

North San Joaquin Valley Almond Day

Modesto Junior College Pavilion, February 10, 2015

New Research on Navel Orangeworm Management

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Entomology and Nematology

UC Davis

Recent NOW Studies

- Infestation of pre-infested nuts
- Monitoring and spring treatment timing
- Residual activity
- Spray coverage

Almond strand method

- Surrogate mummies
- Collect almonds with intact hulls in Fall
- Hot glue 20 almonds to vegetable mesh strand
- Deploy in orchards in spring according to experimental design



Pre-infested nut infestation by NOW

Percent damage and larval infestation of previously uninfested almonds vs. previously infested almonds hung in almond orchard at Manteca (Delta College) during spring navel orangeworm flight in 2013 and 2014

Treatment	Year	n=	NOW exposure	Mean \pm SD percent infestation
Uninfested	2013	20	April 16-June 5	14.4 \pm 12.4
Preinfested*	2013	9	April 16-June 5	36.7 \pm 15.5 ¹
Uninfested	2014	14	April 4-May 28	9.9 \pm 16.1
Preinfested*	2014	14	April 4-May 28	54.6 \pm 12.6 ²

* Previously infested nuts were held at -20°C for >10 weeks before deploying.

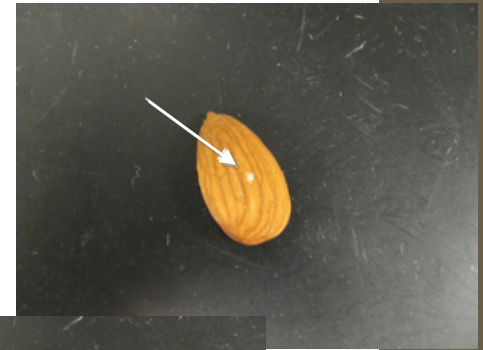
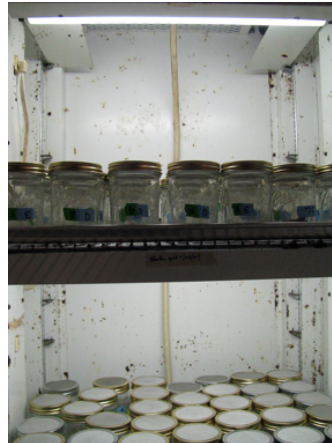
¹ ANOV statistics, $F=17.2634$, $df=1,28$, $P<0.0003$

² ANOV statistics, $F=60.2221$, $df=1,27$, $P<0.0001$

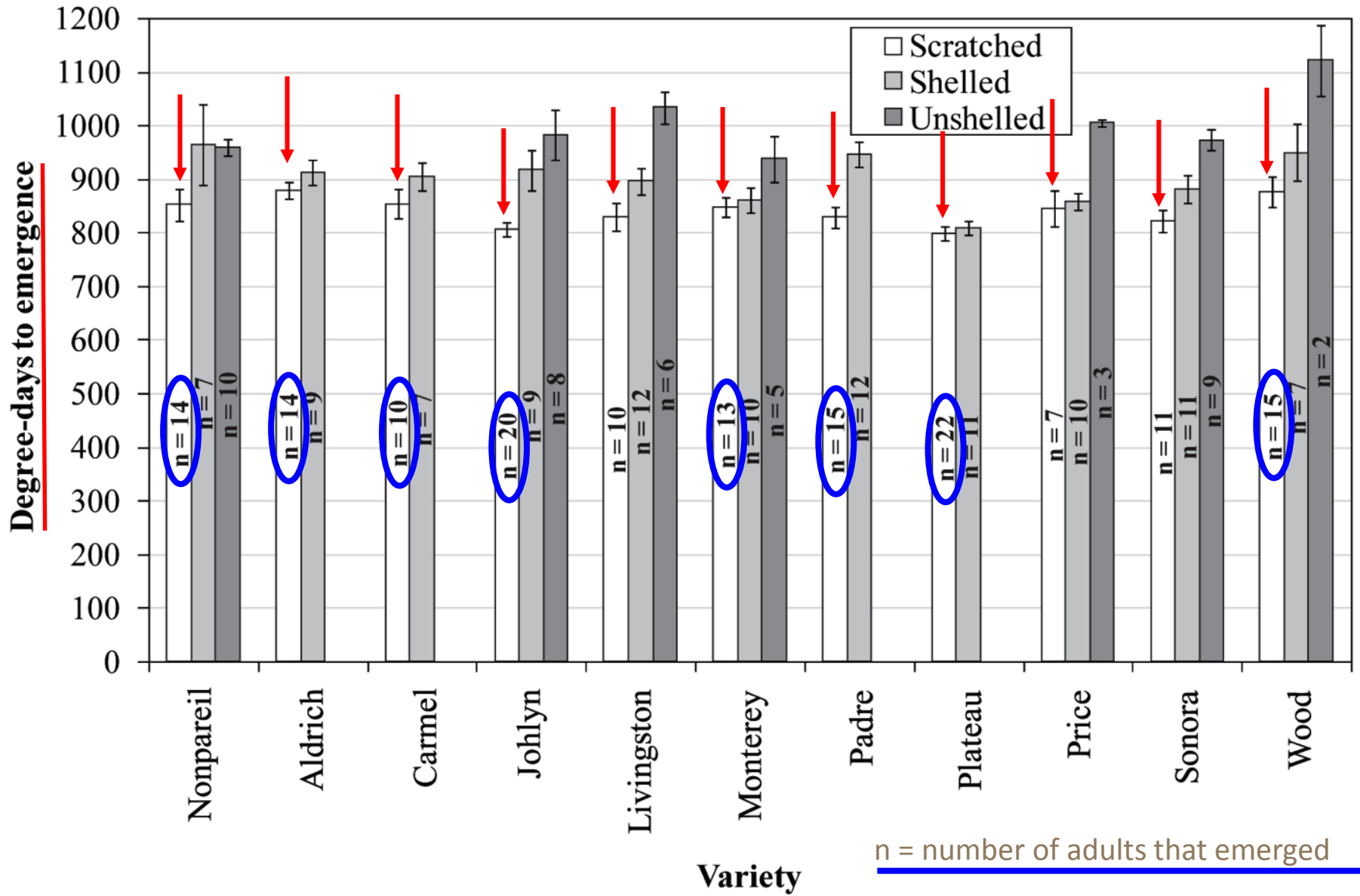
Number of mummies and especially pre-infested mummies is important

Cultivar, Damage and NOW Success

- Nuts hand-poled from trees at the harvest timing of 11 cultivars at the Delta College RAVT site in 2010
- 10 nuts of each cultivar placed into jars and infested with 20 1st instar NOW larvae
- Treatments = 1 mm scratch through pellicle, shelled (not scratched) and unshelled
- Placed in growth chamber at 25°C
- Checked daily for adult emergence



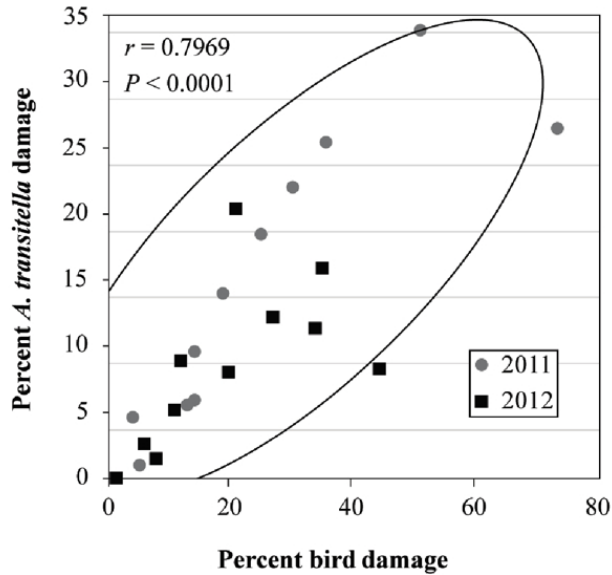
NOW female degree-days to emergence and total female moths emerging



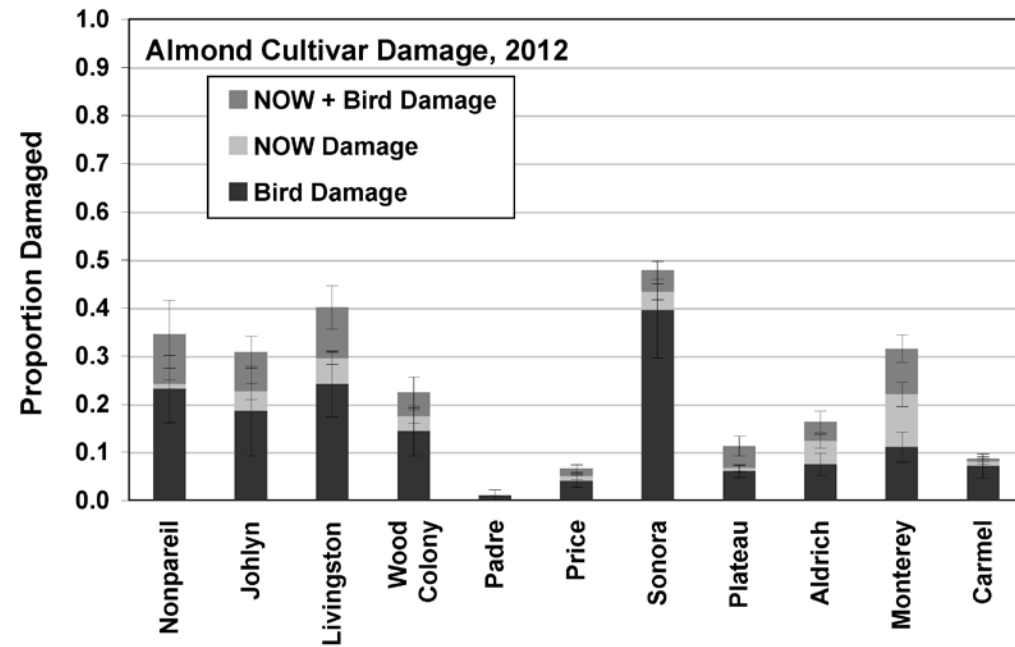
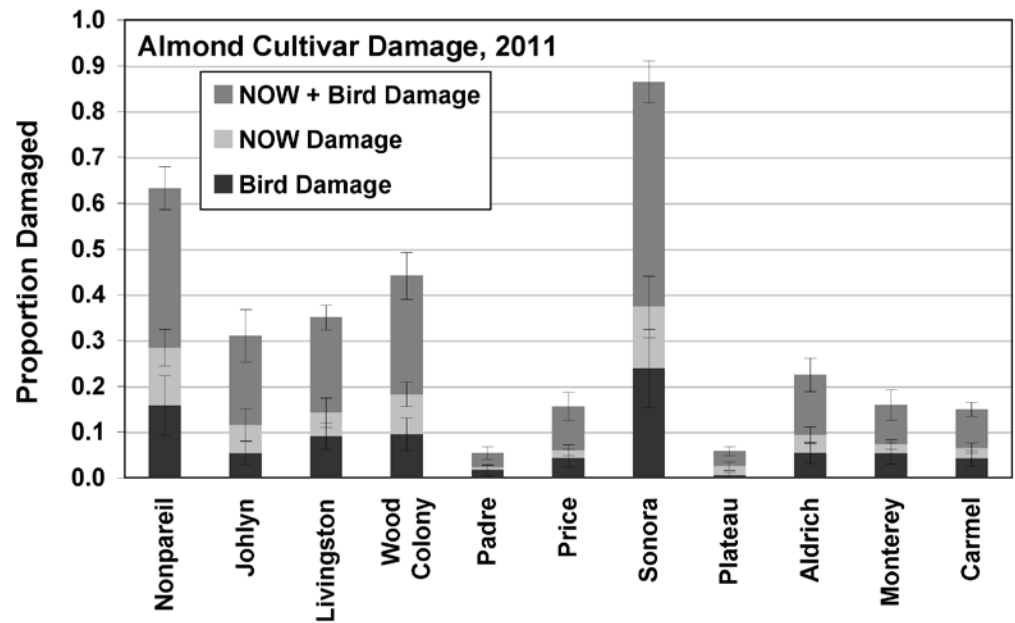


Sentinel Mummies

Percent NOW and bird damage for each cultivar, 2011 and 2012



Positive correlation between bird damage and navel orangeworm infestation:
 $r = 0.7969, n = 22, p < 0.0001$



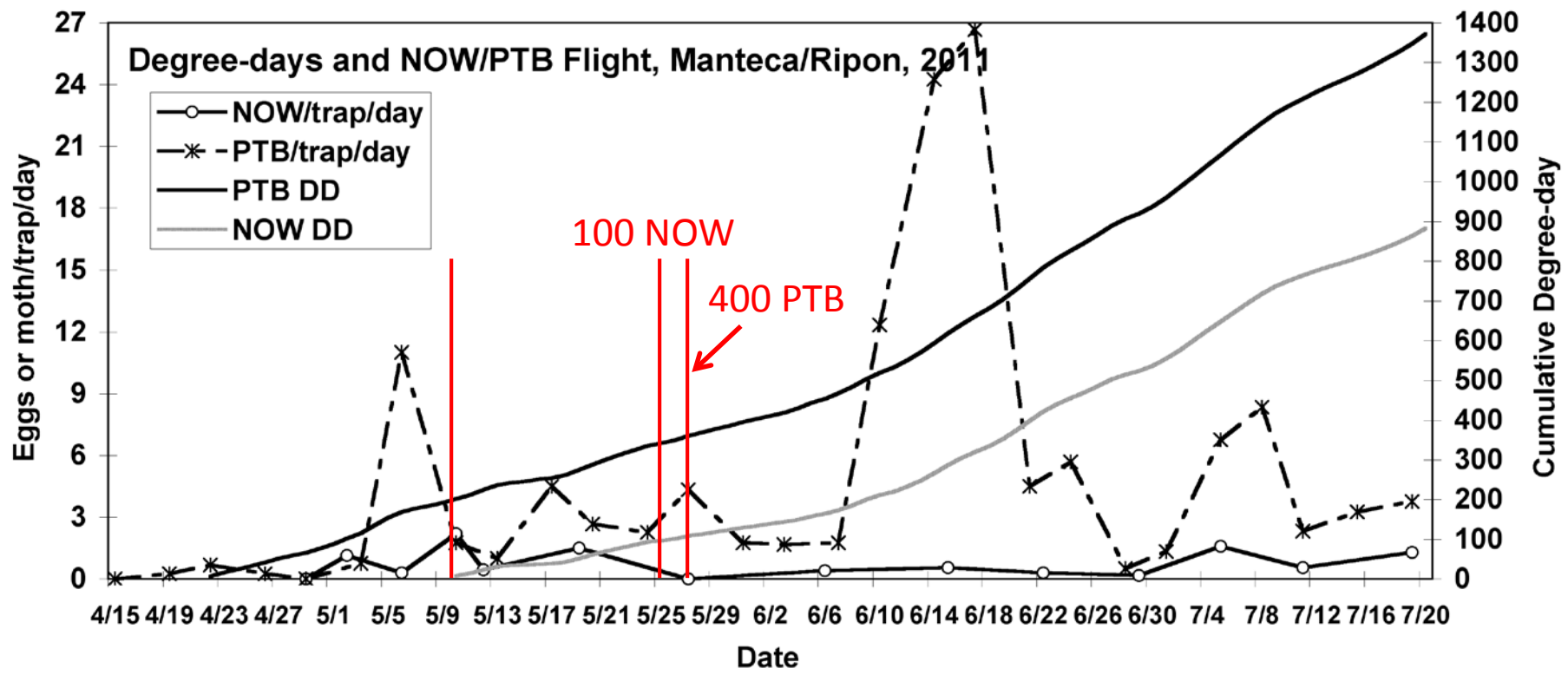
May Sprays

Peach twig borer -
400 DD after biofix
(first moth capture)

Navel orangeworm -
100 DD after biofix
(eggs on 50% of traps for 2
consecutive weeks)



Cumulative degree-days from navel orangeworm and peach twig borer biofix dates at Manteca, 2011



Percent of navel orangeworm infested mummies, Ripon, 2011

Treatment	Amt/ac	Chemical	Treatment date	Mean \pm SD ¹	percent infested
Control (water)				10.9 \pm 15.7	ABCD
Dimilin 2L	12 oz	diflubenzuron	5/25	14.3 \pm 11.5	A
diflubenzuron (generic)	12 oz	diflubenzuron	5/25	11.0 \pm 11.8	ABC
Intrepid 2F ³	16 oz	methoxyfenozide	5/10	1.7 \pm 3.7	E
Intrepid 2F ³	16 oz	methoxyfenozide	5/25	1.5 \pm 3.2	E
Intrepid 2F ³	16 oz	methoxyfenozide	5/27	0.9 \pm 2.6	E
Altacor 35WDG ³	4 oz	chlorantraniliprole	5/10	0.8 \pm 2.4	E
Altacor 35WDG ³	4 oz	chlorantraniliprole	5/25	1.9 \pm 4.2	E
Altacor 35WDG ³	4 oz	chlorantraniliprole	5/27	0.0 \pm 0.0	E
Belt 4SC ²	4 oz	flubendiamide	5/27	2.7 \pm 4.6	E
Delegate 25WG ³	4.5 oz	spinetoram	5/10	2.6 \pm 4.2	E
Delegate 25WG ³	4.5 oz	spinetoram	5/25	2.2 \pm 4.6	E
Delegate 25WG ³	4.5 oz	spinetoram	5/27	0.7 \pm 2.3	E
Dipel (2 apps)	1 lb.	Bt	5/9 & 5/27	4.9 \pm 9.3	DE
Assail 70WP	4.1 oz	acetamiprid	5/25		
+ Lambda-Cy 11.4EC	+ 2.56 oz	+ lambda cyhalothrin		4.4 \pm 6.1	CDE
Assail 70WP	4.1 oz	acetamiprid	5/25		
+ Lambda-Cy 11.4EC	+ 5.12 oz	+ lambda cyhalothrin		3.5 \pm 8.3	E
Lorsban	4 pt	chlorpyrifos	5/25	0.0 \pm 0.0	E

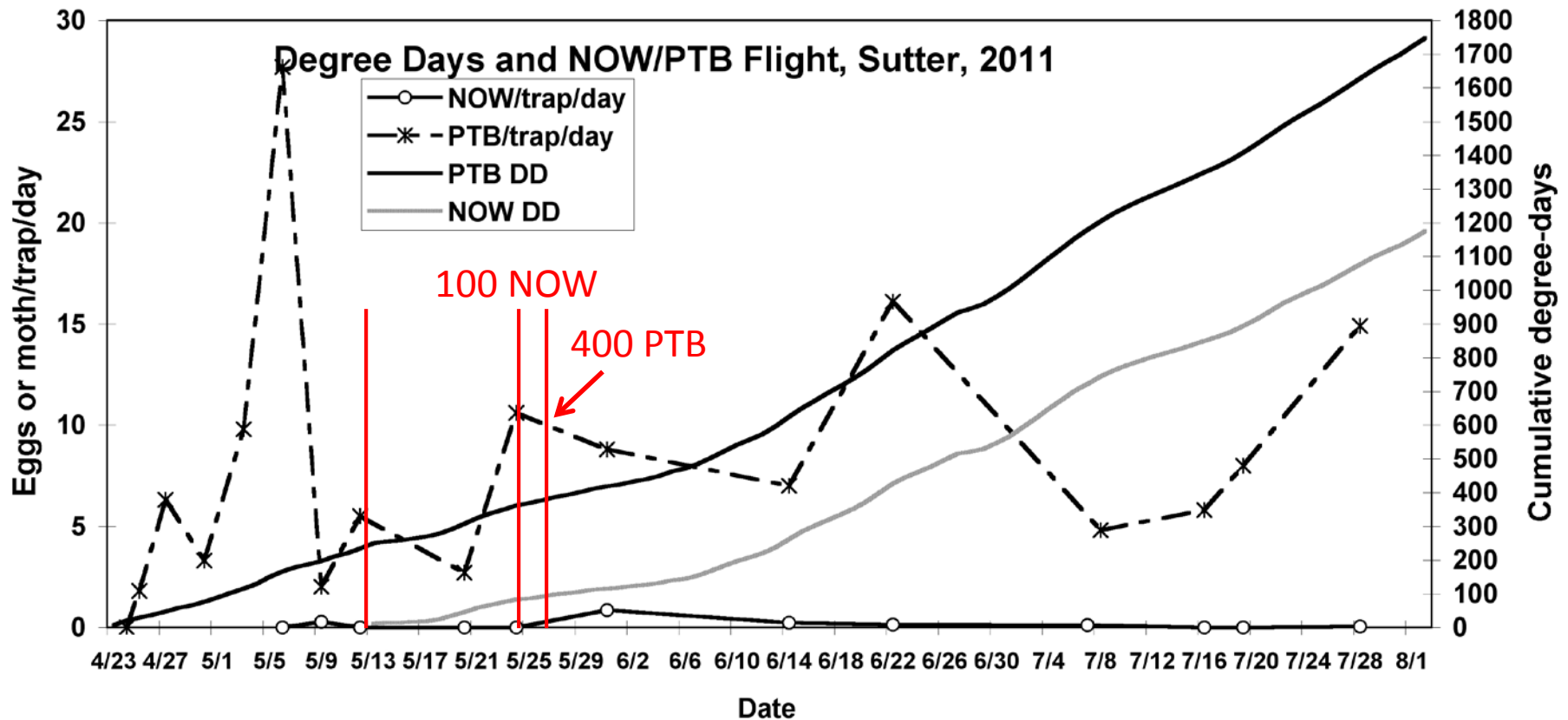
¹ ANOV statistics, $F=3.8322$, $df=21,222$, $P<0.0001$. Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test following arcsine transformation.

² Mixed with Dyne-Amic at 0.25% v/v

³ Mixed with Induce at 1.0% v/v

⁴ NOW biofix date 5/10/2011

Cumulative degree-days from navel orangeworm and peach twig borer biofix dates at Sutter, 2011



Mean (\pm SD) PTB shoot strikes per tree, Sutter, 2011

Treatment	Rate	Application date	PTB strikes/tree*	Mean \pm SD	
untreated	na	na	5.4 \pm 4.8	4.8	A
Dipel ¹	1 lb	5/9 & 5/24/11	2.3 \pm 2.9	2.9	CDE
Dimilin 2L	12 oz	5/24/11	3.5 \pm 3.0	3.0	ABCD
diflubenzuron 2L (generic)	12 oz	5/24/11	5.2 \pm 3.3	3.3	AB
Lorsban	4 pt	5/24/11	2.0 \pm 1.7	1.7	CDE
Intrepid 2F ³	16 oz	5/13/11	2.5 \pm 2.0	2.0	BCDE
Intrepid 2F ³	16 oz	5/24/11	2.0 \pm 1.5	1.5	CDE
Intrepid 2F ³	16 oz	5/26/11	2.3 \pm 1.8	1.8	CDE
Delegate WG ³	4.5 oz	5/24/11	0.5 \pm 0.5	0.5	E
Delegate WG ³	7.0 oz	5/24/11	0.3 \pm 0.5	0.5	E
Altacor ²	4.0 oz	5/13/11	0.2 \pm 0.4	0.4	E
Altacor ²	4.0 oz	5/24/11	0.2 \pm 0.4	0.4	E
Altacor ²	4.0 oz	5/26/11	0.3 \pm 0.5*	0.5*	E
Assail 70WP + Lamda-Cy EC	4.1 oz + 2.56 oz	5/24/11	0.8 \pm 0.8	0.8	DE
Assail 70WP + Lamda-Cy EC	2.3 oz + 5.12 oz	5/24/11	0.5 \pm 0.5	0.5	E
Belt SC ²	4 oz	5/24/11	0.3 \pm 0.8	0.8	E

ANOVA results - $F=4.1015$, $df=17,113$, $P<0.0001$

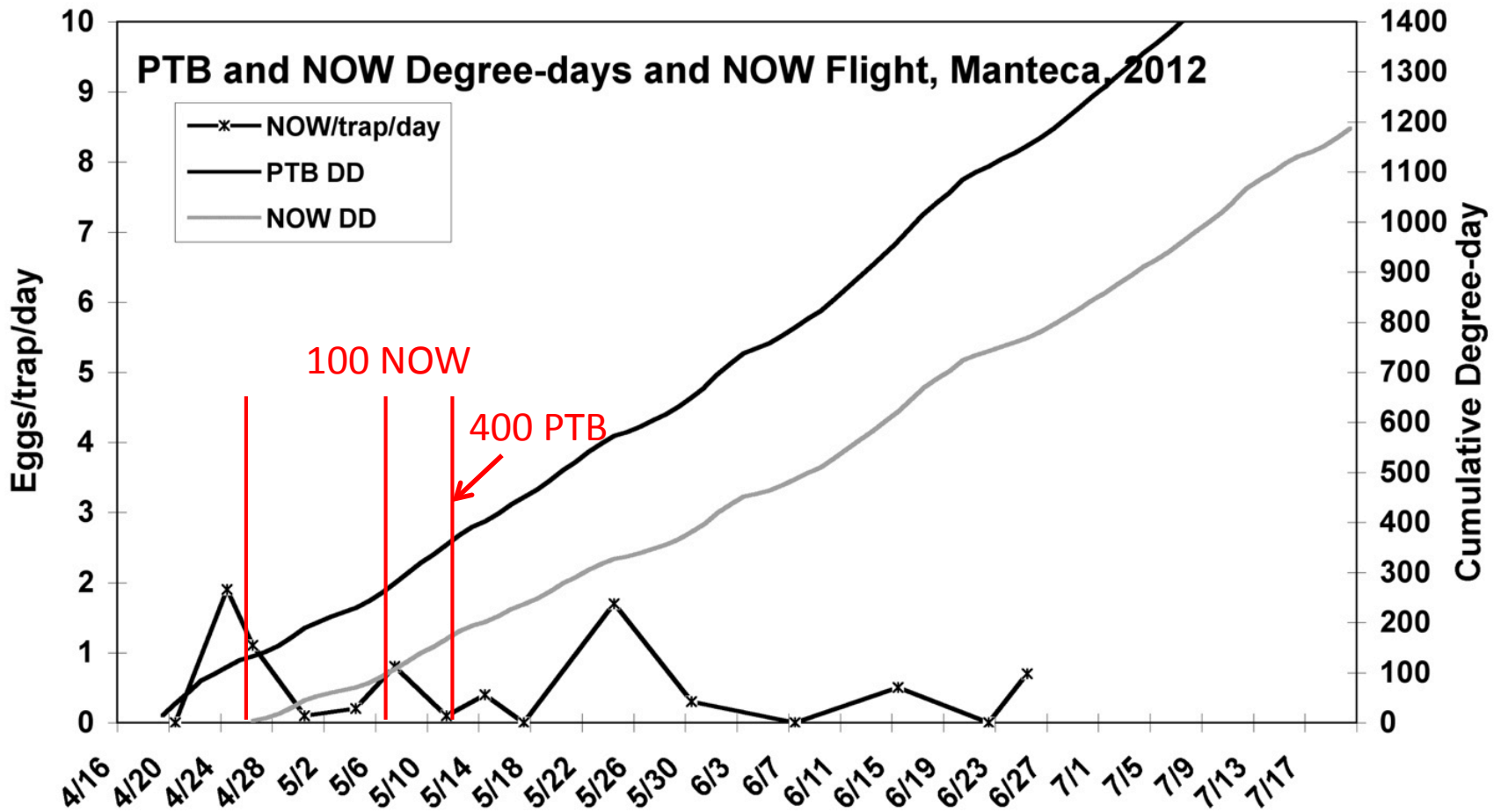
* Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test following arcsine transformation.

¹ LI-700 added @ 0.5% v/v

² Dyne-Amic added @ 0.25% v/v

³ Induce added @ 0.25% v/v

Cumulative degree-days from navel orangeworm and peach twig borer biofix dates at Manteca, 2012



Percent of navel orangeworm infested mummies, Ripon,

2012

Treatment	Amt/ac	Chemical	Treatment date	Mean ± SD ¹	percent damage
Control (water)				2.7 ± 3.2	A
Dimilin 2L ²	12 oz	diflubenzuron	5/7	2.2 ± 2.9	AB
Intrepid ²	16 oz	methoxyfenozide	5/7	0.0 ± 0.0	D
Altacor ²	4 oz	chlorantraniliprole	4/26	0.5 ± 1.7	CD
Altacor ²	4 oz	chlorantraniliprole	5/7	0.5 ± 1.7	CD
Altacor ²	4 oz	chlorantraniliprole	5/14	0.0 ± 0.0	D
Belt ²	4 oz	flubendiamide	4/26	0.0 ± 0.0	D
Belt ²	4 oz	flubendiamide	5/7	1.2 ± 2.6	BCD
Belt ²	4 oz	flubendiamide	5/14	0.0 ± 0.0	D
Tourismo ²	10 oz	flubendiamide & buprofezin	5/7	0.6 ± 1.9	CD
Tourismo ²	14 oz	flubendiamide & buprofezin	5/7	0.0 ± 0.0	D
HGW86 10SE ²	13.5 oz	cyazypyr	5/7	0.0 ± 0.0	D
HGW86 10SE ²	16.9 oz	cyazypyr	5/7	0.0 ± 0.0	D
Dipel	1 lb	Bt	5/7 & 5/17	1.6 ± 2.6	ABC
Dipel	1 lb	Bt	5/14 & 5/24	0.0 ± 0.0	D
TriTek	1 gal	mineral oil	5/7 & 5/17	2.2 ± 2.9	AB
TriTek	2 gal	mineral oil	5/14 & 5/24	1.2 ± 2.4	ABCD
Lorsban ²	4 pt	chlorpyrifos	5/7	0.0 ± 0.0	D

¹ ANOV statistics, $F=3.1868$, $df=18,198$, $P<0.0001$. Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test following arcsine transformation.

² Mixed with Dyne-Amic at 0.25% v/v

³ NOW biofix date, 4/26/2012

Conclusions from 2009-2012 studies

- Registered insecticides representing spinosyns (Delegate), diamides (Altacor, Belt), and avermectins (Proclaim) are as effective as pyrethroid and organophosphate insecticides in controlling navel orangeworm
- Among insect growth regulators, the ecdysone receptor agonist methoxyfenozide (Intrepid) is effective in controlling navel orangeworm, but the chitin synthesis inhibitor diflubenzuron (Dimilin) is not
- Diamide insecticides, spinetoram (and methoxyfenozide) are effective in controlling navel orangeworm at the recommended May treatment timing for peach twig borer

Navel Orangeworm Pheromone

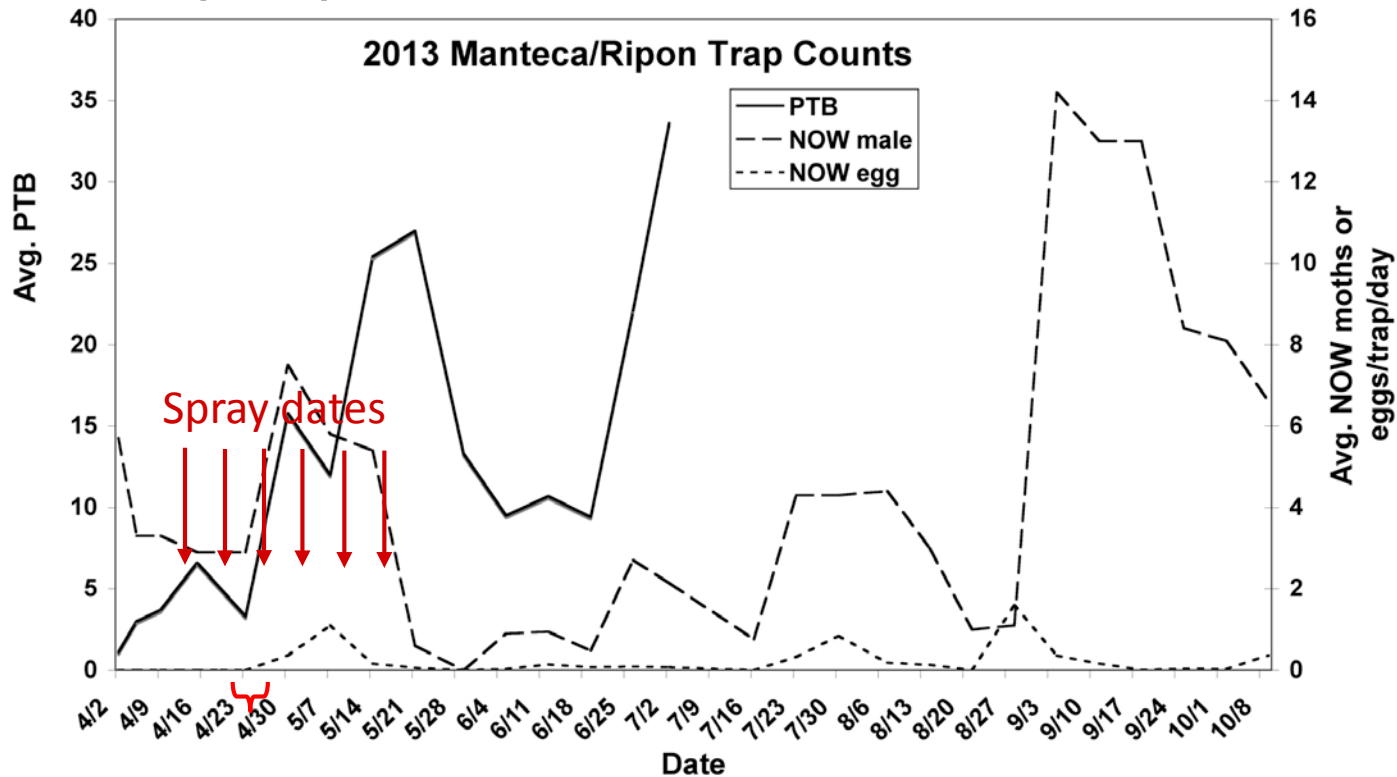
- Introduced by Suterra in late winter, 2013
- Lures capture NOW male moths in wing traps (similar to PTB pheromone lures)
- NOW male moths are captured during hullsplit and after, unlike NOW egg traps that are 'shut down' during this period

Questions?

- How do NOW male moth captures relate to NOW egg trap captures?
- How can NOW male moth captures be used to time spring treatments for NOW?

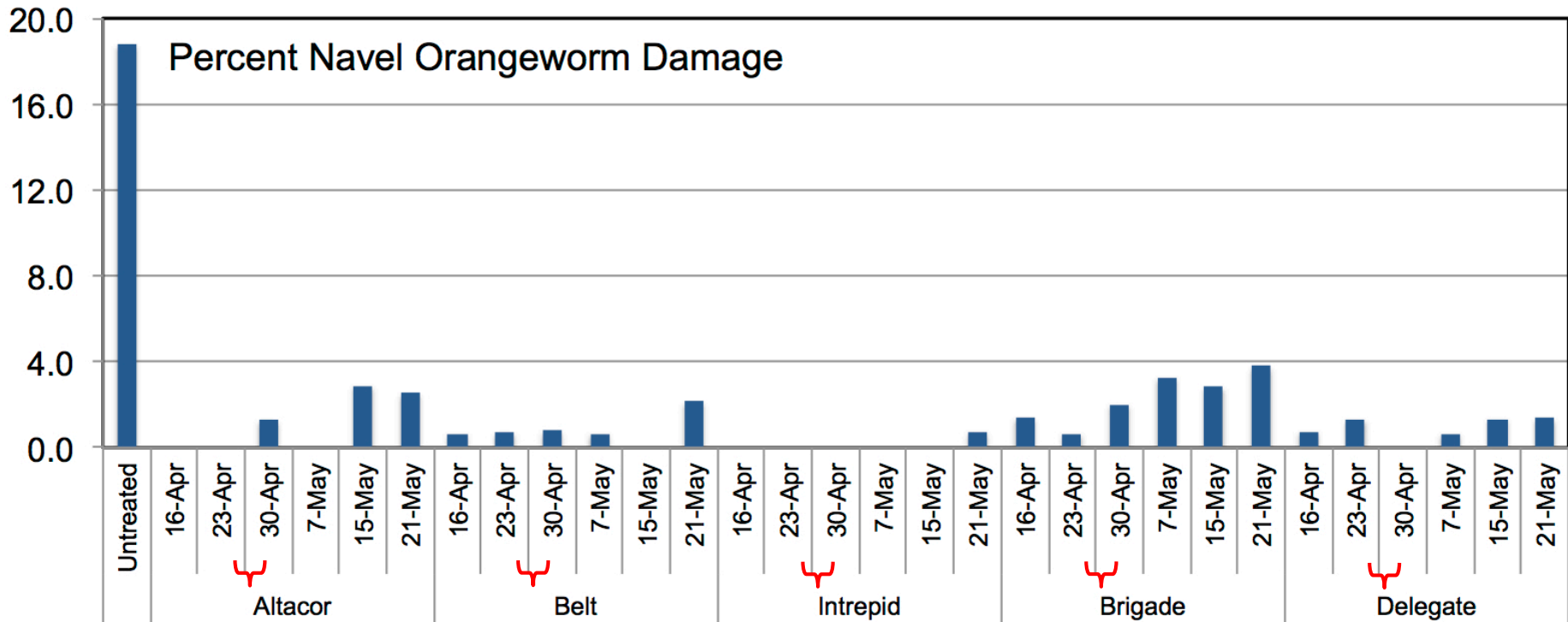
Spring treatment timing

Trap captures and treatment dates, 2013



400 PTB DD = April 28
100 NOW DD = April 26
(based on egg traps)

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, 2013.



ANOVA statistics, $F=10.9699$; $df=30,258$; $P<0.0001$

400 PTB DD = April 28
 100 NOW DD = April 26
 (based on egg traps)

Infestation and damage of almond mummies treated at weekly intervals starting at the initiation of oviposition of the overwintering flight of NOW at Ripon, 2013.

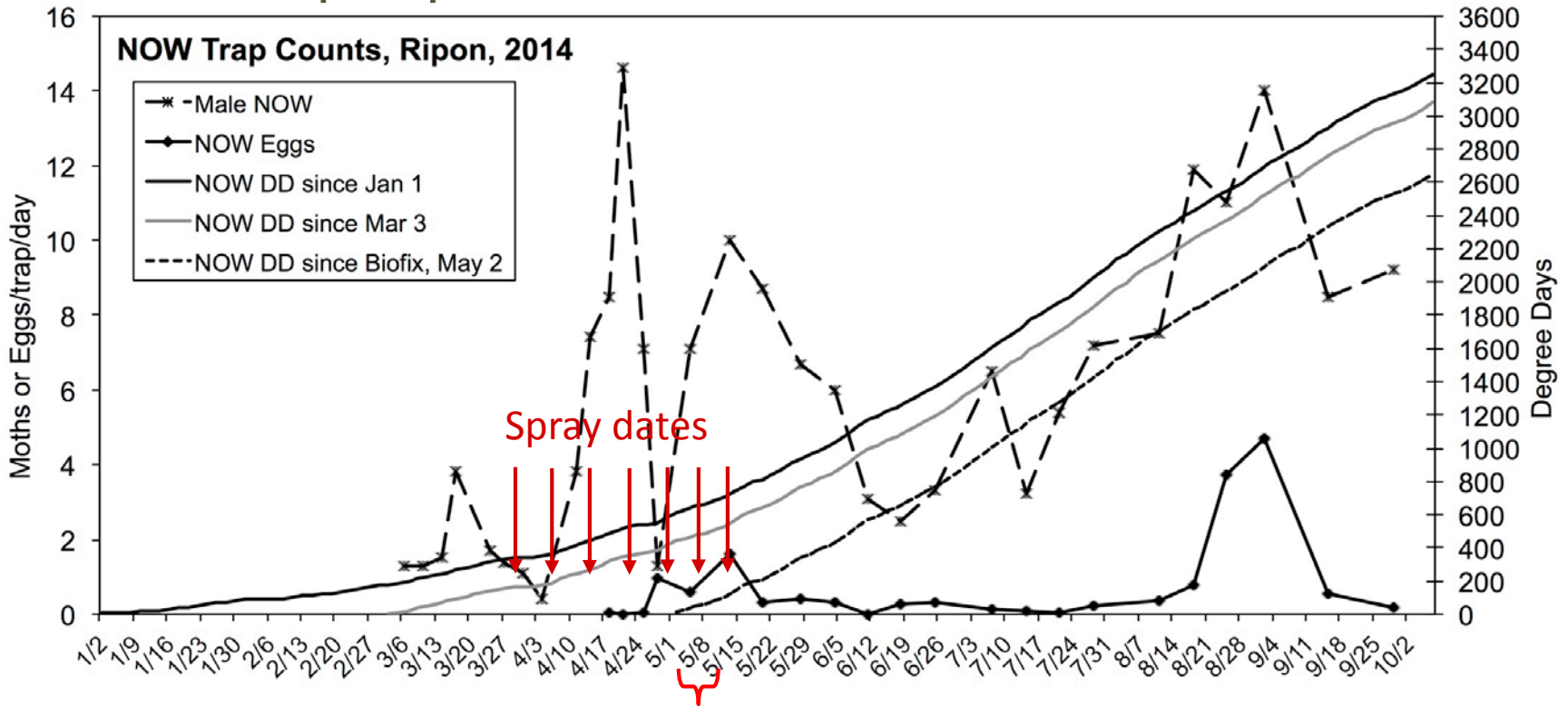
Treatment	Spray date	Rate/ac.	Mean \pm SD ¹		Mean \pm SD ²	
			% infestation		% damage	
Control	n/a	-	14.4	A	18.8 \pm 12.4	A
Altacor	4/16	4 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Altacor	4/23	4 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Altacor	4/30	4 oz.	0.0 \pm 0.0	B	1.3 \pm 2.4	B
Altacor	5/7	4 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Altacor	5/15	4 oz.	1.4 \pm 2.5	B	2.9 \pm 4.2	B
Altacor	5/21	4 oz.	1.3 \pm 3.5	B	2.5 \pm 3.8	B
Belt	4/16	4 oz.	0.7 \pm 1.9	B	0.7 \pm 1.9	B
Belt	4/23	4 oz.	0.0 \pm 0.0	B	0.7 \pm 2.0	B
Belt	4/30	4 oz.	0.0 \pm 0.0	B	0.8 \pm 2.2	B
Belt	5/7	4 oz.	0.0 \pm 0.0	B	0.7 \pm 1.9	B
Belt	5/15	4 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Belt	5/21	4 oz.	0.0 \pm 0.0	B	2.1 \pm 3.0	B
Intrepid	4/16	16 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Intrepid	4/23	16 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Intrepid	4/30	16 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Intrepid	5/7	16 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Intrepid	5/15	16 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Intrepid	5/21	16 oz.	0.0 \pm 0.0	B	0.7 \pm 2.1	B
Brigade	4/16	16 oz.	0.0 \pm 0.0	B	1.4 \pm 2.6	B
Brigade	4/23	16 oz.	0.7 \pm 2.0	B	0.7 \pm 1.9	B
Brigade	4/30	16 oz.	0.0 \pm 0.0	B	2.0 \pm 4.1	B
Brigade	5/7	16 oz.	3.0 \pm 4.2	B	3.3 \pm 3.5	B
Brigade	5/15	16 oz.	1.7 \pm 3.3	B	2.8 \pm 4.2	B
Brigade	5/21	16 oz.	0.7 \pm 2.0	B	3.8 \pm 5.2	B
Delegate	4/16	17 oz.	0.0 \pm 0.0	B	0.8 \pm 2.0	B
Delegate	4/23	17 oz.	0.0 \pm 0.0	B	1.3 \pm 2.4	B
Delegate	4/30	17 oz.	0.0 \pm 0.0	B	0.0 \pm 0.0	B
Delegate	5/7	17 oz.	0.0 \pm 0.0	B	0.7 \pm 1.9	B
Delegate	5/15	17 oz.	0.7 \pm 2.0	B	1.4 \pm 2.5	B
Delegate	5/21	17 oz.	1.4 \pm 3.9	B	1.4 \pm 3.9	B

¹ ANOVA statistics, $F=8.1816$, $df=30,258$, $P<0.0001$. Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test following arcsine transformation.

² ANOVA statistics, $F=10.9699$, $df=30,258$, $P<0.0001$. Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test following arcsine transformation.

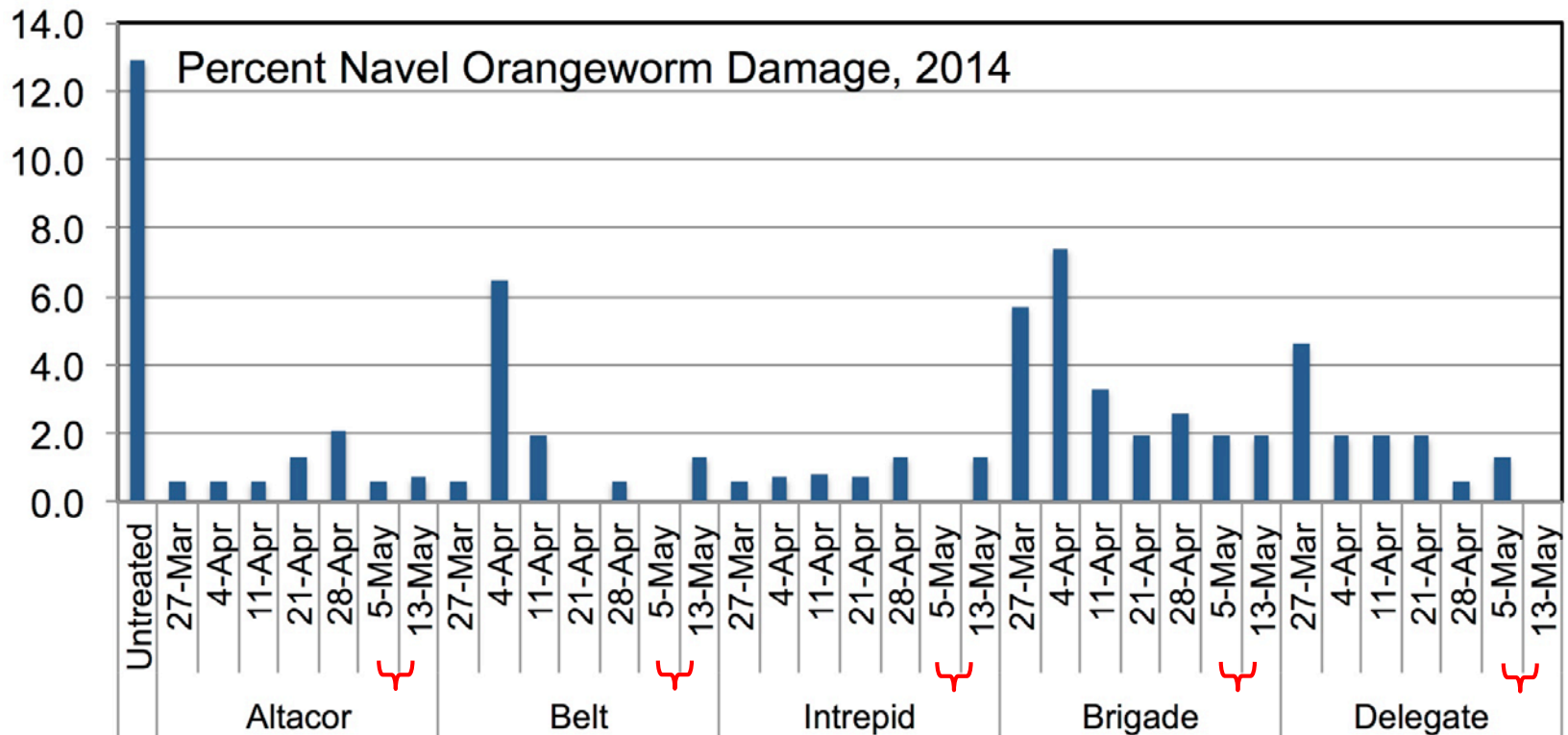
Spring treatment timing

Trap captures and treatment dates, 2014



400 PTB DD = May 4
100 NOW DD = May 12
(based on egg traps)

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, 2014.



ANOVA statistics, $F=5.3717$, $df=35,317$, $P<0.0001$

400 PTB DD = May 4
 100 NOW DD = May 12
 (based on egg traps)

Infestation and damage of almond mummies treated at weekly intervals starting at the initiation of oviposition of the overwintering flight of NOW at Ripon, 2014.

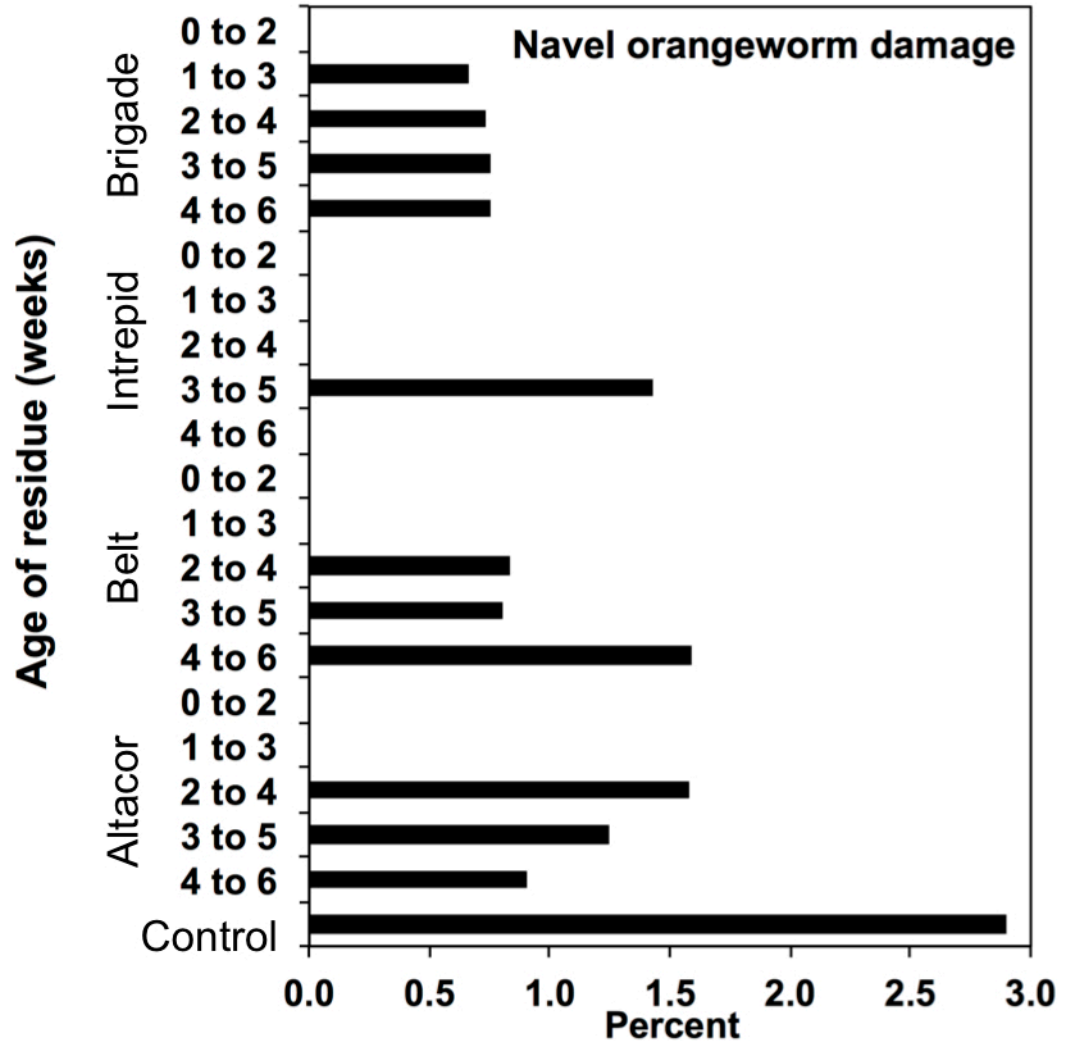
Treatment	Spray date	Rate/ac.	Mean \pm SD ¹			Mean \pm SD ²		
			% infestation			% damage		
Control	n/a	-	11.6	12.2	A	12.9 \pm 10.8	A	
Altacor	3/27	4 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Altacor	4/4	4 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Altacor	4/11	4 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Altacor	4/21	4 oz.	0.9 \pm 2.5	BC	1.3 \pm 3.5	DE		
Altacor	4/28	4 oz.	0.0 \pm 0.0	C	2.1 \pm 2.8	CDE		
Altacor	5/5	4 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Altacor	5/13	4 oz.	0.9 \pm 2.5	BC	0.7 \pm 1.9	DE		
Belt	3/27	4 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Belt	4/4	4 oz.	0.7 \pm 1.9	C	6.5 \pm 8.8	BC		
Belt	4/11	4 oz.	0.0 \pm 0.0	C	1.9 \pm 2.7	CDE		
Belt	4/21	4 oz.	0.0 \pm 0.0	C	0.0 \pm 0.0	E		
Belt	4/28	4 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Belt	5/5	4 oz.	0.0 \pm 0.0	C	0.0 \pm 0.0	E		
Belt	5/13	4 oz.	0.0 \pm 0.0	C	1.3 \pm 2.4	DE		
Intrepid	3/27	16 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Intrepid	4/4	16 oz.	0.0 \pm 0.0	C	0.7 \pm 2.0	DE		
Intrepid	4/11	16 oz.	0.0 \pm 0.0	C	0.8 \pm 2.2	DE		
Intrepid	4/21	16 oz.	0.0 \pm 0.0	C	0.7 \pm 1.9	DE		
Intrepid	4/28	16 oz.	0.0 \pm 0.0	C	1.3 \pm 2.4	DE		
Intrepid	5/5	16 oz.	0.0 \pm 0.0	C	0.0 \pm 0.0	E		
Intrepid	5/13	16 oz.	0.0 \pm 0.0	C	1.3 \pm 2.4	DE		
Brigade	3/27	16 oz.	5.7 \pm 9.1	B	5.7 \pm 7.8	BCD	}	
Brigade	4/4	16 oz.	1.4 \pm 2.6	BC	7.4 \pm 11.5	B		
Brigade	4/11	16 oz.	1.0 \pm 2.9	BC	3.3 \pm 3.9	BCDE	}	
Brigade	4/21	16 oz.	1.7 \pm 3.3	BC	1.9 \pm 2.6	CDE		
Brigade	4/28	16 oz.	2.2 \pm 3.1	BC	2.6 \pm 2.8	BCDE	}	
Brigade	5/5	16 oz.	0.0 \pm 0.0	C	1.9 \pm 2.7	CDE		
Brigade	5/13	16 oz.	2.1 \pm 5.9	BC	1.9 \pm 2.7	CDE	}	
Delegate	3/27	7 oz.	2.2 \pm 6.2	BC	4.6 \pm 5.8	BCDE		
Delegate	4/4	7 oz.	0.0 \pm 0.0	C	1.9 \pm 2.7	CDE	}	
Delegate	4/11	7 oz.	0.0 \pm 0.0	C	1.9 \pm 2.7	CDE		
Delegate	4/21	7 oz.	0.9 \pm 2.5	BC	1.9 \pm 3.8	CDE	}	
Delegate	4/28	7 oz.	0.0 \pm 0.0	C	0.6 \pm 1.8	DE		
Delegate	5/5	7 oz.	0.0 \pm 0.0	C	1.3 \pm 2.4	DE	}	
Delegate	5/13	7 oz.	0.0 \pm 0.0	C	0.0 \pm 0.0	E		

¹ ANOVA statistics, $F=5.0621$, $df=35,317$, $P<0.0001$. Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test following arcsine transformation.

² ANOVA statistics, $F=5.3717$, $df=35,317$, $P<0.0001$. Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test following arcsine transformation.

Residual activity

Average percent navel orangeworm damage resulting from nuts pre-treated weekly over a six week period and then simultaneously exposed to navel orangeworm oviposition for a two week period in a commercial almond orchard near Ripon in May, 2013.



The period when residues were sufficient to avoid infestation was about 2 weeks for Brigade, 4 weeks for Intrepid, 3 weeks for Belt, and 3 weeks for Altacor.

Spray coverage – CURES, Colusa Co., 2014

Navel orangeworm drift and efficacy study

- 1) Determine the spray deposition on targeted trees and off-target areas for a typical grower spray application rate **comparing** three methods of application--inward-only spraying (outside nozzle shut off), conventional application (nozzles operating in both directions), and gear up /throttle down treatment
- 2) Establish efficacy for navel orangeworm control on almond nuts at hullsplit for each of these methods

Spray coverage – CURES, Colusa Co., 2014

GEAR UP/THROTTLE DOWN?

- Tractor engine speed and PTO output are reduced
- Ground speed increased,
- Larger nozzle size
- Application rate and tank mix remain the same
- Result is larger droplet size and reduced drift

Spray coverage – CURES, Colusa Co., 2014

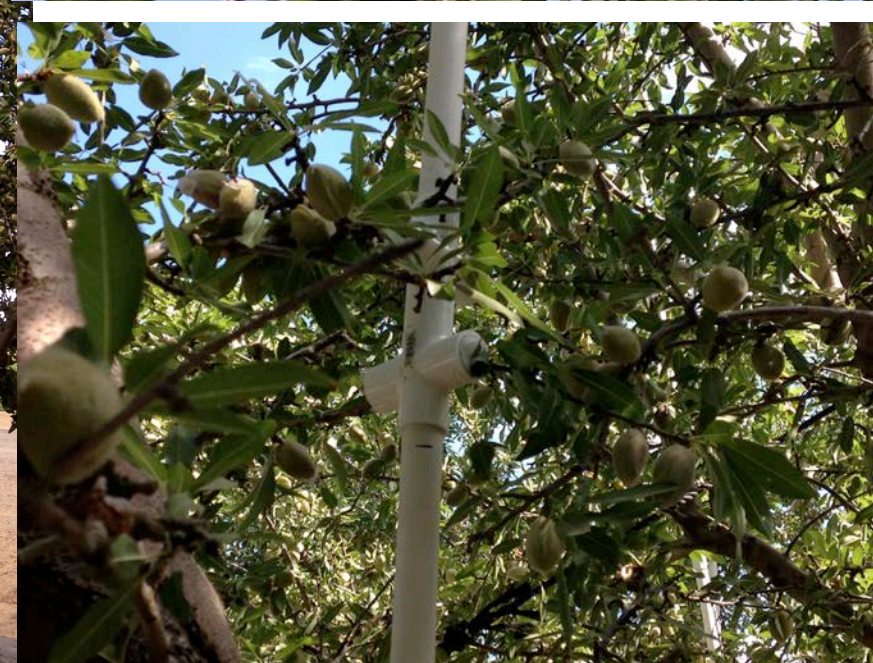
Navel orangeworm efficacy

- Mature (orange) eggs laid on paper towels cut into strips containing 10 eggs, strips were pinned to almonds at 8' and 16' in tree canopy
- 4 reps per treatment and replicate
- Papers collected after application and returned to UC Davis and placed into individual Petri dishes containing NOW diet
- Larval survival determined after 17 days

Spray coverage – CURES, Colusa Co., 2014

Navel orangeworm efficacy

- 13 nuts collected from each treatment and replicate at both 8' and 16' heights and from in canopy and near outside of canopy (52 nuts per treatment and replicate)
- Collected at 1 day and 14 days after application
- Returned to UC Davis and marked with permanent pin for identification
- Egg strip (10 eggs) pinned to each nut
- Nuts with egg strips from each treatment and replicate placed into individual containers
- Infestation determined after 6 weeks



Percent navel orangeworm larval survival at 17 days from eggs pinned to almonds at 8' and 16' heights during application Colusa Co., 2014.

Treatment	Height	n=	Mean % NOW Survival \pm SD ¹	
Control	8 ft.	4	56.5 \pm 8.2	A
Control	16 ft.	4	56.5 \pm 7.5	A
GUTD	8 ft.	4	1.0 \pm 2.0	C
GUTD	16 ft.	4	5.0 \pm 6.6	C ←
Inward Only	8 ft.	4	8.0 \pm 3.7	C
Inward Only	16 ft.	4	21.0 \pm 9.6	B ←
Standard Spray	8 ft.	4	2.0 \pm 4.0	C
Standard Spray	16 ft.	4	5.5 \pm 7.2	C ←

¹ Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test.

$F=51.9373$, $df=7,31$ $P<.0001$ (Data not transformed; normal distribution)

Percent navel orangeworm infestation from eggs pinned to almonds 14 days after treatment that were collected at 8' and 16' heights from the inner and outer canopy Colusa Co., 2014.

Treatment	Height	Location	n=	Mean % Infested			
				Nuts	± SD ¹		
Control	8 ft.	n/a	4	53.8	± 3.1		AB
Control	16 ft.	n/a	4	56.7	± 10.1		A
GUTD	8 ft.	In	4	5.9	± 4.0		FG
GUTD	8 ft.	Out	4	3.8	± 4.4		G
GUTD	16 ft.	In	4	15.4	± 10.9	}	EFG
GUTD	16 ft.	Out	4	28.8	± 13.1		BCDE
Inward Only	8 ft.	In	4	23.1	± 6.3		CDE
Inward Only	8 ft.	Out	4	17.3	± 20.2		EFG
Inward Only	16 ft.	In	4	38.5	± 6.3	}	ABCD ←
Inward Only	16 ft.	Out	4	23.1	± 19.9		DEF
Standard Spray	8 ft.	In	4	5.8	± 3.8		FG
Standard Spray	8 ft.	Out	4	3.8	± 4.4		G
Standard Spray	16 ft.	In	4	44.2	± 23.8	}	ABC ←
Standard Spray	16 ft.	Out	4	15.4	± 16.6		EFG

¹ Means followed by the same letter do not differ significantly at $P=0.05$ by Student's t-test

$F=6.6972$, $df=13,55$ $P<.0001$ (arcsine transformed data)

North San Joaquin Valley Almond Day

Modesto Junior College Pavilion, February 10, 2015

New Research on Navel Orangeworm Management

Frank Zalom

Entomology and Nematology

UC Davis