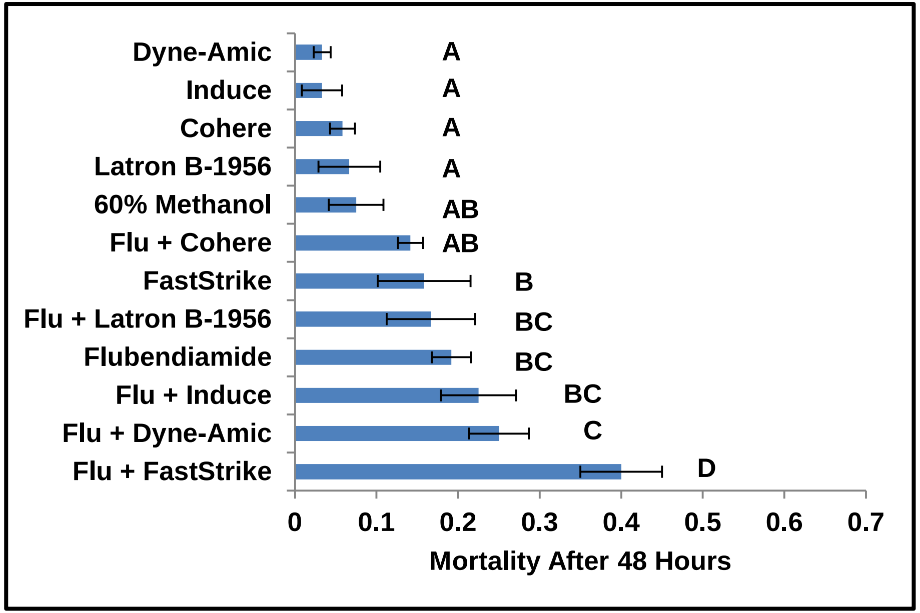
Susceptible (CPQ) strain of NOW

Results-Adult Sprays

Chlorantraniliprole



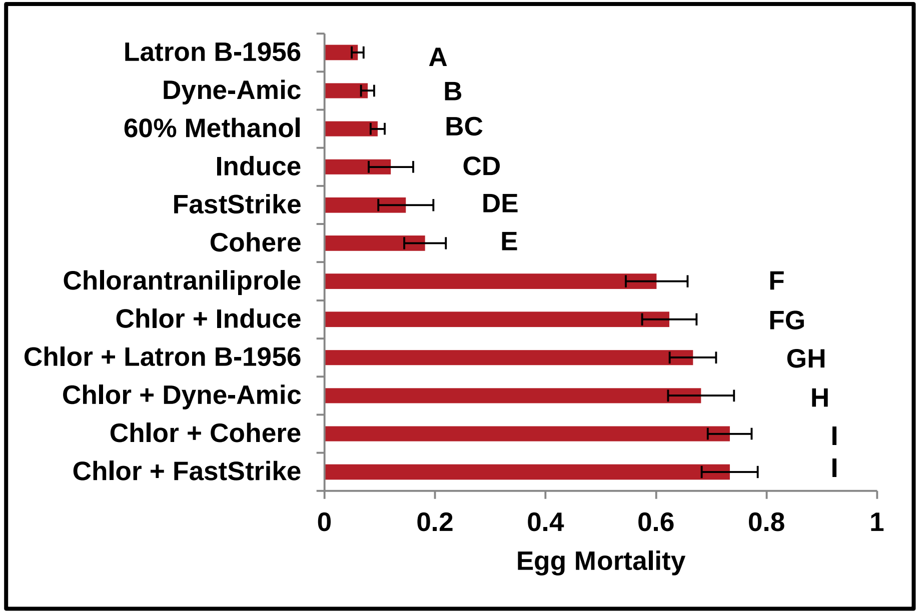
Flubendiamide



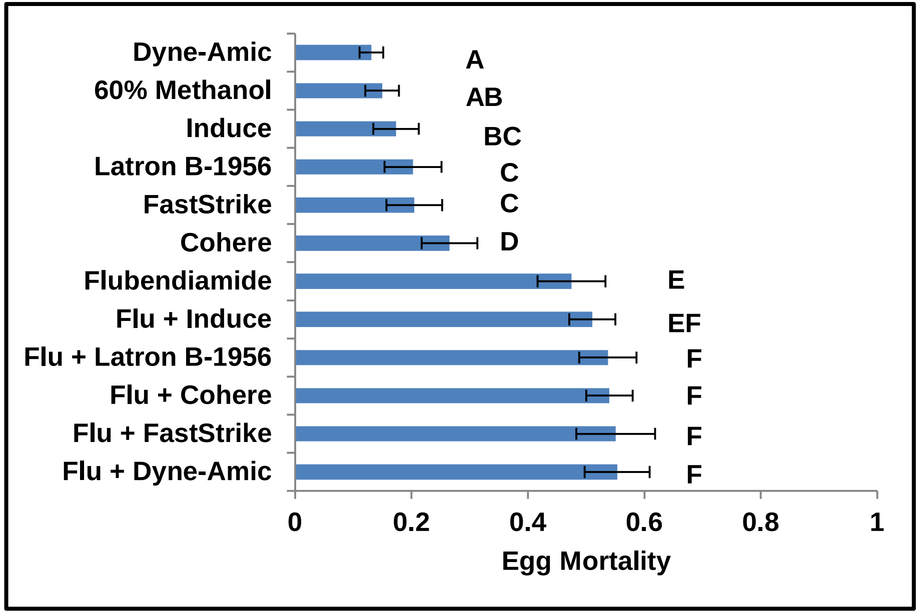
Controls and treatments: 40 adults, equal sex ratio, 3 replicates (n=120)
Mortality Assessed at 24, 48, and 72 hours

Results-Egg Sprays

Chlorantraniliprole



Flubendiamide



Controls and treatments: 250 eggs per spray, 3 replicates (n=750)
Larval Mortality and Egg mortality assessed after 2 weeks

Conclusions

- FastStrike was the only adjuvant that was more toxic than the 60% methanol carrier solution among the controls in adult/egg assays with chlorantraniliprole
- FastStrike increased mortality for both chlorantraniliprole and flubendiamide when applied to adults and eggs
- Egg mortality was enhanced by each class of adjuvant except for the wetter-spreader Induce for both chlorantraniliprole and flubendiamide
- Navel orangeworm may be more vulnerable to certain insecticide-adjuvant combinations at different stages in its life cycle
- If adjuvants have differential impact on the toxicity of current insecticides used to control navel orangeworm, then this may result in new chemical management strategies that incorporate effective insecticide-adjuvant combinations in field sprays.

Acknowledgments

Matt Rodriguez

Erik Rangel

Siegel Laboratory

Walse Laboratory

Almond Board of California

Daniel Bush,
University of Illinois

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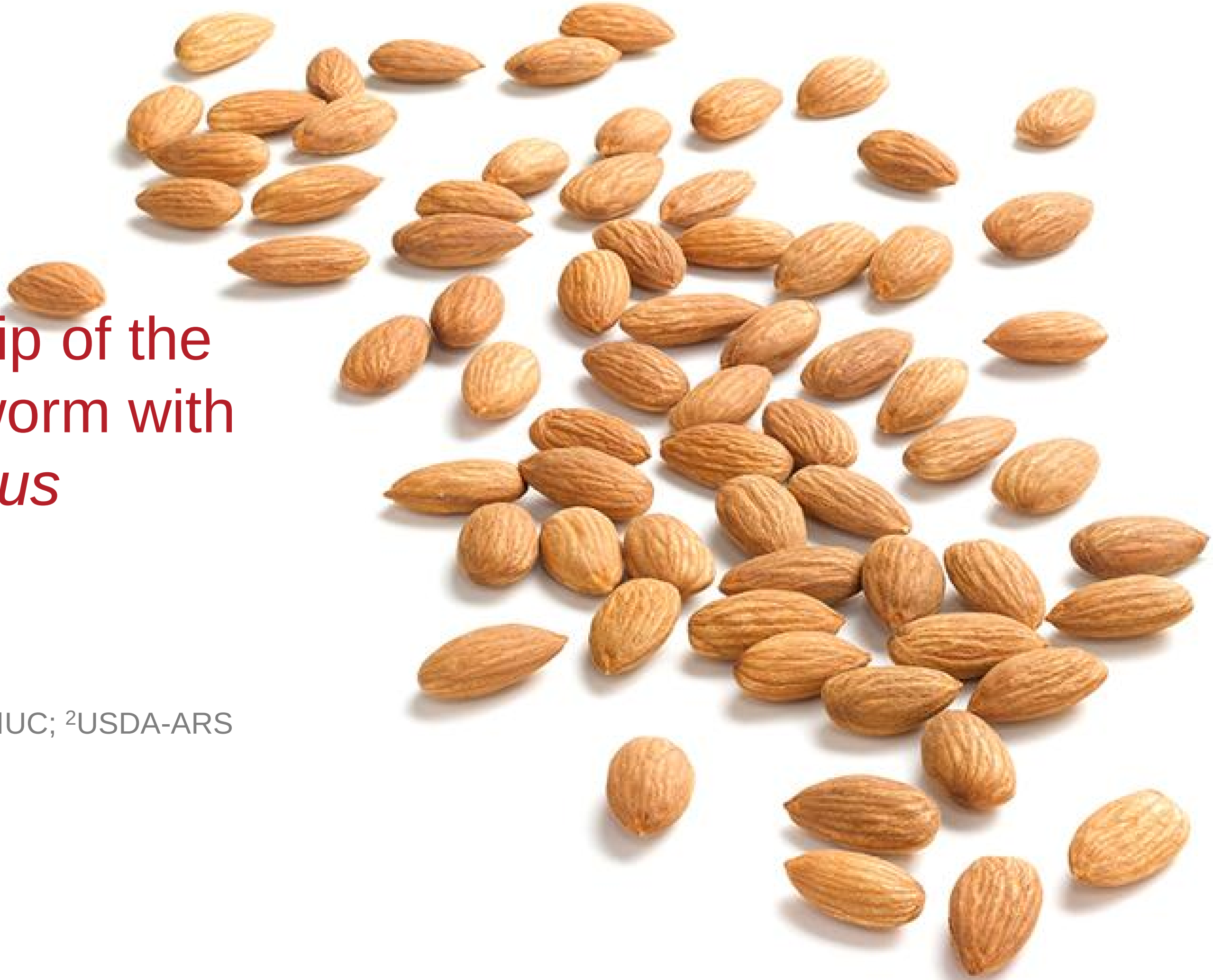

The Relationship of the Navel Orangeworm with *Aspergillus flavus*

Daniel S. Bush[1]

Joel P. Siegel[2]

May R. Berenbaum[1]

[1]Department of Entomology, UIUC; [2]USDA-ARS

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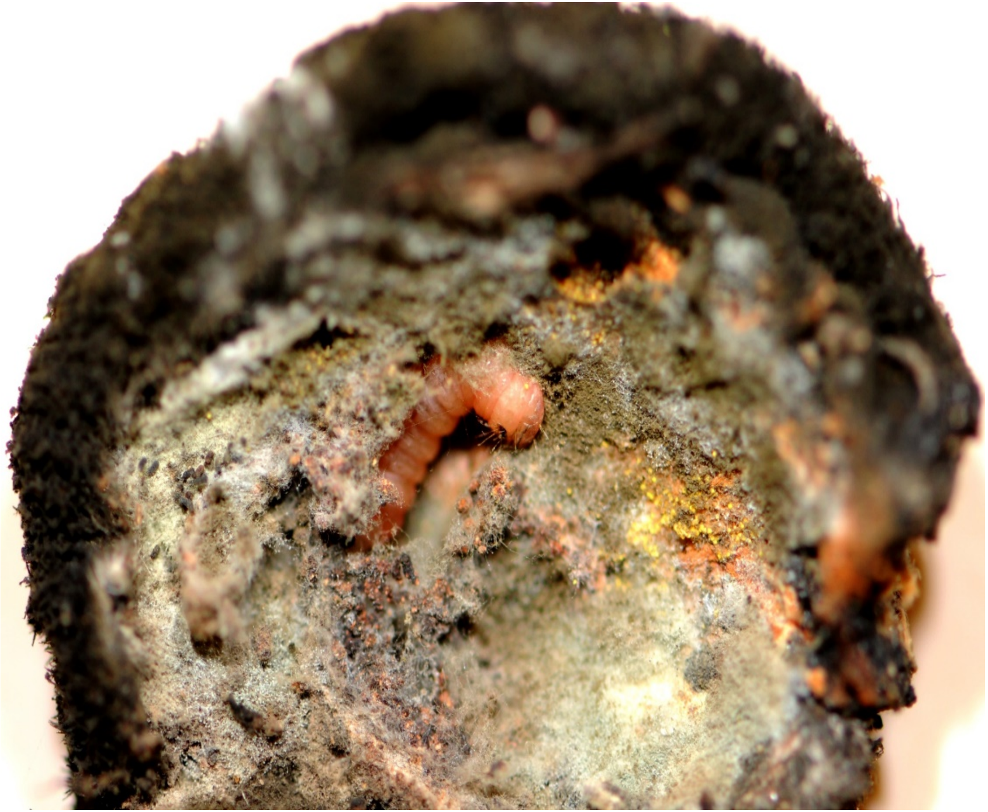
Introduction: A Facultative Mutualism

- The navel orangeworm (*Amyelois transitella*) is frequently associated with fungal pathogens.

- *Aspergillus flavus* is a common crop pathogen that produces ochratoxins and carcinogenic aflatoxins.

- Together they are perhaps the most economically damaging pest complex in California orchards (Zalom 2012).

- There is evidence (Palumbo et al. 2014, Ampt et al. 2015) of a mutualism between these two pests.



Objective 1: Larval Performance

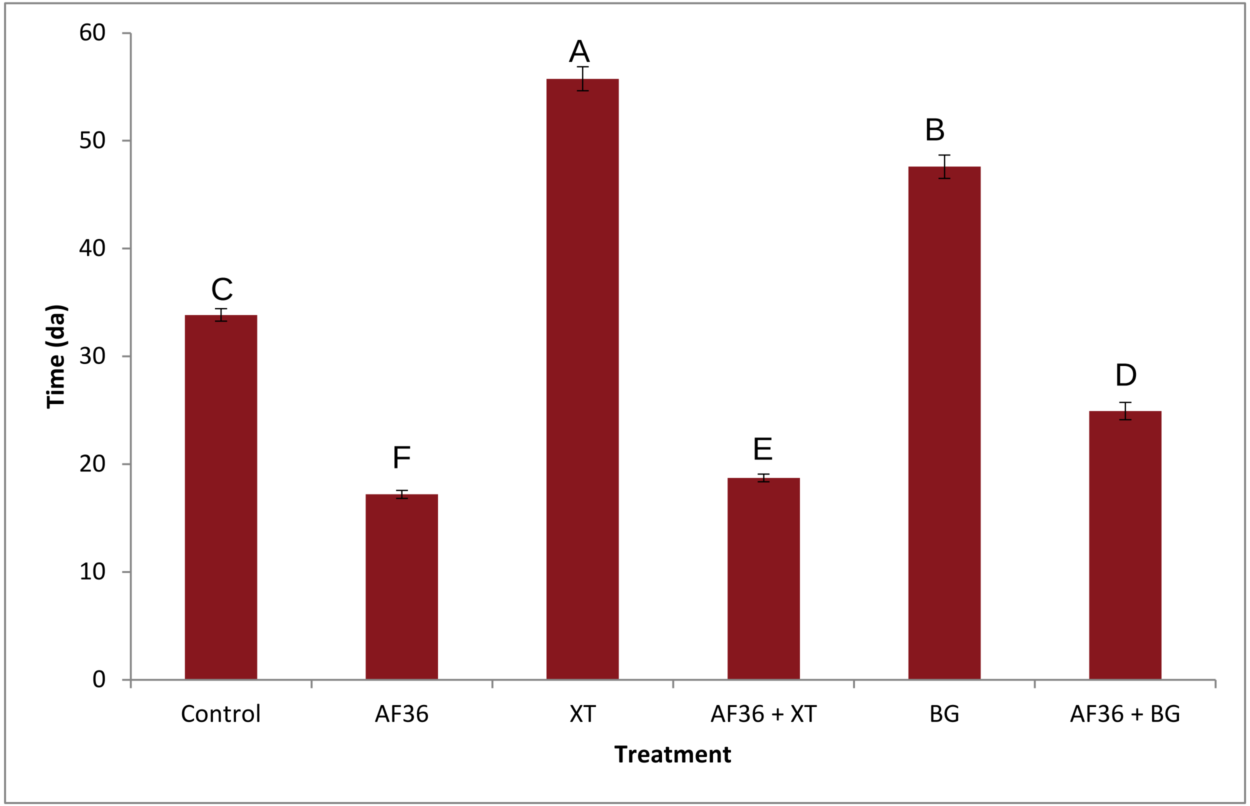
- **Do NOW larvae perform better (i.e. grow faster, larger) in the presence of *A. flavus*?**

- Caterpillars from a laboratory colony of *A. transitella* were raised under conditions of 28 ± 4^{o}C with a 16:8 (L:D) hour photoperiod.

- Third instar caterpillars were placed on almond potato dextrose agar (PDA) diet with and without *A. flavus* and with and without xanthotoxin or bergapten (furanocoumarins found in some hosts).

- Stage-specific life tables were created, and significant differences in time to pupation and pupal weight were determined via ANOVA.

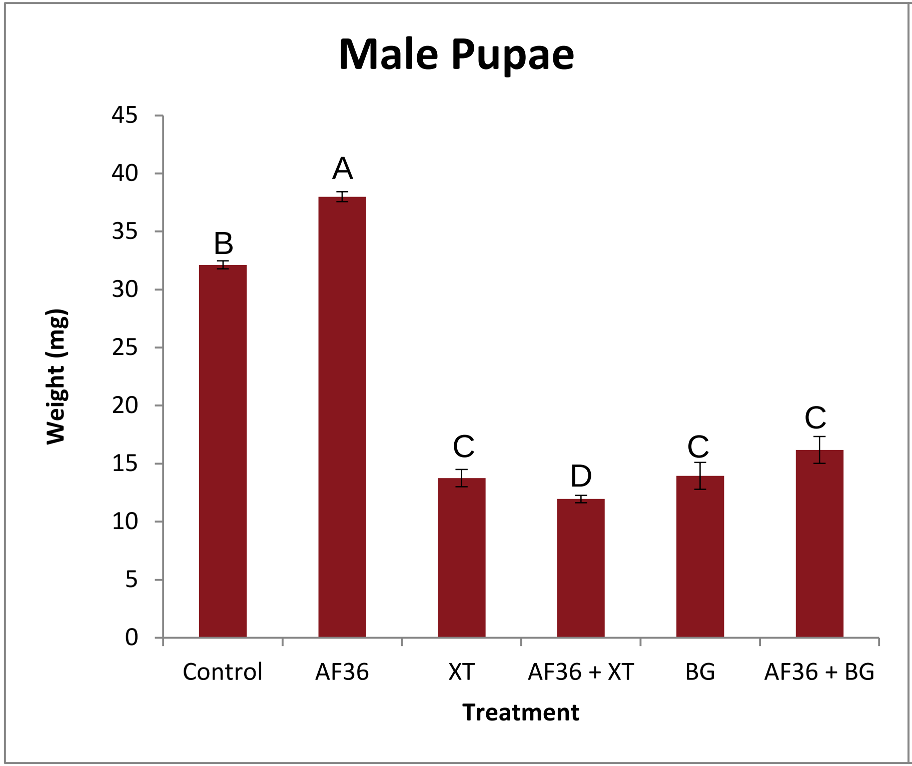
Results 1: Larval Growth Rate



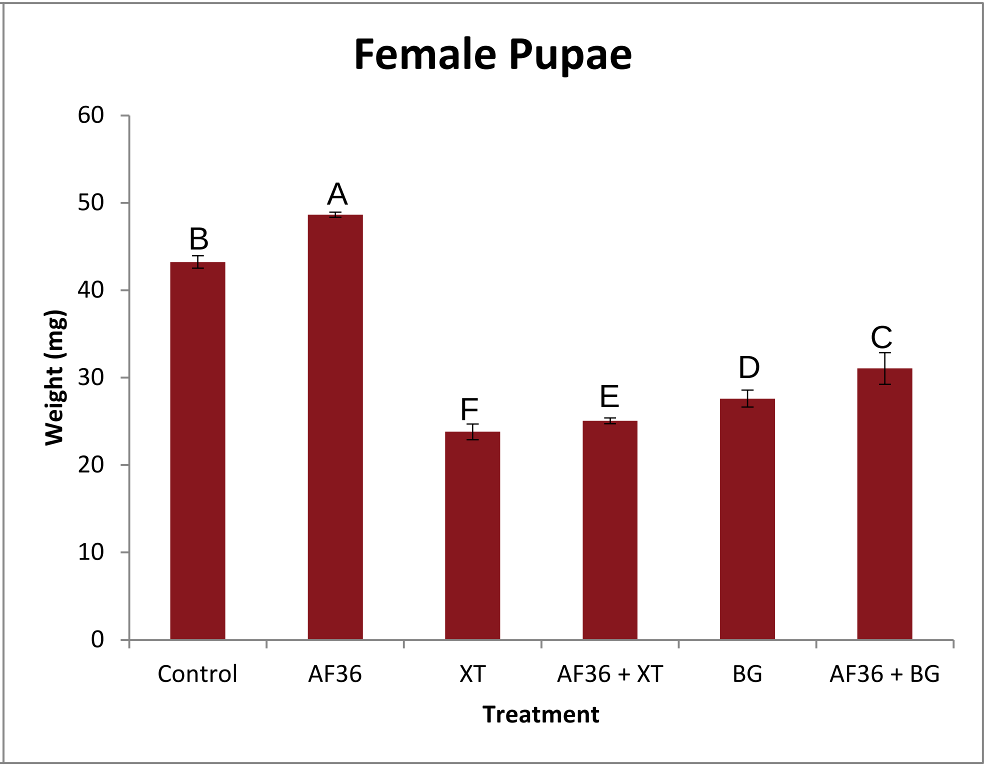
- Figure: time to pupation for larvae raised on control diet, with and without *A. flavus* (AF36), and with and without xanthotoxin (XT) or bergapten (BG).

- Diet ($P < 0.001$), *A. flavus* presence ($P < 0.001$), and the interaction of diet and fungal presence ($P < 0.001$) had significant effects on development time.

Results 1 (Continued): Pupal Weights



(F = 328.09; df = 5; P < 0.001)



(F = 83.00; df = 5; P < 0.001)

Objective 2: Fungal Performance

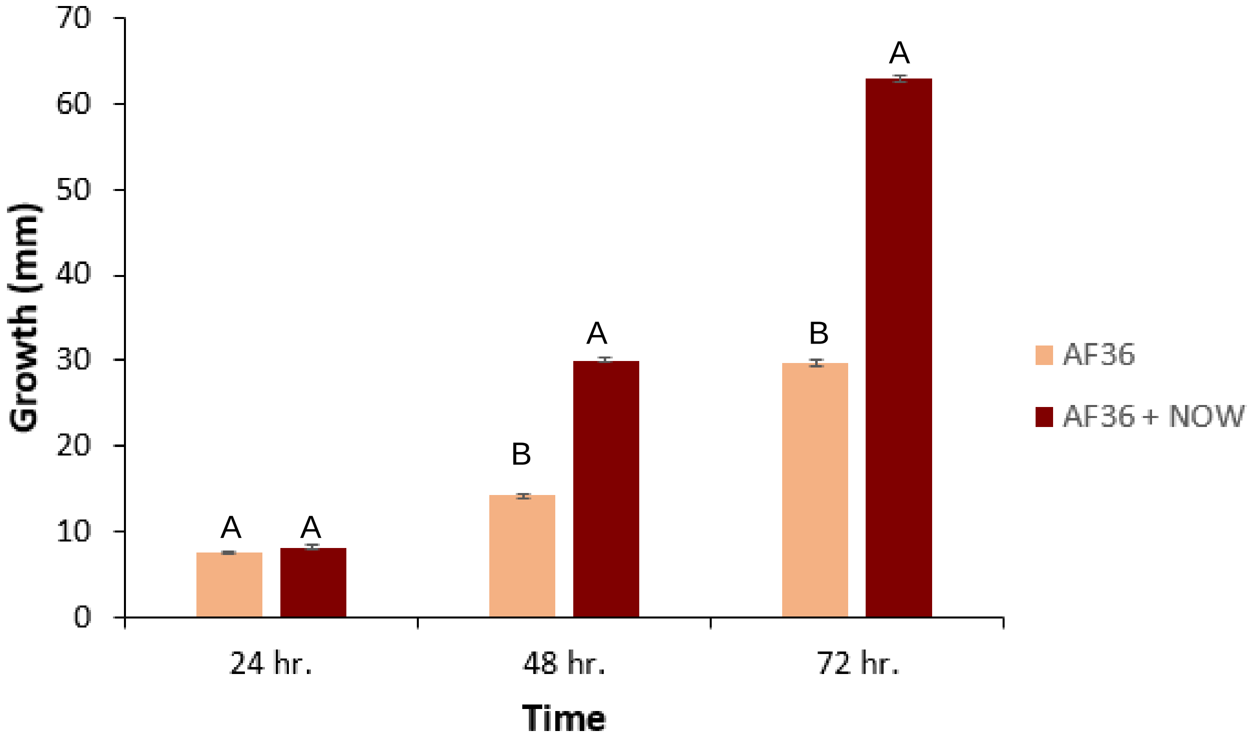
- **Is there also a growth benefit for *Aspergillus flavus*?**

- AF36 inoculum was placed on almond PDA with and without NOW larvae.

- Fungal growth was monitored for 72 hours; growth was determined by averaging colony diameter from four axes (due to irregular colony shape in the presence of larvae).

- Differences in 72-hour growth analyzed via paired *t*-test.

Results 2: Fungal Growth Rate



- Figure: *A. flavus* 72-hour growth ($t = 52.14$; $df = 19$; $P < 0.001$)
- Increase from 29.7 mm (alone) to 61.9 mm (with NOW)

Discussion

- **Do NOW larvae perform better (i.e. grow faster larger) in the presence of *A. flavus*?**
  - **Yes, growth rate, mortality, and pupal weight improve.**
  - **This is also true (to a lesser extent) even in the presence of furanocoumarins.**
- **Is there also a growth benefit for *Aspergillus flavus*?**
  - **Yes, 72-hour growth improves.**

- These results lend support to a facultative mutualism between the navel orangeworm and *Aspergillus flavus* and suggest that *A. flavus* may be capable of detoxifying furanocoumarins.

- Management efforts should address both pests in order to reduce direct and indirect damage to crops.

Acknowledgments

- Thanks to Mark Demkovich, Katie Dana, and the Berenbaum lab for help with navel orangeworm rearing and methods
- Thanks to Daniel Raudabaugh and Dr. Andy Miller for help with fungal methods and to Dr. Themis Michailides for providing AF36

Jay Rosenheim,
University of California, Davis

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Sampling methods and development of thresholds for use under conventional and mating-disruption based management of navel orangeworm

Jay Rosenheim & Bradley Higbee

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Navel orangeworm management

- Traditionally, has relied on insecticide sprays at hull-split
  - Resistance is a growing problem
  - Spider mite outbreaks
- Historical difficulty: accurately estimating NOW densities
  - NOW is damaging at very low densities
  - Egg traps used primarily to time insecticides, not to decide if a treatment is needed

New tools for NOW management

- Mating disruption
  - Effective, but supplementary sprays may still be needed
- Pheromone lures provide new tool for estimating NOW density
  - But, trap shut-down under mating disruption may render pheromone traps ineffective as a population monitoring device
    - We need to quantify trap shut-down
    - Lures may still provide useful information about edge effects and to monitor the disruption of sexual communication

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Many *possibly* useful methods for estimating NOW population size:

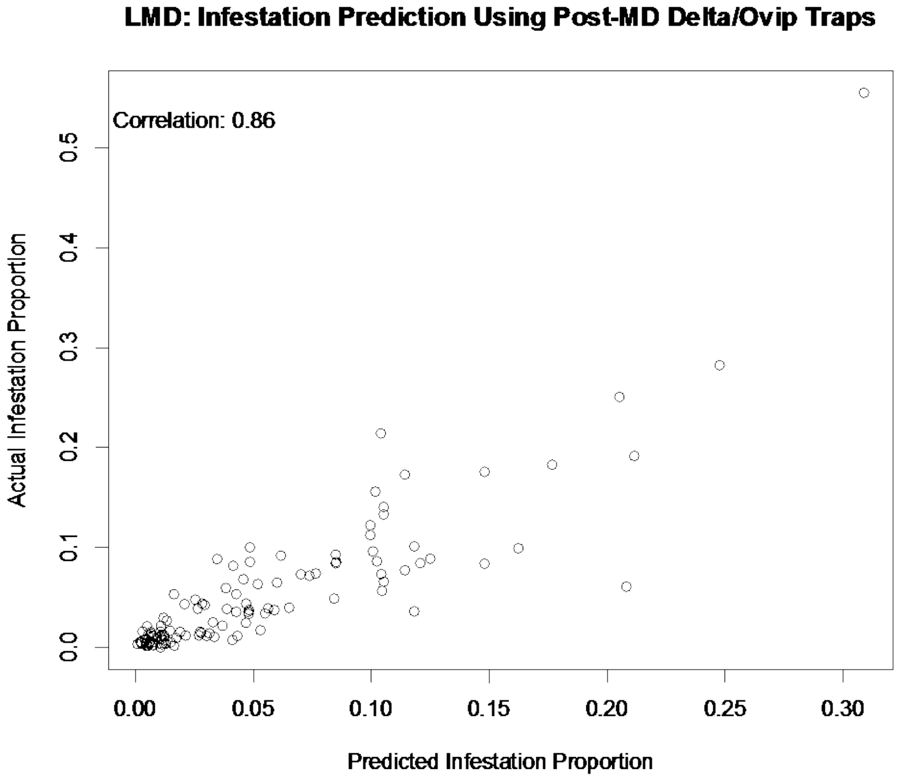
- Prior-year infestation of crop
  - Estimate of ‘starting’ population size
- Mummy nut densities and infestation % after sanitation
- Egg traps
  - Efficiency may decrease at low NOW densities due to limited area of attraction
- Adult female traps, using almond meal as an attractant
- Pheromone traps
  - Not as useful with mating disruption
- Pre-harvest samples of new nuts with split hulls
  - NOW on nuts with early hull split may be ‘diluted’ as more hulls split

→ Which of these is most useful? (. . . Accurate, easy)

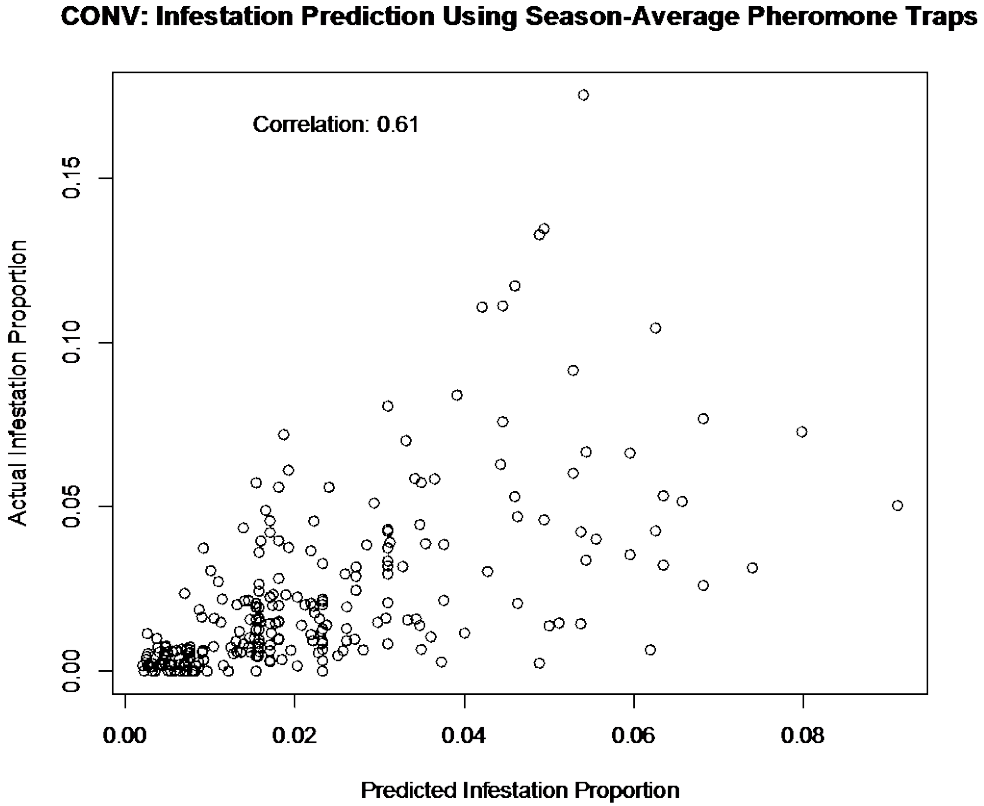
Project will work strictly with pre-existing dataset:

- Area-wide mating disruption trials directed by Brad Higbee (Wonderful Orchards, formerly Paramount Farming)
  - Two locations
  - 2009-2014
  - Conventional and mating-disruption management

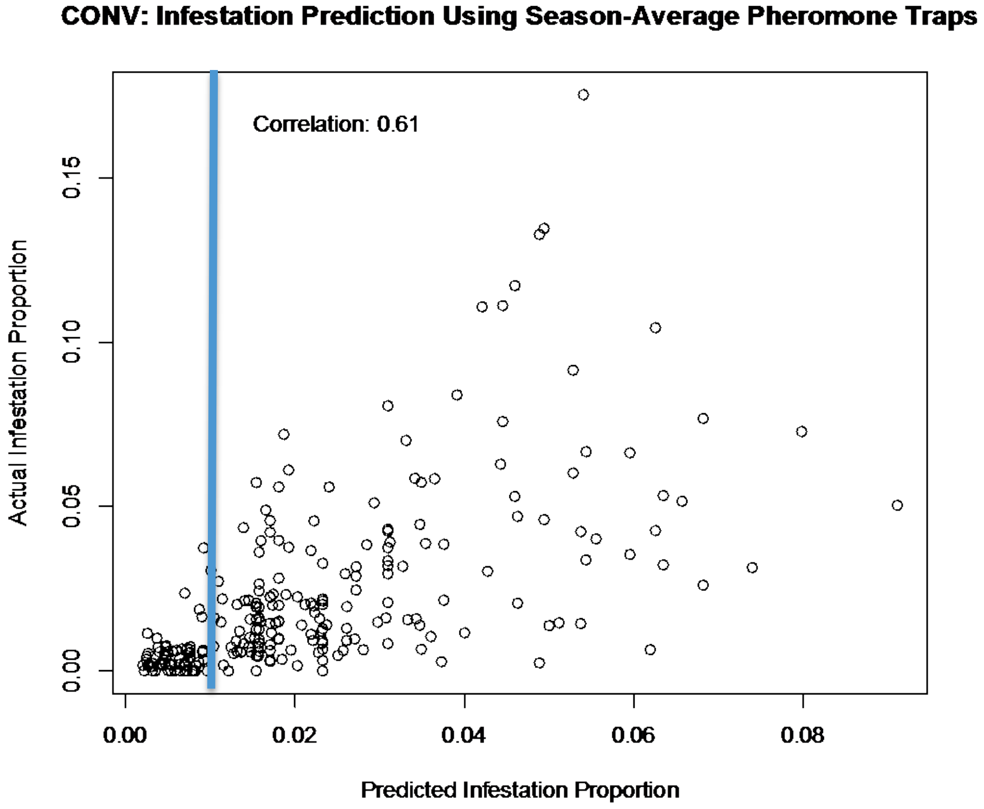
Can we predict crop infestation with enough accuracy?



Can we predict crop infestation with enough accuracy?



Can we predict crop infestation with enough accuracy?



Research goals:

- Determine which sampling method is the best predictor of crop infestation
- Develop thresholds for use with conventional and mating-disruption management

Ring Carde,
University of California, Riverside

Monitoring the Adult Navel Orangeworm Moths with Pheromone and Host-Plant Volatiles

- Ring Cardé, Nancy Power, Brad Higbee[1] and John Beck[2]
- Department of Entomology, University of California, Riverside CA, 92521 USA
- [1.] Wonderful Orchards [2.] Agricultural Research Service, Albany

Quest for host-plant volatiles that induce attract mated females perhaps males.

Tested many volatiles identified by John Beck and colleagues

- We have tested in a wind tunnel host-plant volatiles at 3 doses (10, 100 and 1000 micrograms) with and without a pheromone lure for males and 3 doses of volatiles (without pheromone) for females. Among the compounds tested so far are octanal plus nonanal, sabinene, (*Z*)-3-hexenal, (*Z*)-3-hexenal plus (*Z*)-3-hexenol, 3-octen-2-one, methyl salicylate, sabinene hydrate, linalool, limonene, a pistachio blend and other compounds. Each treatment is tested with 20 males (140 males/host volatile and 60 mated females/host volatile).

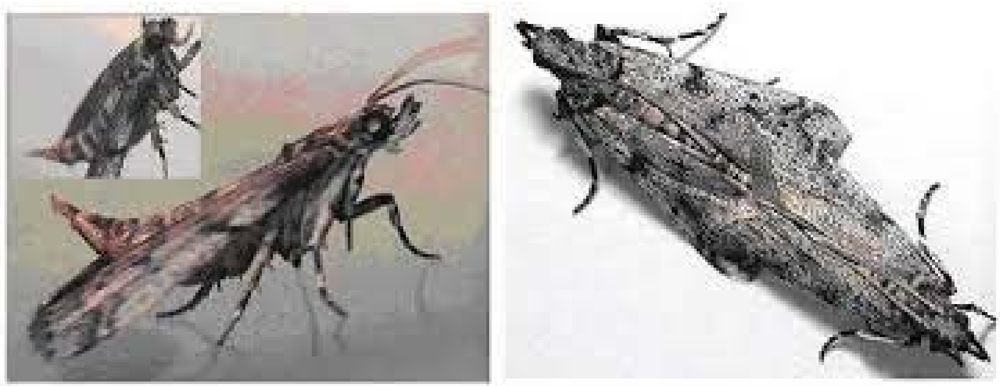
- These compounds were selected for behavioral work because they were predominant in airborne collections and electroantennogram active.

New study related to mating disruption—does the presence of pheromone from a mating disruption formulation alter calling and possible dispersal?

Precedent in other moths—presence of synthetic pheromone or nearby calling females generally advances calling, depleting her pheromone and making her less likely to attract a mate.

Do females (like males) need the complete (4-component) blend?

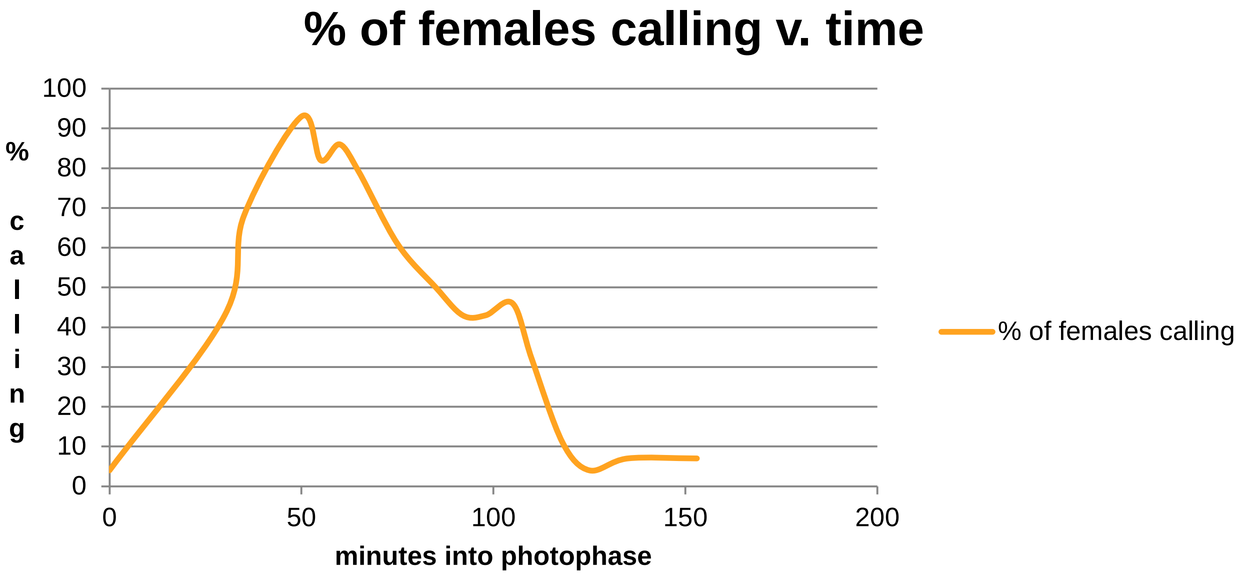
Calling in the almond moth is distinctive—but when does it occur?



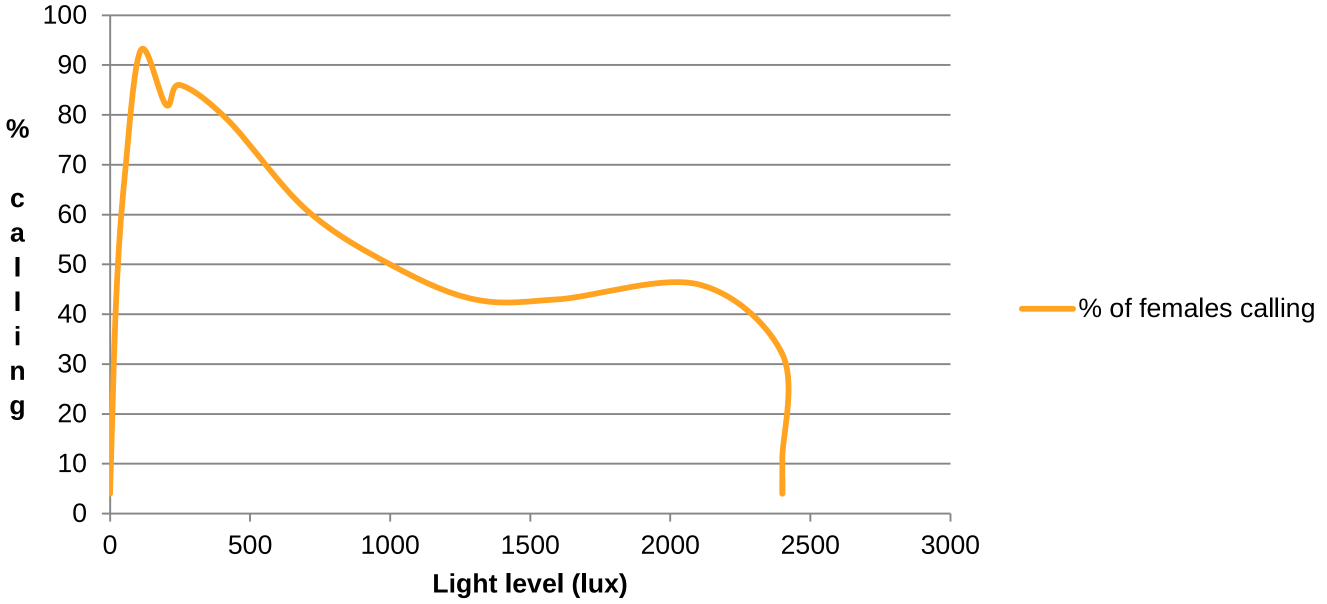
Female navel orangeworm calling periodicity under a gradual increase in light from below moonlight level

Hours into photophase	Light level (lux)	% of females calling
0	*	04
0:30	22	43
0:35	53	68
0:50	110	93
0:55	200	82
1:00	250	86
1:05	420	79
1:15	700	61
1:25	1000	50
1:32	1300	43
1:38	1600	43
1:45	2100	46
1:50	2400	32
1:58	2400	11
2:05	2400	04
2:15	2400	07
2:33	2400	07

*not detectable by light meter, but light table was on at a low setting
Light levels were measured with a Gossen Ultra Pro light meter set for reflected light. The meter sensor was pointed down at the light table from 5 cm above the table.
n=28


% of females calling v. time
%
calling
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
minutes into photophase
% of females calling

% of female navel orangeworm calling vs. light level



Next steps—check to see if the rhythm is endogenous (circadian).

Do nearby females influence calling in their neighbors?

If so, is this contingent of the complete (4-component) blend?

Continuing work

The quest for attractive volatiles continues

Understanding if possible female responses to her own pheromone ("autodetection") contributes to mating disruption

John Beck,
USDA-ARS, Albany, California

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Host Plant Volatile Blend to Monitor NOW Populations

John J. Beck USDA   Bradley S. Higbee Wonderful orchards.

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Synthetic Host Plant Volatile Blend

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

J. Agric. Food Chem. **2012**, *60*, 8090-8096

Article

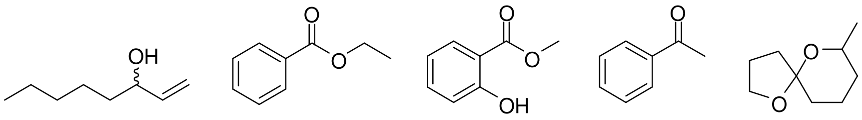
pubs.acs.org/JAFC

Hull Split and Damaged Almond Volatiles Attract Male and Female Navel Orangeworm Moths

John J. Beck,[*,†] Bradley S. Higbee,[‡] Douglas M. Light,[†] Wai S. Gee,[†] Glory B. Merrill,[†] and Jennifer M. Hayashi[†]

[†]Plant Mycotoxin Research, Western Regional Research Center, Agricultural Research Service, U.S. Department of Agriculture, 800 Buchanan Street, Albany, California 94710, United States

[‡]Paramount Farming Co., 33141 E. Lerdo Highway, Bakersfield, California 93308, United States



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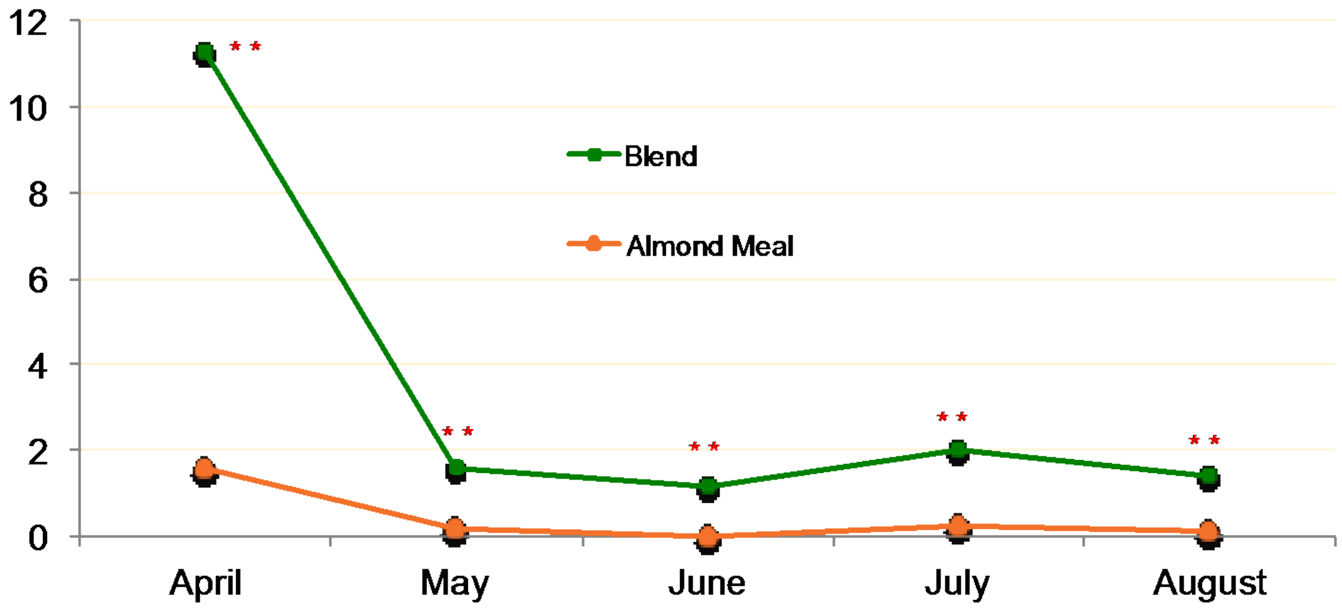
Initial Data – 2011 Conventional Orchard



Male and female moths captured/trap/week

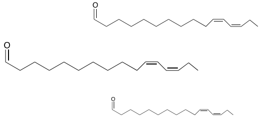
Consistency – Conventional Orchard

- Superior performance over almond meal proven in conventional orchard (8-13x better)
  - 2011
  - 2012
  - 2013

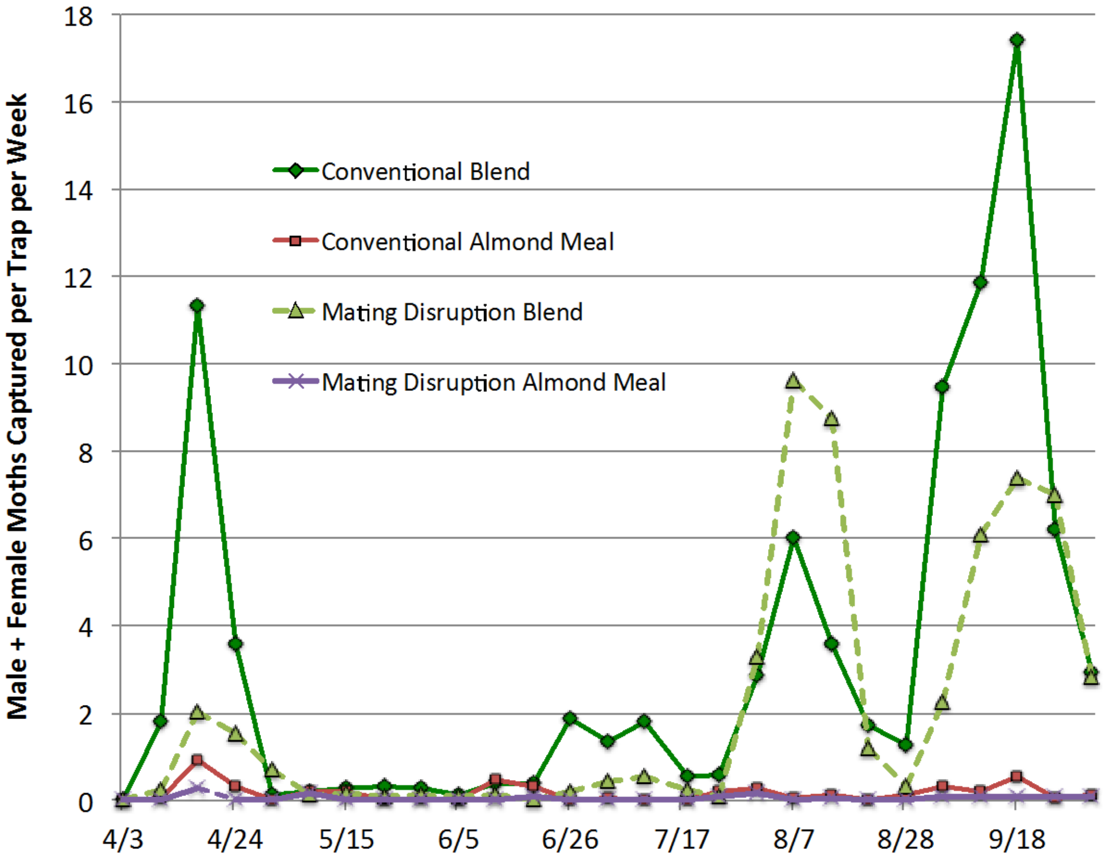
Consistency – Conventional Orchard

- Superior performance over almond meal proven in conventional orchard (8-13x better)
  - 2011
  - 2012
  - 2013

- Will “The Blend” maintain sensitivity and resolution in a mating disruption-treated orchard?

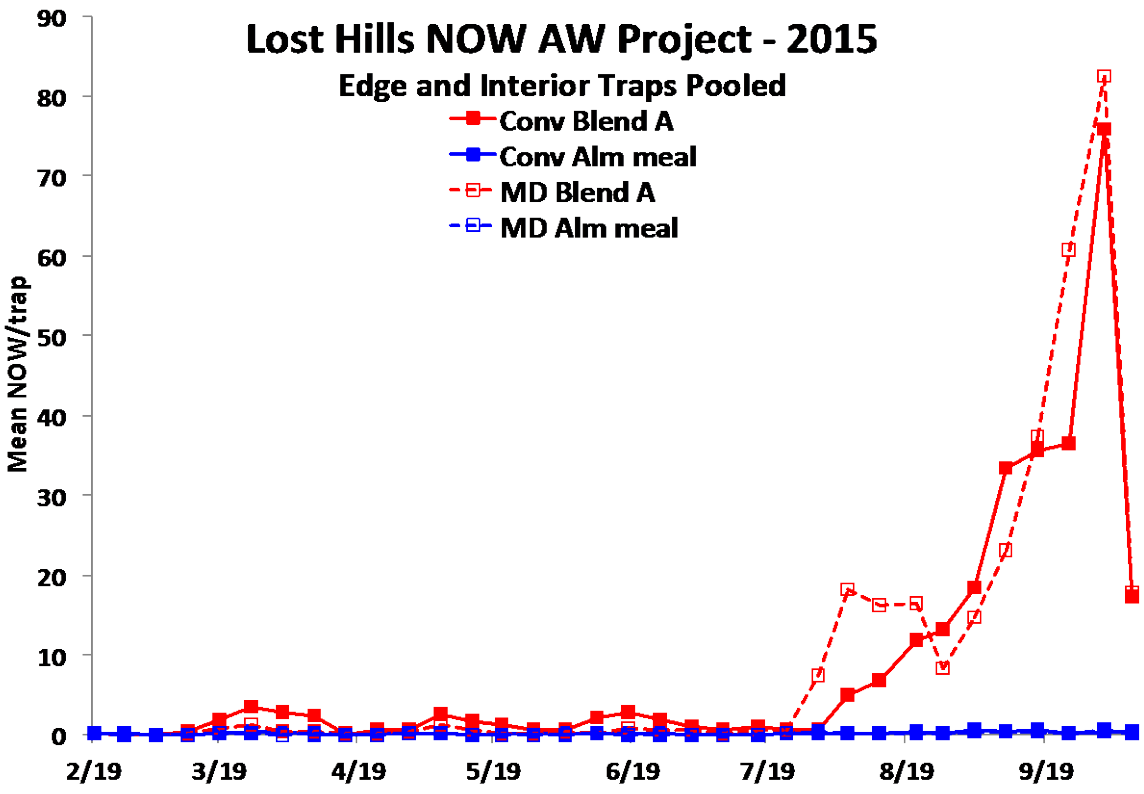


Mating Disruption-Treated Almond Orchard – **Year 1**



2014

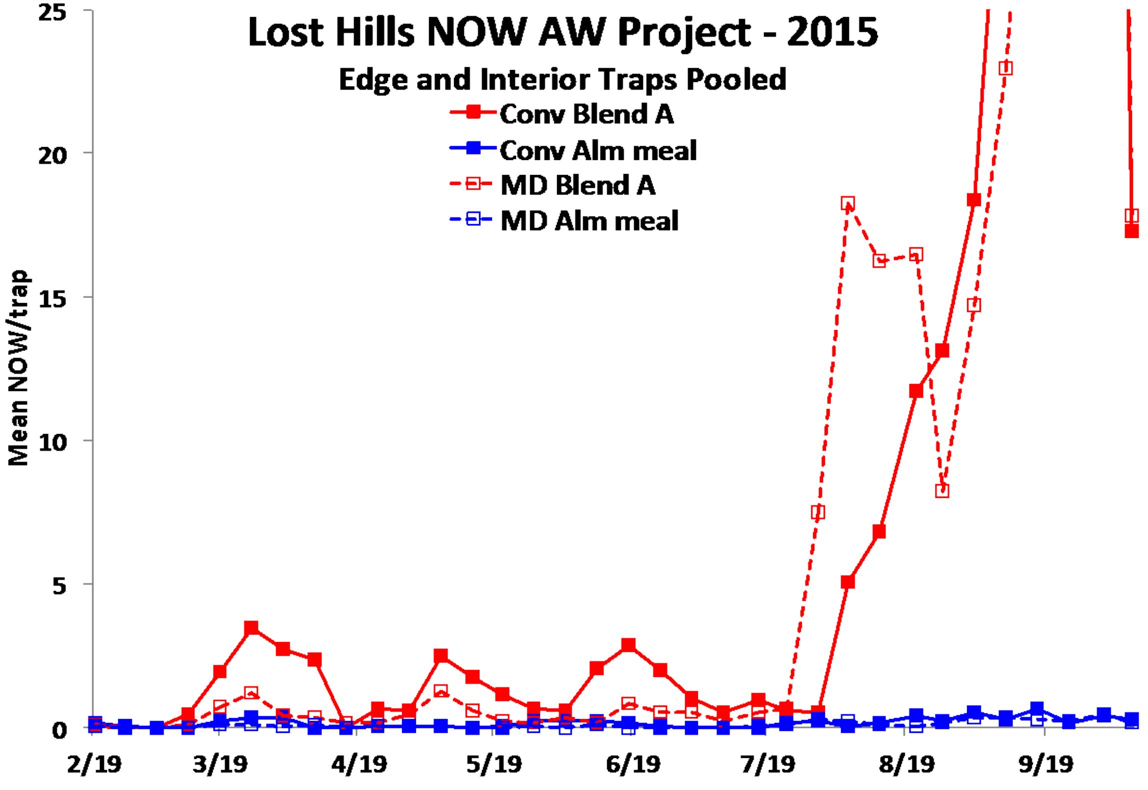
Mating Disruption-Treated Almond Orchard – **Year 2**



2015

Mating Disruption-Treated Almond Orchard – **Year 2**

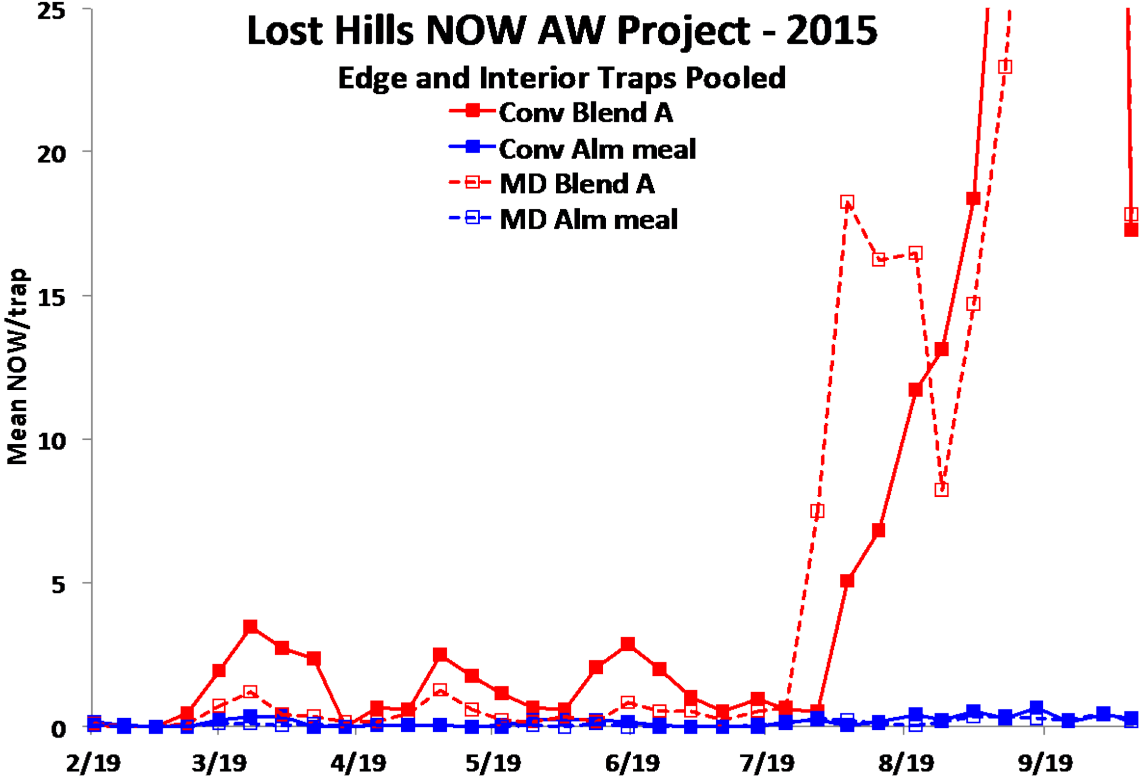
2015



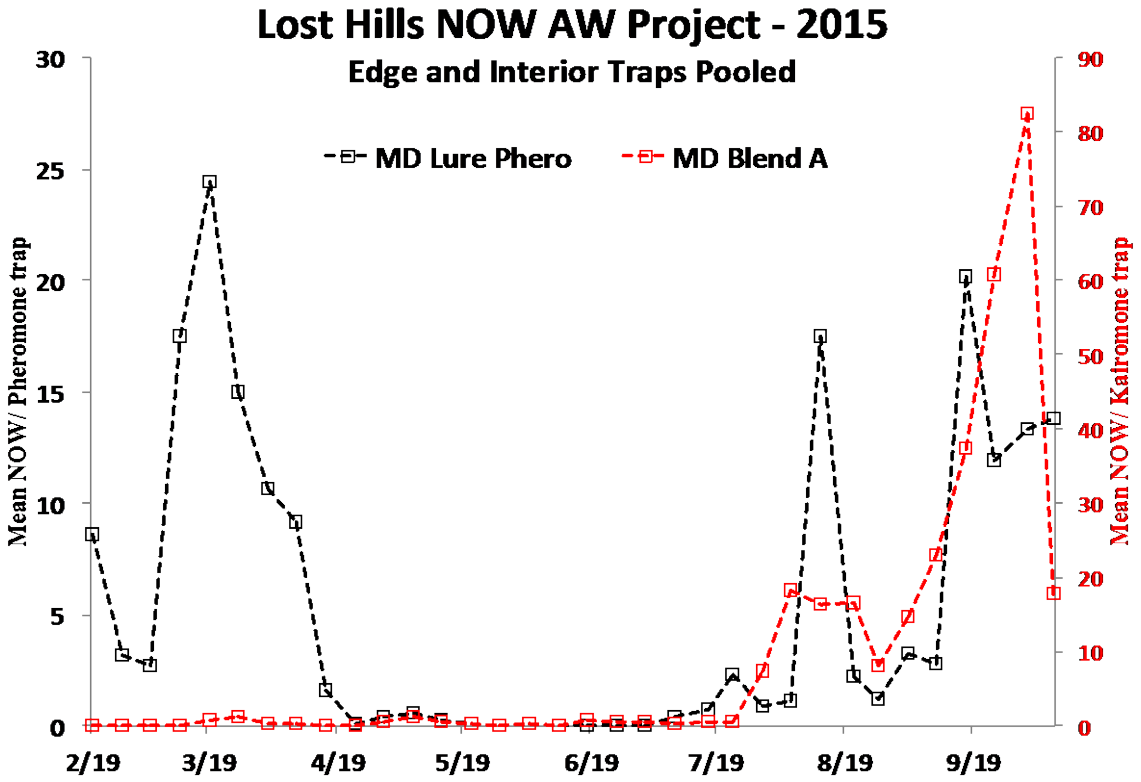
Mating Disruption-Treated Almond Orchard – **Year 2**

The Host Plant Volatile Blend is superior to almond meal

2015



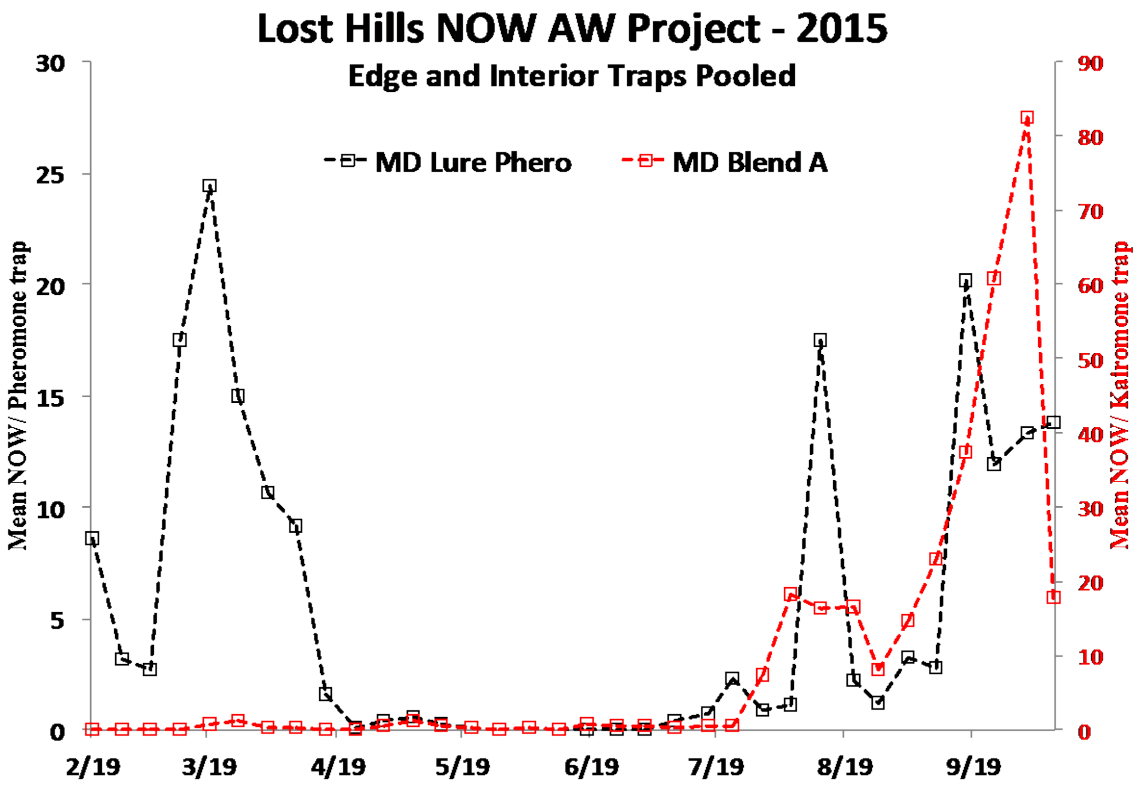
Mating Disruption-Treated Almond Orchard – **Year 2**



2015

Mating Disruption-Treated Almond Orchard – **Year 2**

Pheromone blend and the Host Plant Volatile Blend show similar population dynamic trends in later months



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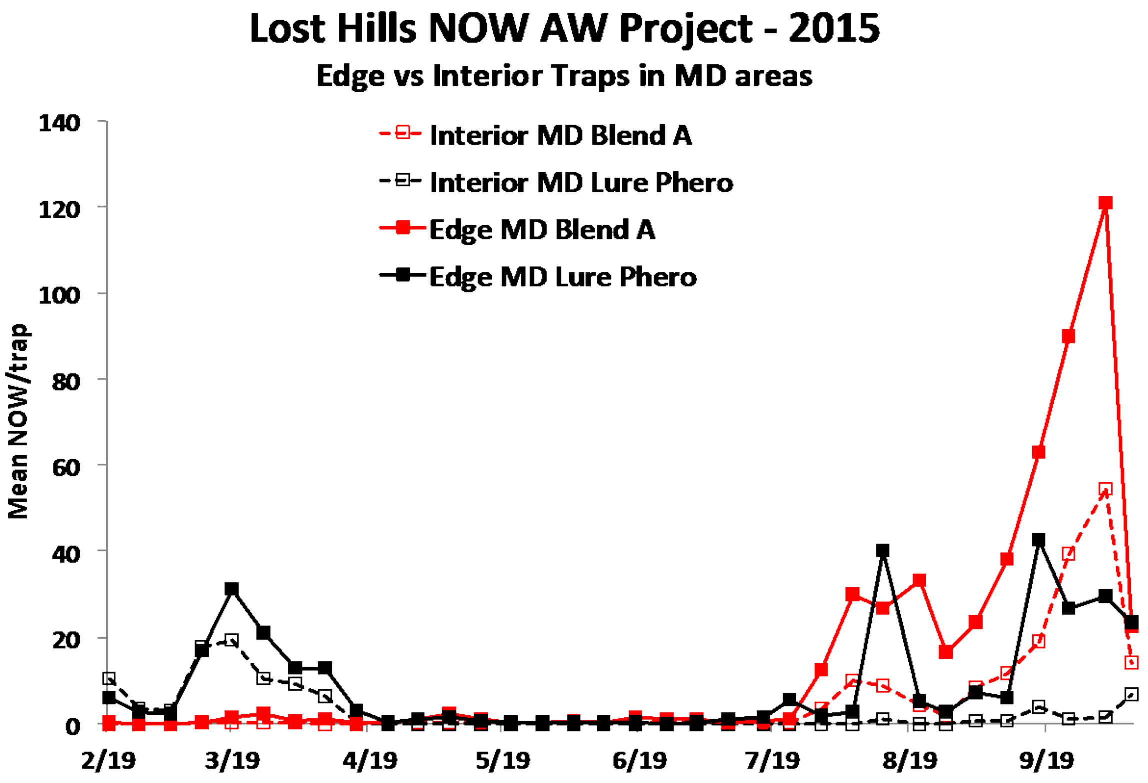
Mating Disruption-Treated Almond Orchard – **Year 2**

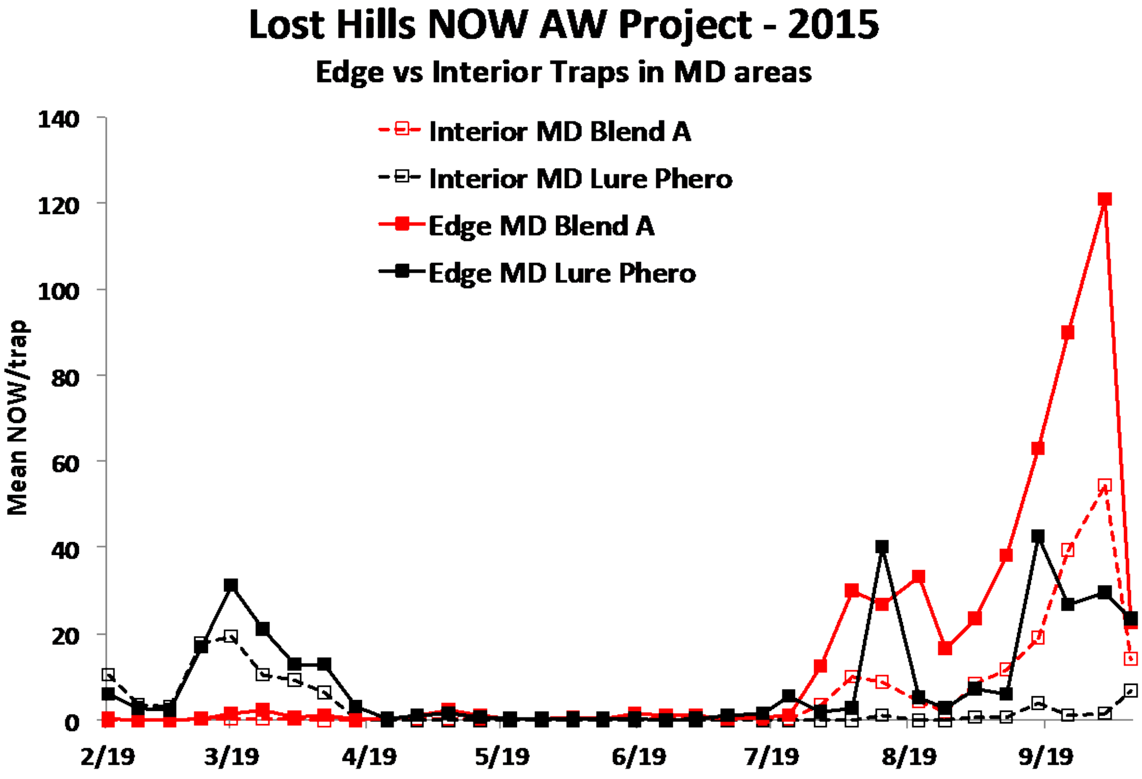


2015

Mating Disruption-Treated Almond Orchard – **Year 2**

Host Plant Volatile Blend shows good interior and exterior resolution in later months…

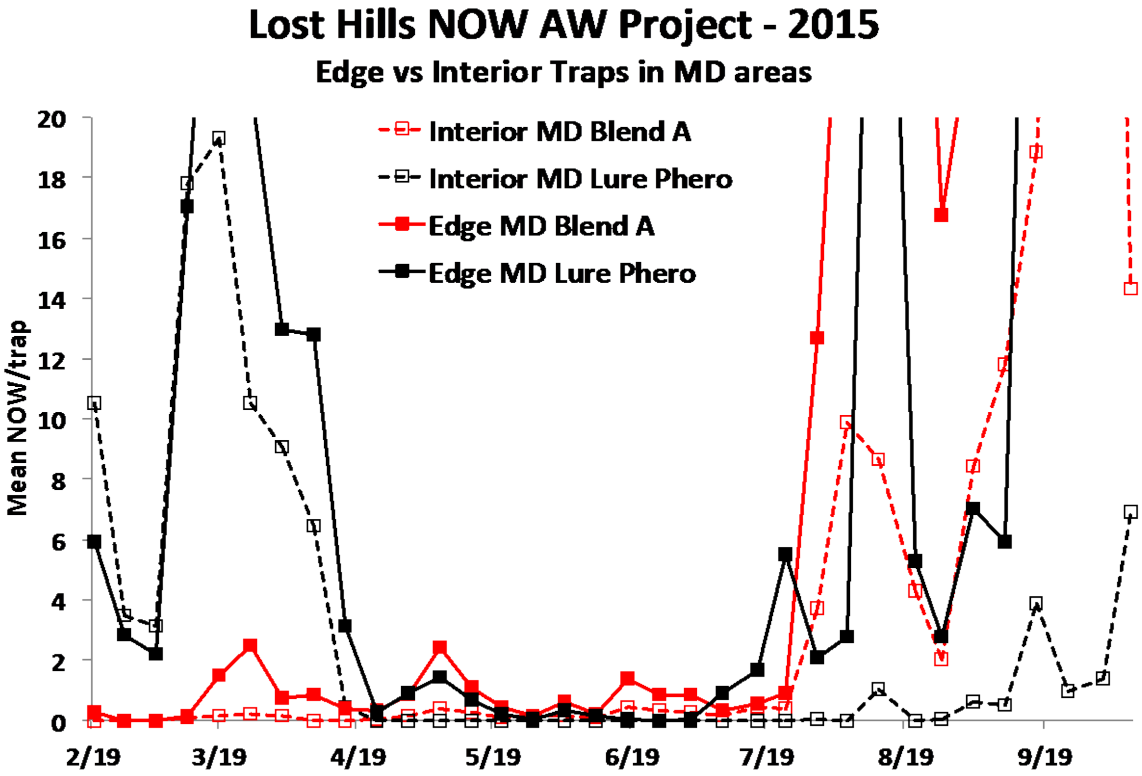
2015



Mating Disruption-Treated Almond Orchard – **Year 2**

…but does show some resolution for edge in early and middle months when closely evaluated

2015



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The Blend in MD and Conventional Orchards

- Provides more sensitive population dynamics information in MD environments
  - relative to sex pheromone or almond based attractants
- Interior versus exterior captures valuable for identifying risk from outside sources
- Correlations to damage in both conventional and mating disruption orchards *being analyzed from* 1^{st} *and* 2^{nd} *year*
- Need one more year of data

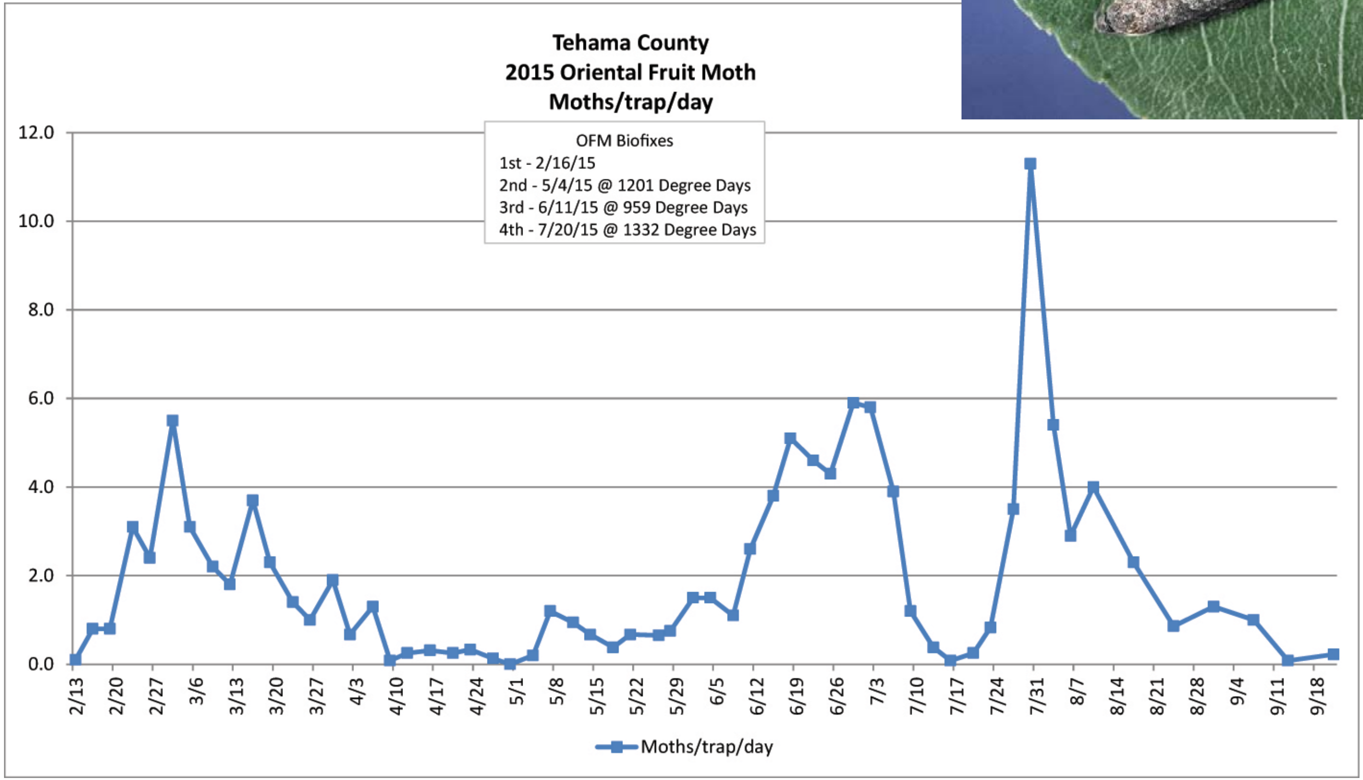
california almonds
Almond Board of California

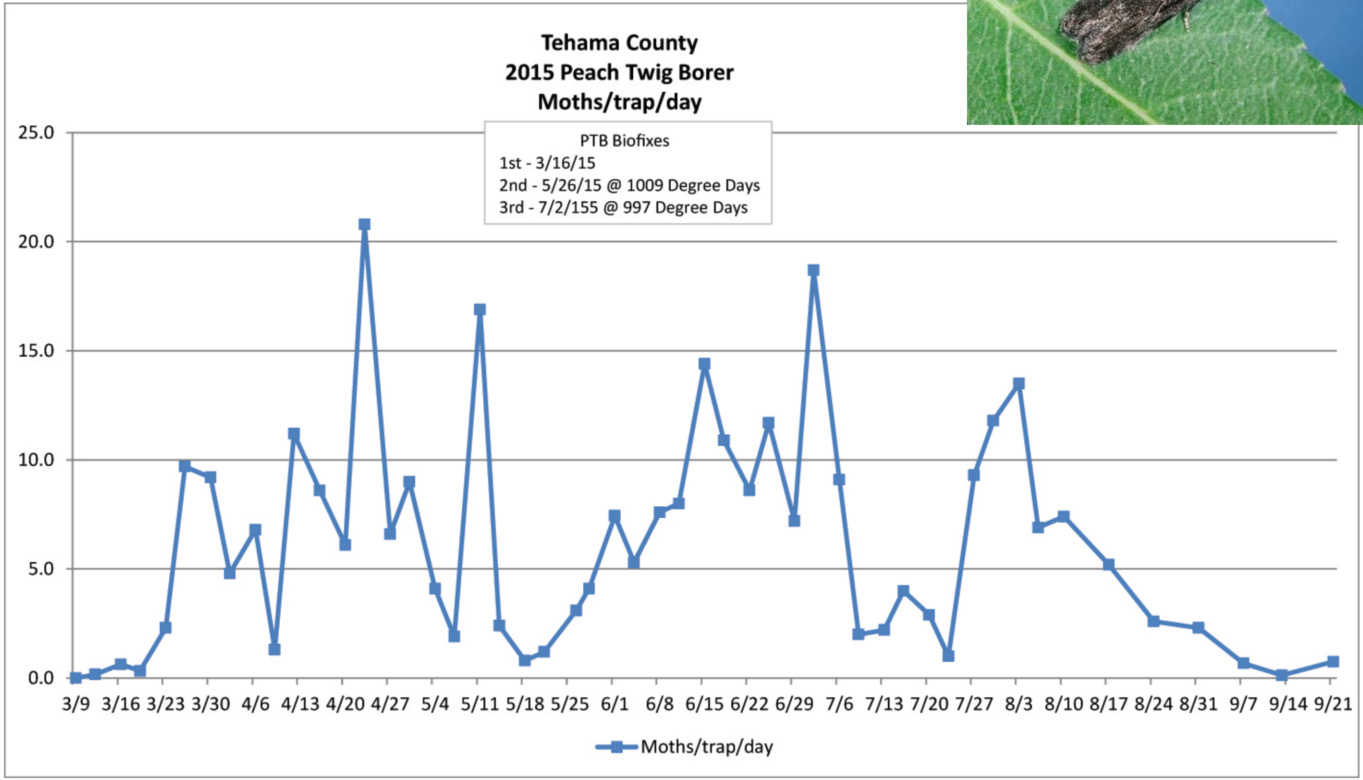
Richard Buchner,
UCCE - Tehama/Shasta Counties

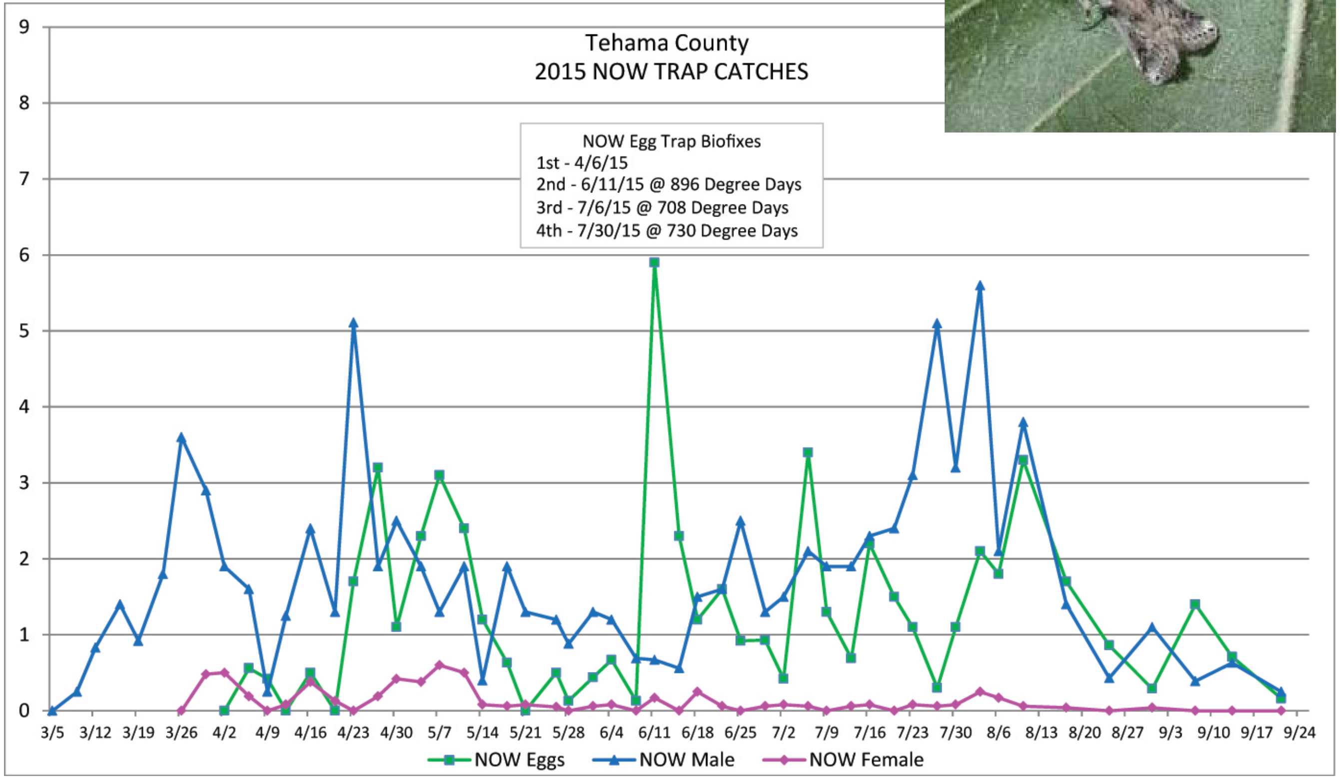
Monitoring and Reporting of Almond Insect Pest Dynamics in Tehama County

Richard P. Buchner, UCCE
Tehama/Glenn/Butte Counties

Cyndi K. Gilles, Tehama Research Assistant


Tehama County
2015 Oriental Fruit Moth
Moths/trap/day
OFM Biofixes
1st - 2/16/15
2nd - 5/4/15 @ 1201 Degree Days
3rd - 6/11/15 @ 959 Degree Days
4th - 7/20/15 @ 1332 Degree Days
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2/13
2/20
2/27
3/6
3/13
3/20
3/27
4/3
4/10
4/17
4/24
5/1
5/8
5/15
5/22
5/29
6/5
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
Moths/trap/day



Tehama County
2015 Peach Twig Borer
Moths/trap/day
PTB Biofixes
1st - 3/16/15
2nd - 5/26/15 @ 1009 Degree Days
3rd - 7/2/155 @ 997 Degree Days
25.0
20.0
15.0
10.0
5.0
0.0
3/9
3/16
3/23
3/30
4/6
4/13
4/20
4/27
5/4
5/11
5/18
5/25
6/1
6/8
6/15
6/22
6/29
7/6
7/13
7/20
7/27
8/3
8/10
8/17
8/24
8/31
9/7
9/14
9/21
Moths/trap/day


Tehama County
2015 NOW TRAP CATCHES
NOW Egg Trap Biofixes
1st - 4/6/15
2nd - 6/11/15 @ 896 Degree Days
3rd - 7/6/15 @ 708 Degree Days
4th - 7/30/15 @ 730 Degree Days
0
1
2
3
4
5
6
7
8
9
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
8/6
8/13
8/20
8/27
9/3
9/10
9/17
9/24
NOW Eggs
NOW Male
NOW Female

NOW 2015 Tehama Almonds

- ❖Female traps did not catch many females
- ❖Male NOW emerged ahead of females
- ❖Male activity did not clearly mirror female flight or egg laying

University of California Integrated Pest Management Insect Update #29
Tehama County 9/21/15

INSECT	FIRST BIOFIX	SECOND BIOFIX	THIRD BIOFIX	FOURTH BIOFIX	ACTIVITY MOTHS/DAY	AVG. DEG. DAYS/DAY	DAY DEGREES FROM BIOFIX
CODLING MOTH	3/16	5/26	7/13	-	.13	18.4	1829
ORIENTAL FRUIT MOTH	2/16	5/4	6/11	7/20	.22	23.4	1957
PEACH TWIG BORER	3/16	5/26	7/2	-	.75	18.3	2115
NAVEL ORANGE WORM EGGS	4/6	6/11	7/6	7/30	.16	13.4	1101
SAN JOSE SCALE	3/9	-	-	-	-	17.3	4056
WALNUT SCALE	5/4	8/10			-		

Additional Pest management information is available at the UC IPM website including a day degree calculator. http://www.ipm.ucdavis.edu.

Tehama Pest management updates are also available at
http://cetehama.ucanr.edu/Orchard_Crops/Insect_Updates

Richard P. Buchner and Cyndi K. Gilles
Orchard Advisor & Research Associate
UC Cooperative Extension Tehama County
(530) 527-3101

Emily Symmes,
UCCE IPM Advisor

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Navel Orangeworm Monitoring in the Sacramento Valley

Emily J. Symmes

University of California Area IPM Advisor, Sacramento Valley

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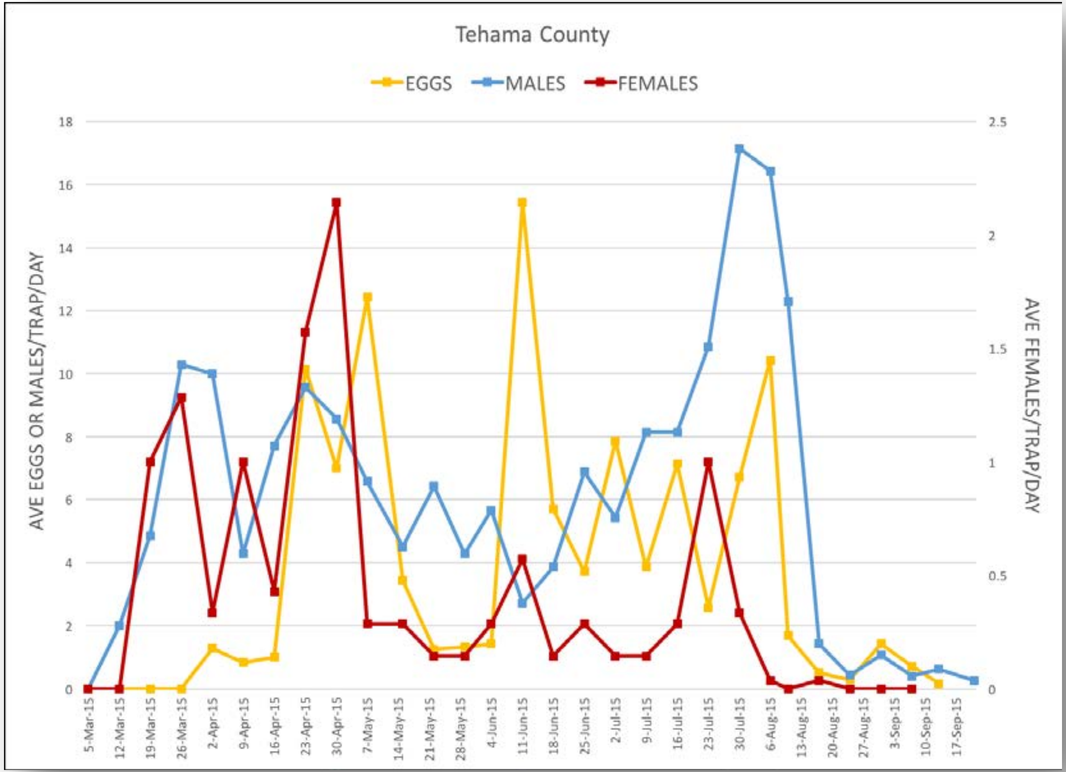
2015 NOW Trapping
Sacramento Valley, CA

5 sites, 4 counties


Photo: E. Peterson


Tehama County
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY
18
16
14
12
10
8
6
4
2
0
2.5
2
1.5
1
0.5
0
5-Mar-15
12-Mar-15
19-Mar-15
26-Mar-15
2-Apr-15
9-Apr-15
16-Apr-15
23-Apr-15
30-Apr-15
7-May-15
14-May-15
21-May-15
28-May-15
4-Jun-15
11-Jun-15
18-Jun-15
25-Jun-15
2-Jul-15
9-Jul-15
16-Jul-15
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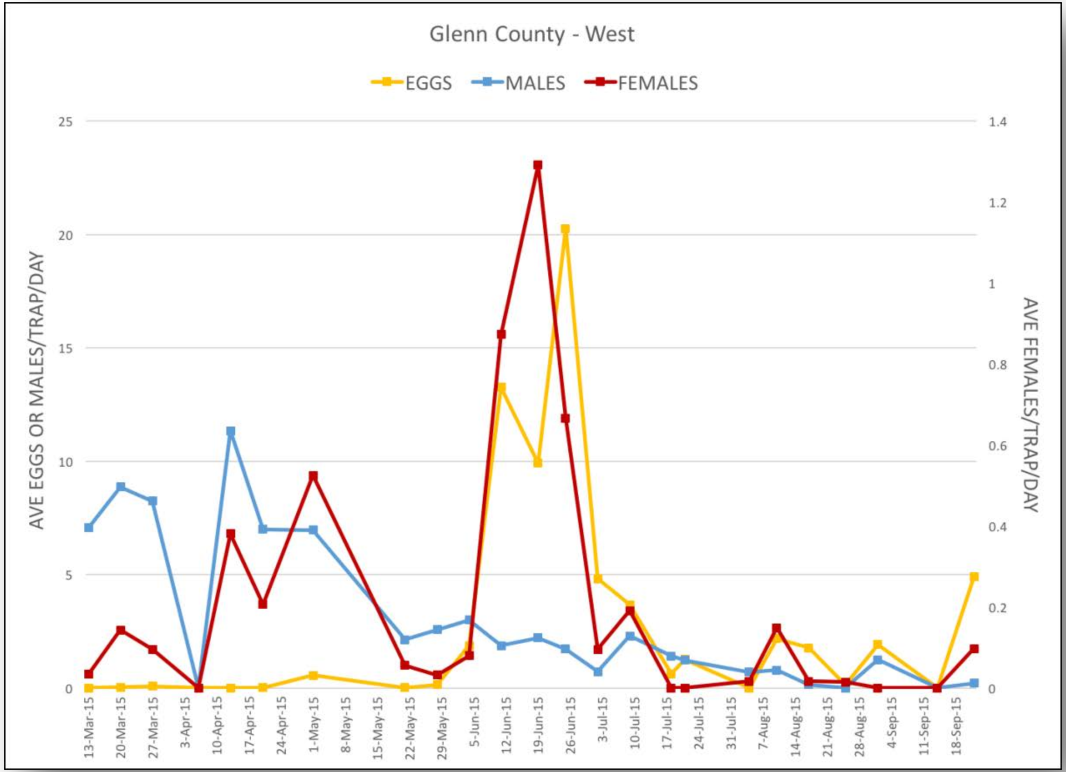
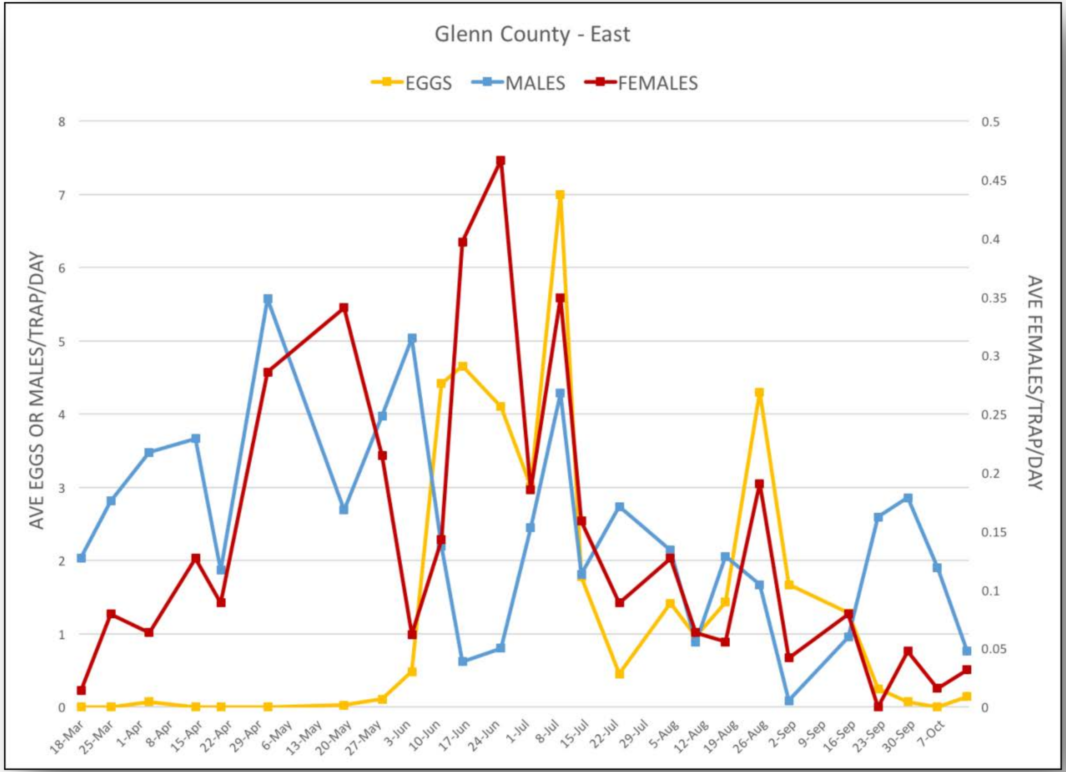
10-Sep-15
17-Sep-15


Glenn County - West
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
13-Mar-15
20-Mar-15
27-Mar-15
3-Apr-15
10-Apr-15
17-Apr-15
24-Apr-15
1-May-15
8-May-15
15-May-15
22-May-15
29-May-15
5-Jun-15
12-Jun-15
19-Jun-15
26-Jun-15
3-Jul-15
10-Jul-15
17-Jul-15
24-Jul-15
31-Jul-15
7-Aug-15
14-Aug-15
21-Aug-15
28-Aug-15
4-Sep-15
11-Sep-15
18-Sep-15


Glenn County - East
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY
0
1
2
3
4
5
6
7
8
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
18-Mar
25-Mar
1-Apr
8-Apr
15-Apr
22-Apr
29-Apr
6-May
13-May
20-May
27-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
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12-Aug
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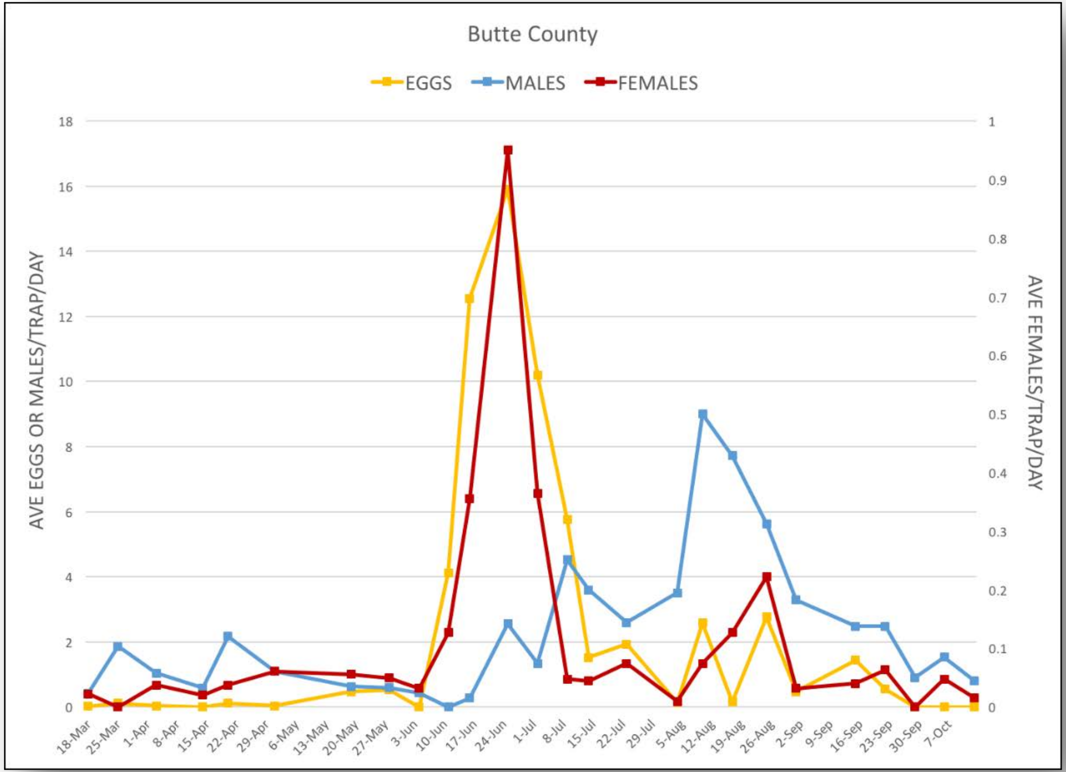
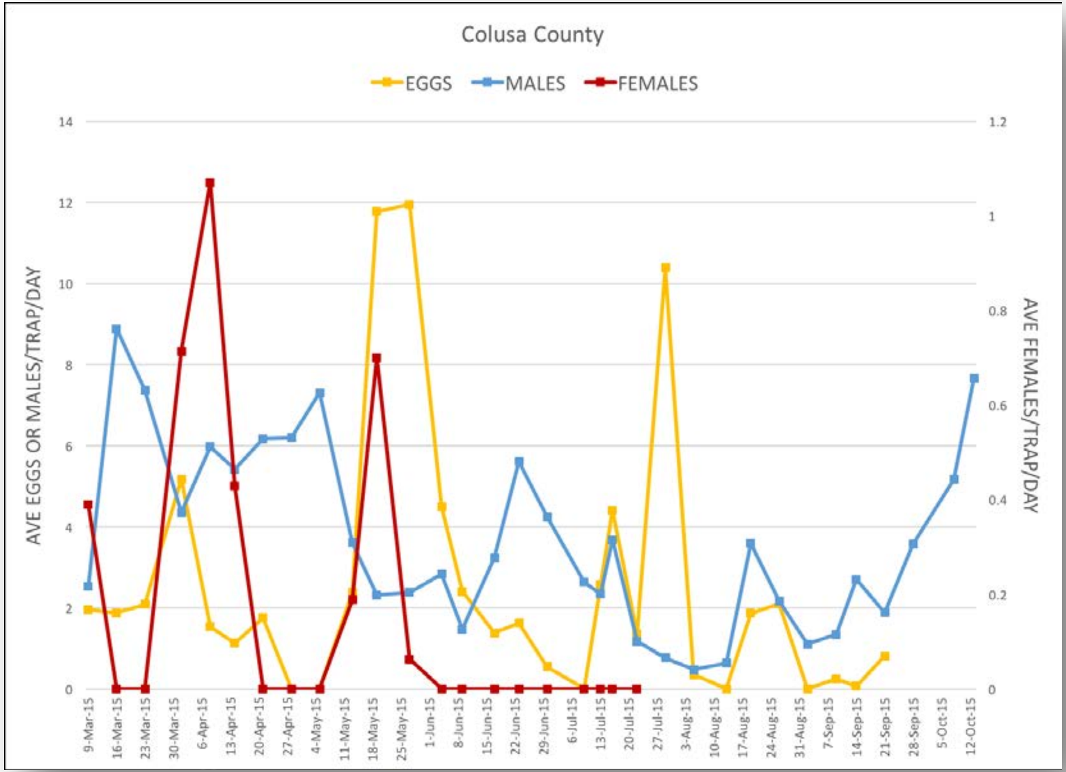
2-Sep
9-Sep
16-Sep
23-Sep
30-Sep
7-Oct


Butte County
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY
18
16
14
12
10
8
6
4
2
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
18-Mar
25-Mar
1-Apr
8-Apr
15-Apr
22-Apr
29-Apr
6-May
13-May
20-May
27-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
5-Aug
12-Aug
19-Aug
26-Aug
2-Sep
9-Sep
16-Sep
23-Sep
30-Sep
7-Oct


Colusa County
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY
0
2
4
6
8
10
12
14
0
0.2
0.4
0.6
0.8
1
1.2
9-Mar-15
16-Mar-15
23-Mar-15
30-Mar-15
6-Apr-15
13-Apr-15
20-Apr-15
27-Apr-15
4-May-15
11-May-15
18-May-15
25-May-15
1-Jun-15
8-Jun-15
15-Jun-15
22-Jun-15
29-Jun-15
6-Jul-15
13-Jul-15
20-Jul-15
27-Jul-15
3-Aug-15
10-Aug-15
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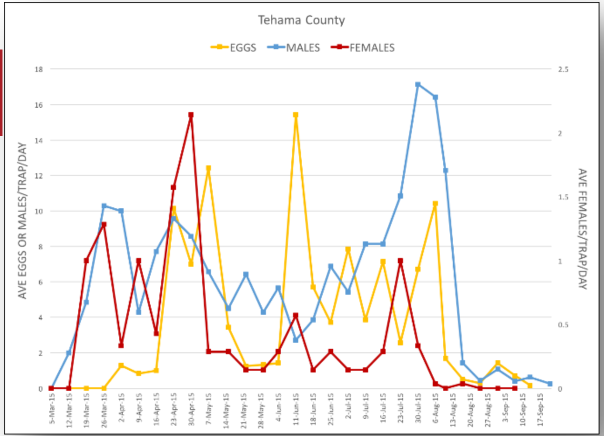
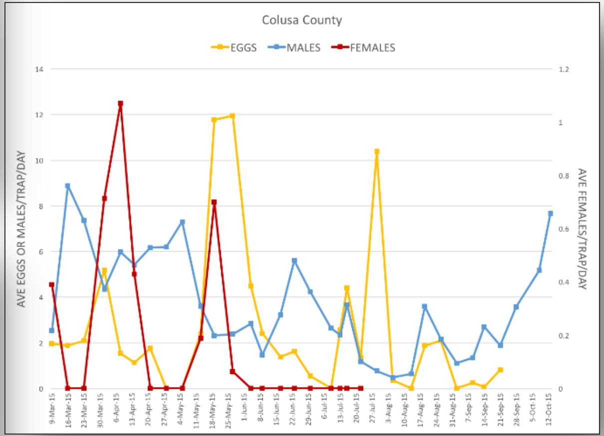
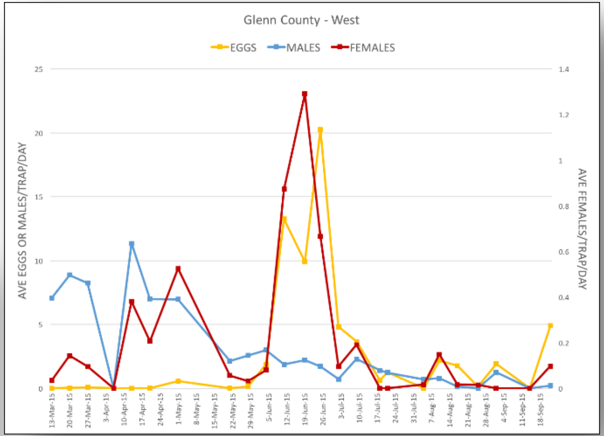
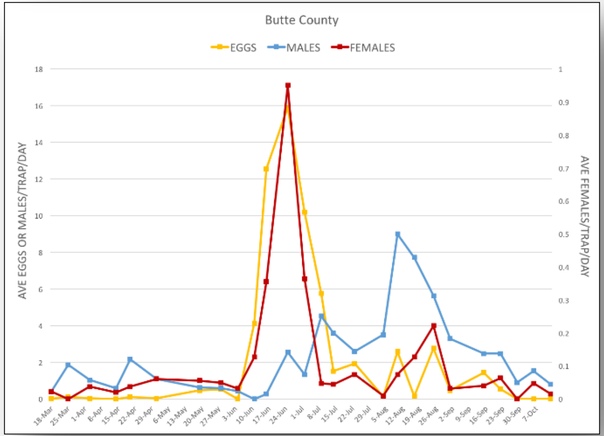
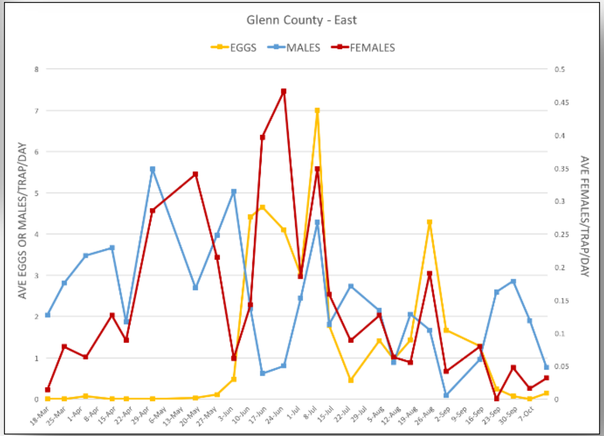
5-Oct-15
12-Oct-15


Tehama County
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY


Colusa County
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY


Glenn County - West
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY


Butte County
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY


Glenn County - East
EGGS
MALES
FEMALES
AVE EGGS OR MALES/TRAP/DAY
AVE FEMALES/TRAP/DAY

Kris Tollerup,
UCCE IPM Advisor

growing
ADVANTAGE
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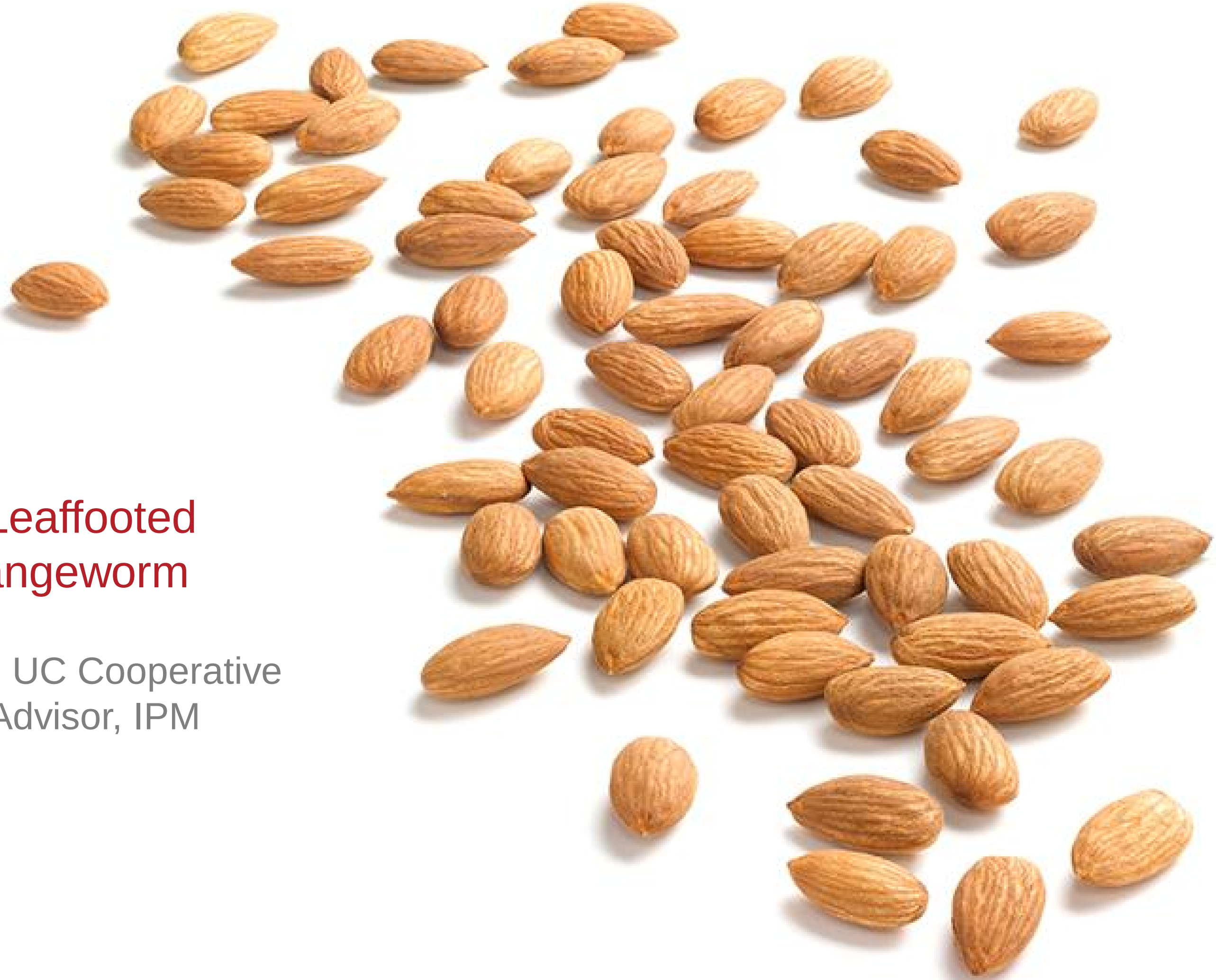
Research Update: Leaffooted Bug, and Navel Orangeworm

K. Tollerup, UC Cooperative Extension Advisor, IPM



california almonds
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Hemipteran, Leaffooted Bug

- Leaffooted bugs identified in San Joaquin Valley
  - *Leptoglossus clypealis.*
  - *Leptogolssus zonatus.*
  - *Leptoglossus occidentalis*?

Monitoring Tools

- Possible tools for monitoring during the early season
  - Pheromone, likely involved in aggregation.
  - Color traps: red, yellow, green, white, and clear.
  - Plant volatile compounds.

Monitoring Tools

- Tested various oils
  - Almond
  - Avocado
  - Coconut
  - Olive
  - Peanut
  - Walnut

Monitoring Tools

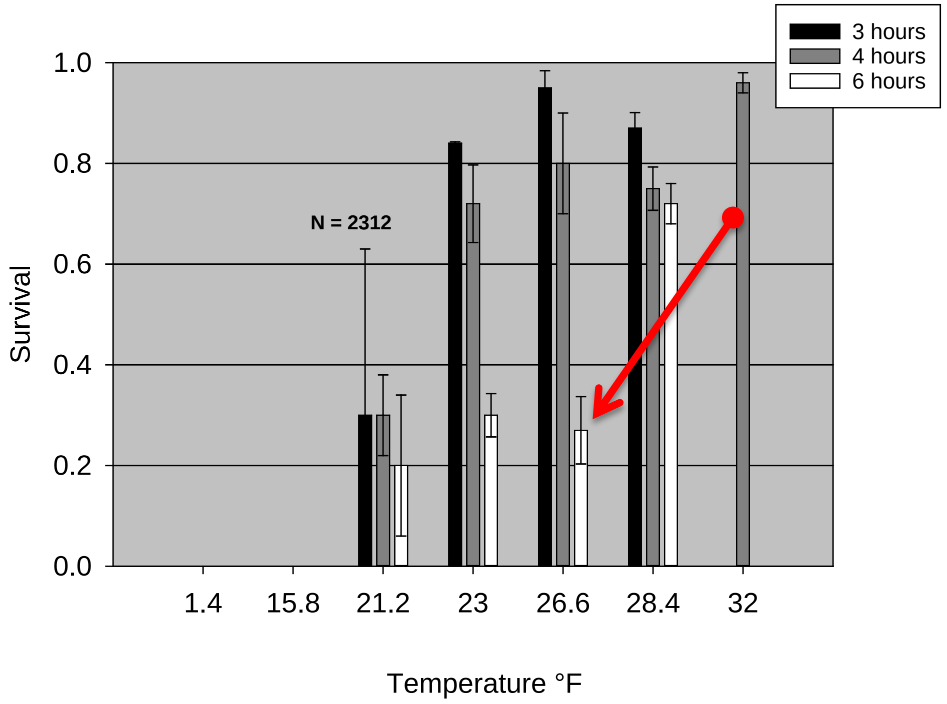
Table 2. Toxicity of various insecticides against adult leaffooted bug.

Treatment		LFB caged on *in situ* pistachio clusters at five times after treatment. Mean survival ± SEM (N = 14, n = 4)						Spray applied on LFB in laboratory. Mean survival ± SEM (N = 40, n = 4)
		24 h	7 d	14 d	21 d	28 d		24 h
Untreated control		94 ± 6.3	88 ± 13	100	100	100		88 ± 5
Brigade		0	0	0	6 ± 6.3	25 ± 5		
Warrior		44 ± 25	69 ± 16	75 ± 2.5	88 ± 13	75 ± 35		
Belay		94 ± 6.3	94 ± 6.3					5 ± 3
Beleaf		94 ± 6.3	94 ± 6.3	100	100			93 ± 3
Bexar		88 ± 7.2	69 ± 19		100			3 ± 3
Closer		94 ± 6.3	88 ± 6.3					
Exirel		100	81 ± 12	88 ± 7.2				0
Sivanto		88 ± 7.2	100					

Table 2. Toxicity of various insecticides against adult leaffooted bug.

Treatment	LFB caged on *in situ* pistachio clusters at five times after treatment. Mean survival ± SEM (N = 14, n = 4)					Spray applied on LFB in laboratory. Mean survival ± SEM (N = 40, n = 4)
	24 h	7 d	14 d	21 d	28 d	24 h
Untreated control	94 ± 6.3	88 ± 13	100	100	100	88 ± 5
Brigade	0	0	0	6 ± 6.3	25 ± 5	
Warrior	44 ± 25	69 ± 16	75 ± 2.5	88 ± 13	75 ± 35	
Belay	94 ± 6.3	94 ± 6.3				5 ± 3
Beleaf	94 ± 6.3	94 ± 6.3	100	100		93 ± 3
Bexar	88 ± 7.2	69 ± 19		100		3 ± 3
Closer	94 ± 6.3	88 ± 6.3				
Exirel	100	81 ± 12	88 ± 7.2			0
Sivanto	88 ± 7.2	100				

Leaffooted Bug, Cold Threshold



Navel Orangeworm: Monitoring

- Study to determine relationship between egg and male moth capture.
  - Two-year study
  - Eighteen field sites in six counties
    - Kern, Fresno, Madera, Merced, Stanislaus, Glenn

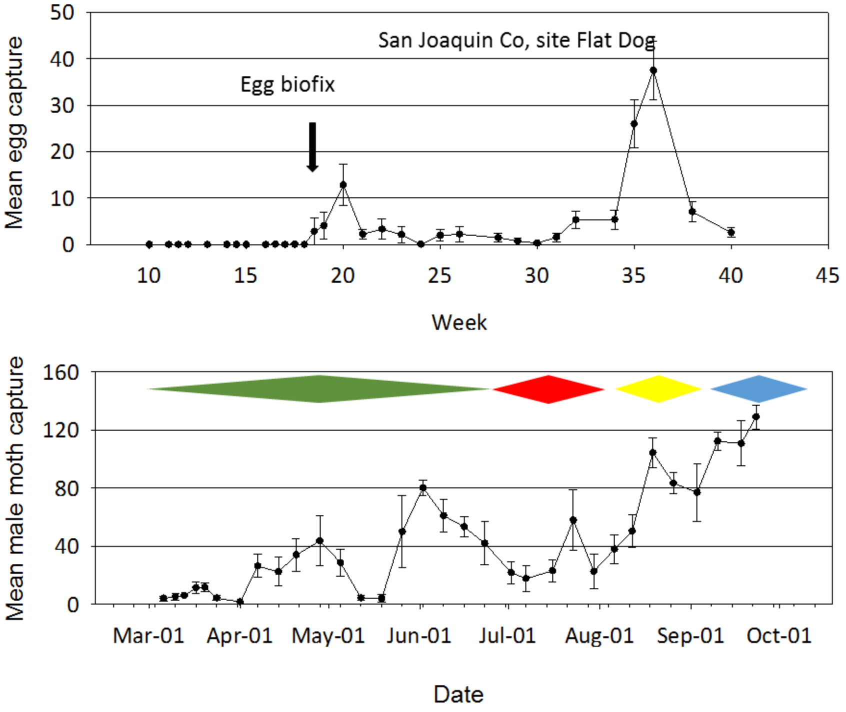


Table 3. Navel orangeworm egg and male moth capture 2014

Site	County	Biofix (egg)	week	Mean male capture at egg biofix	Date (1056 DD from biofix)	Date of DD from 1 Jan		
						700	1400	2100
Forty-five	Kern	11-Apr	15	11.2 (2.8)	28-Jun	16-May	24-Jun	24-Jul
Forty-eight	Kern	29-Apr	18	1.8 (.5)	30-Jun	16-May	24-Jun	24-Jul
Selma	Fresno	no biofix						
Ave 21	Madera	14-Apr	16	26.3 (3.7)	26-Jun	27-May	2-Jul	31-Jul
Ave 19	Madera	19-Apr	17	14 (5.9)	28-Jun	27-May	2-Jul	31-Jul
Atwater	Merced	14-Apr	16	27.3 (3.1)	24-Jun	9-May	19-Jun	20-Jul
Ba	Merced	14-Apr	16	46 (8.5)	24-Jun	9-May	19-Jun	20-Jul
Gb	Merced	14-Apr	16	0.66 (0.33)	24-Jun	9-May	19-Jun	20-Jul
La Grand	Merced	14-Apr	16	63.3 (8)	24-Jun	9-May	19-Jun	20-Jul
Rd	Merced	14-Apr	16	11 (1.7)	24-Jun	9-May	19-Jun	20-Jul
Gz	Merced	17-Apr	16	11.7 (2.7)	25-Jun	9-May	19-Jun	20-Jul
Flat Dog	San Joaquin	18-Apr	16	34 (11.1)	4-Jul	12-May	14-Jun	1-Aug
Delta College	San Joaquin	21-Apr	17	18 (1.5)	5-Jul	12-May	14-Jun	1-Aug
GB	Yolo	11-Apr	15	5.7 (0.9)	25-Jun	7-May	21-Jun	26-Jul
MA	Yolo	10-Apr	15	6.3 (2.8)	25-Jun	7-May	21-Jun	26-Jul
Ht	Glenn	14-Apr	16	35 (5.4)	26-Jun	27-May	3-Jul	1-Aug
Vg	Glenn	10-Apr	15	13.3 (2.6)	26-Jun	27-May	3-Jul	1-Aug

Thank you

Andrea Joyce,
University of California, Merced

growing
ADVANTAGE
The Almond Conference

Leaffooted Plant Bugs: Field-cage Study to Assess Damage

Andrea Joyce, University of California Merced

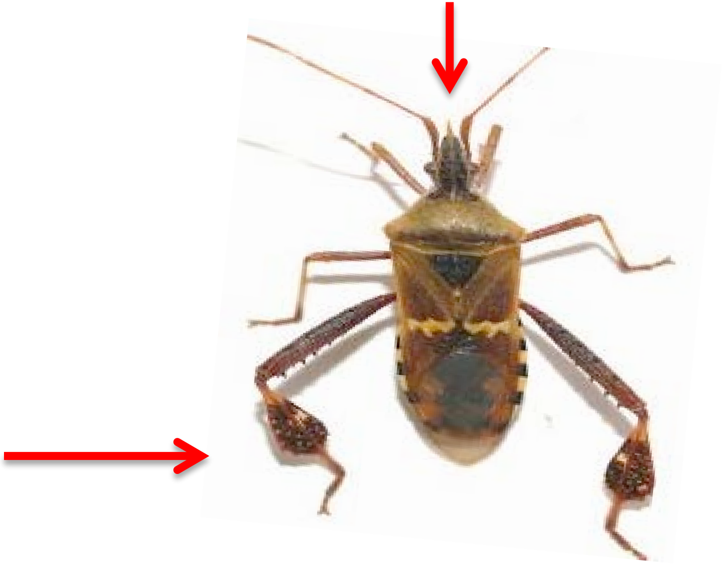
Research Updates, Dec. 10, 2015 Almond Conference



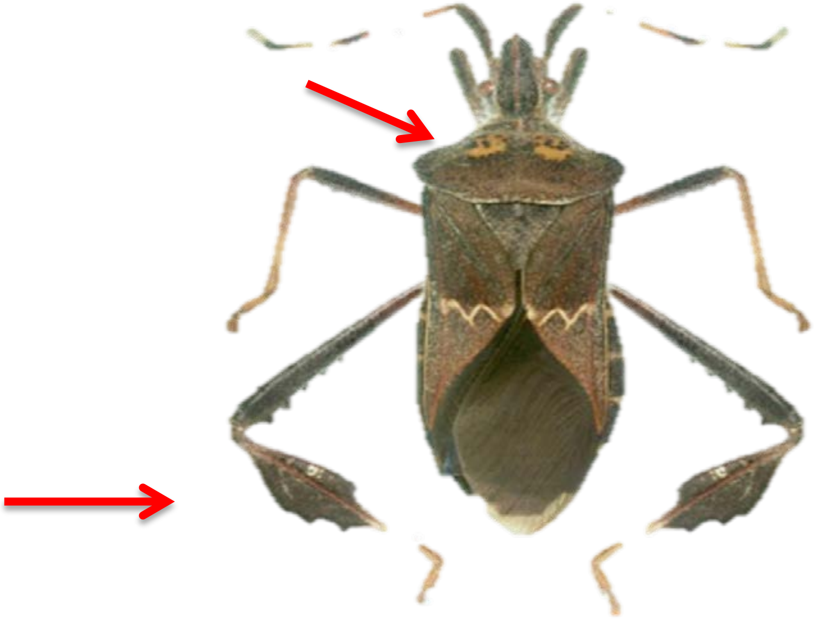
Introduction

Leaffooted Plant Bugs

L. clypealis



L. zonatus



Objectives:

- Establish a colony of Leaffooted bugs for field and lab work
- Examine species of leaffooted bugs and stinkbugs on almonds, pistachios, and pomegranates
- Conduct a field-cage study with two LFPB species feeding on almonds to determine when almonds are most susceptible to feeding damage

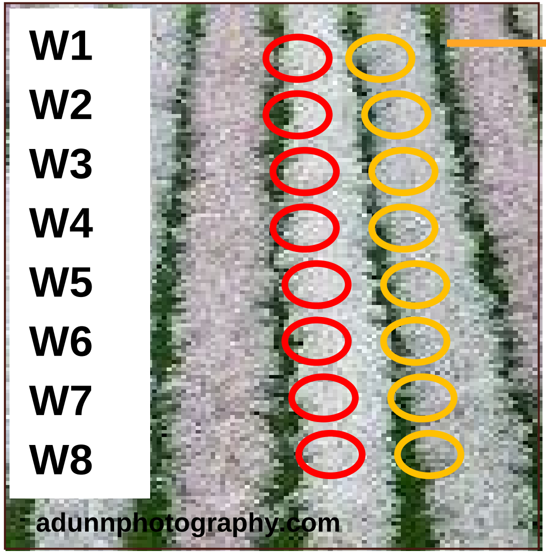
Field-cage Study of LFPB Feeding Damage

Part 1: Assess almond drop and damage by feeding Leaffooted bugs during the growing season as almonds develop

Part 2: Conduct a final assessment of almond kernel damage at harvest

Research Sites Overview

Merced



Monterey, Carmel

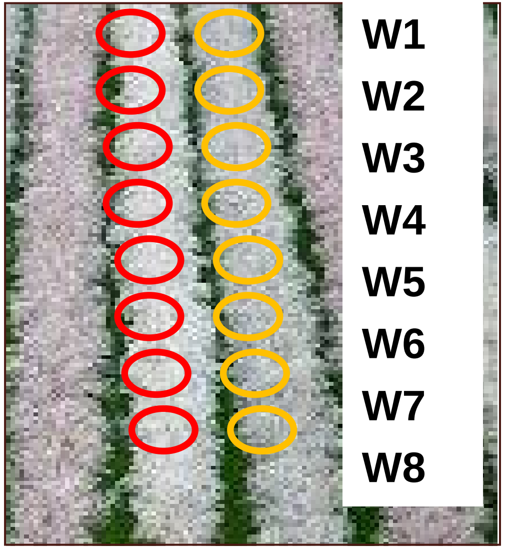
T1, T2

Control (C)
Puncture(P)
(Bugs-*Lc, Lz*)

T1

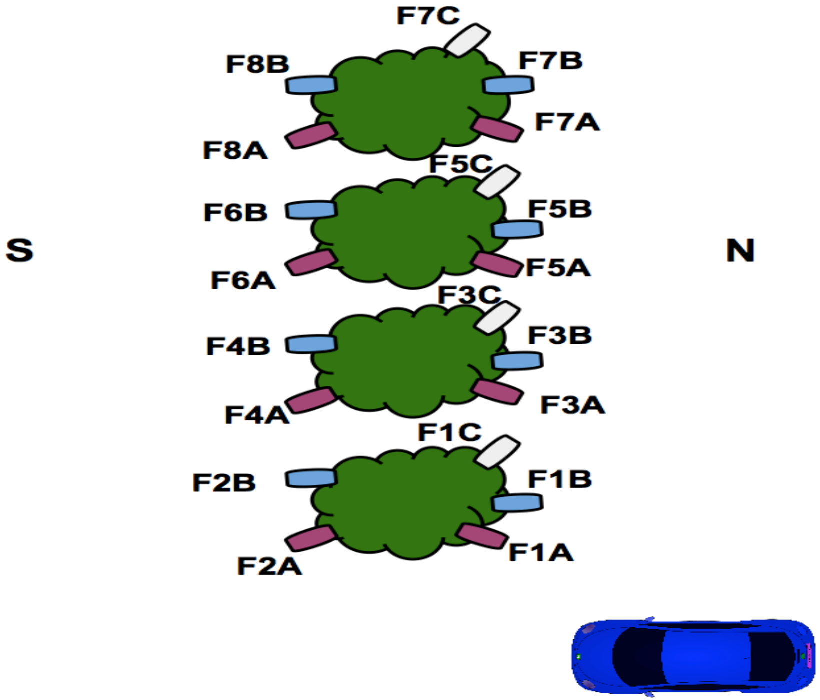
C
P

Winton

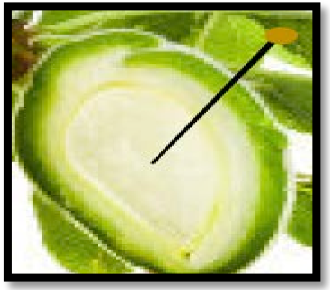


Nonpareil, Fritz

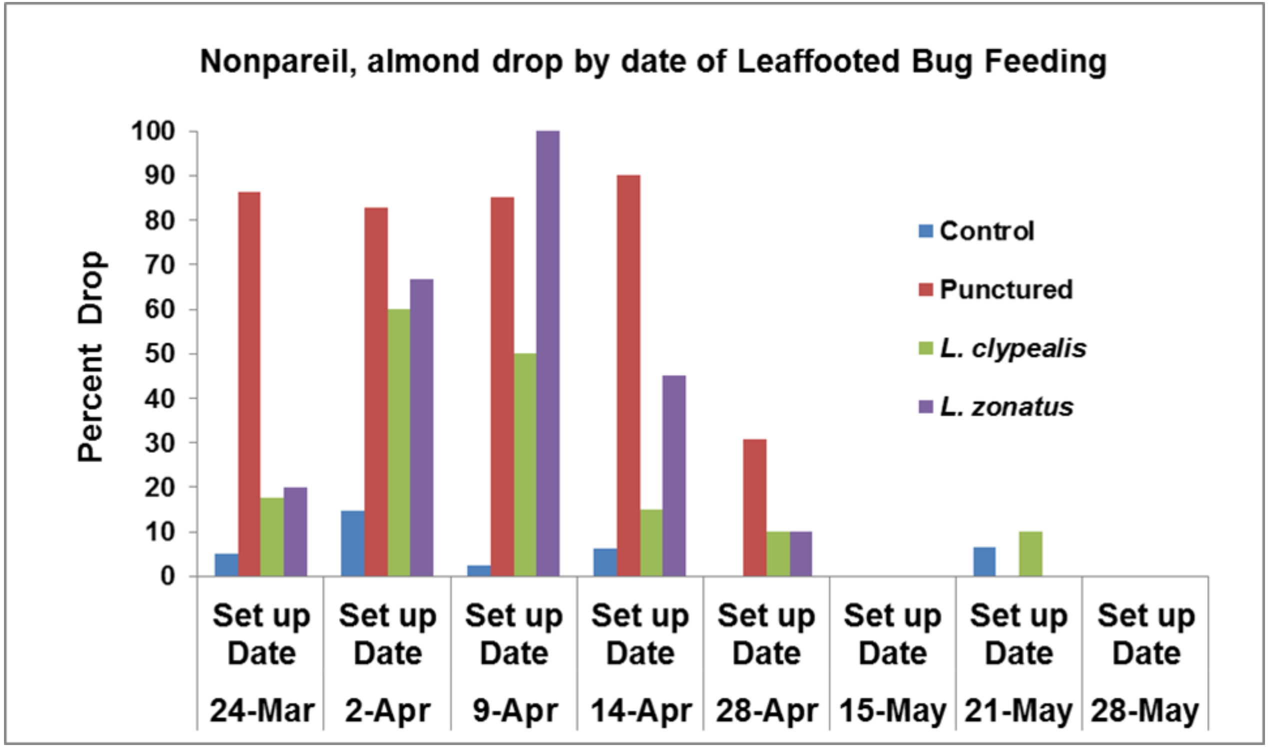
Field Cage Set Up



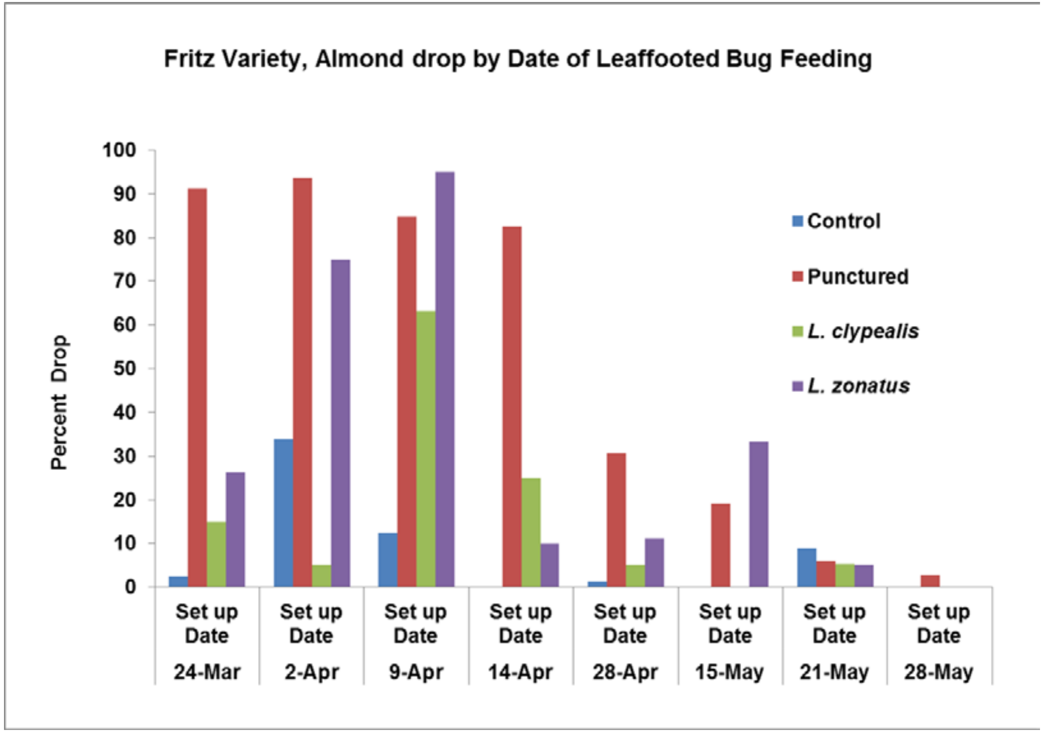
Controls (A) Punctured (B) Bug Fed (C)



Results: Date in Orchard & Almond Drop-Nonpareil



Results: Date in Orchard & Almond Drop-Fritz



Conclusions

1) 2014-2015, *L. zonatus* was the dominant LFPB observed in almonds

2) Late March through mid-April, almonds were most susceptible to drop from LFPBs

3) Most almonds drop 2 weeks after bug feeding occurs

4) Both almond drop and damage at harvest are higher from *Leptoglossus zonatus*

5) LFPBs were seen at almond harvest and pistachio harvest

6) Aggregation behavior in *L. zonatus* might be used for monitoring or trapping

Data will contribute to an IPM program for these insects

Acknowledgements

Almond Board of California

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Dani Lightle,
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Measuring Penetration Potential of Brown Marmorated Stink Bug

Dani Lightle, UC Farm Advisor,
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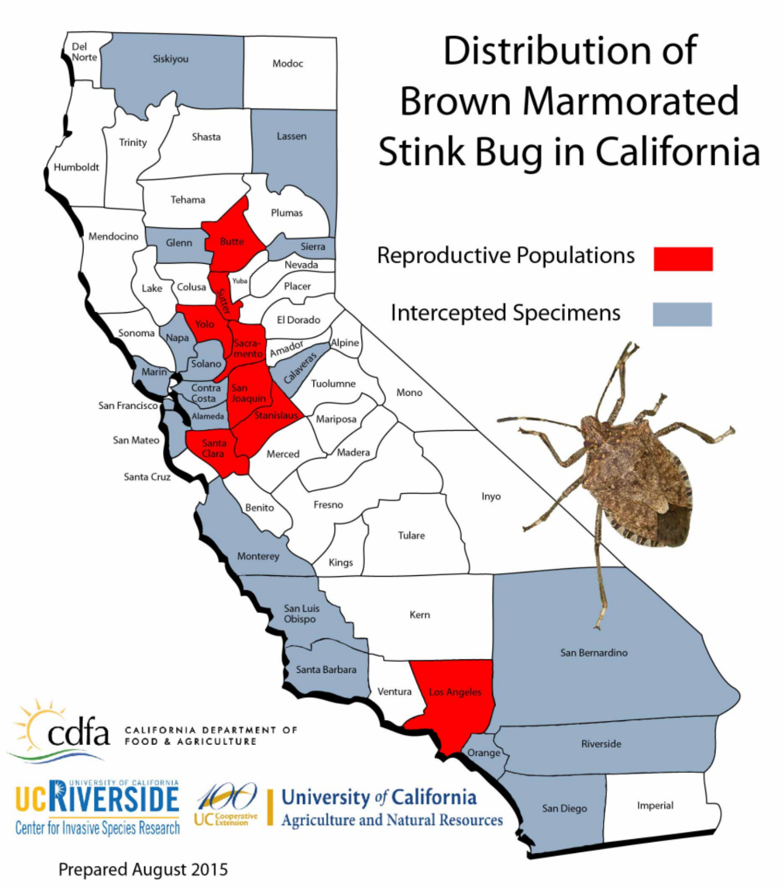
BMSB in California

- Arrived in 2012 and found in Sacramento.
- Has moved up and down I-5 corridor.
- Probably around your hotel! Take a look.



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Stinkbug damage in almonds

- Gumming
- Kernel damage
- Dropped nuts
- Other?

Objective

- Identify critical periods in almond development for kernel damage by BMSB

Methods

- 174 bugs from CDFA colony
- Measured stylet length using a microscope camera
- Calculate ‘penetration potential’

2nd instar

4th instar

adult male

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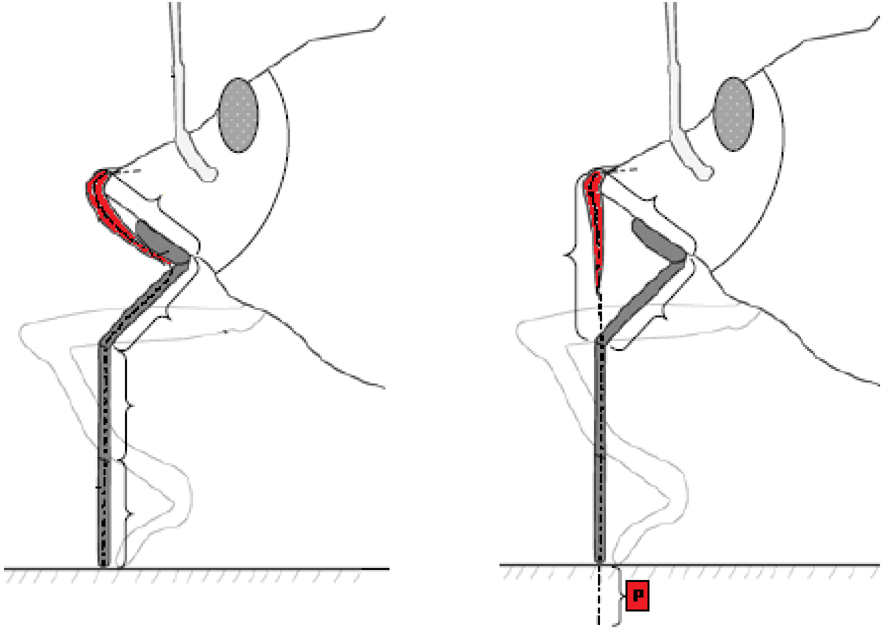
Measuring penetration potential



Results

Stage	Penetration potential
Adult Male	2.39 ± 0.017 mm
Adult Female	2.67 ± 0.018 mm

To be continued…

- Measurements of developing nuts will be taken in 2016