# "Navel Orangeworm Monitoring and Management"

## Central Valley Almond Day


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# Outline

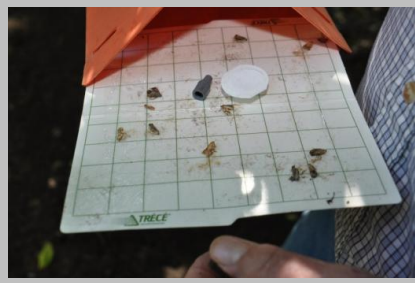
- Intro
- Monitoring for NOW
  - Trapping
  - Early HS evals
- NOW Management
  - Sanitation
  - Insecticides
  - Mating Disruption

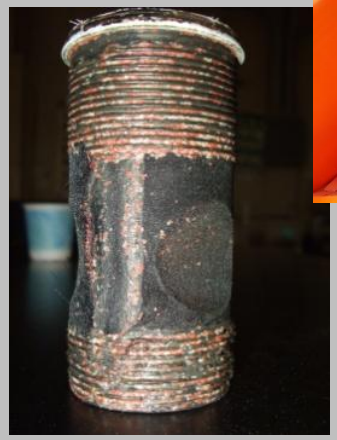

# NOW damage at Historical levels in 2017

- Highest seen since 2006 in many orchards
- Heavy pressure came on late, 3rd and 4th flights
- Monitoring able to give some warning, but growers must be able to respond rapidly
- 2018 may be similar
- What can be done to keep damage at acceptable levels?

# Trapping for NOW

- Pheromone Lure
- Almond/Pistachio/mummy baits
- PPO lure (attracts males and females)
- Synthetic Kairomone lure (under development)



# Early HS monitoring

- Spend 5-10 mins (3-5 trees) at each location starting when very 1st nuts split – typically south edges
- Collect evenly from upper and lower canopy
- Up to 30 split nuts
- Examine for NOW infestation – record % Infested at each location

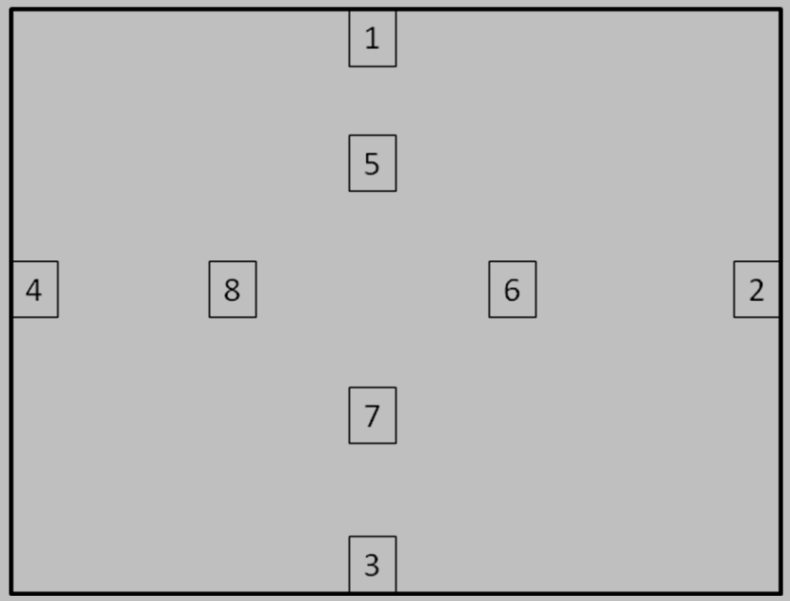
# What is your objective?

- Timing for insecticide spray appls
- Spray application decision
- Under or influenced by MD?

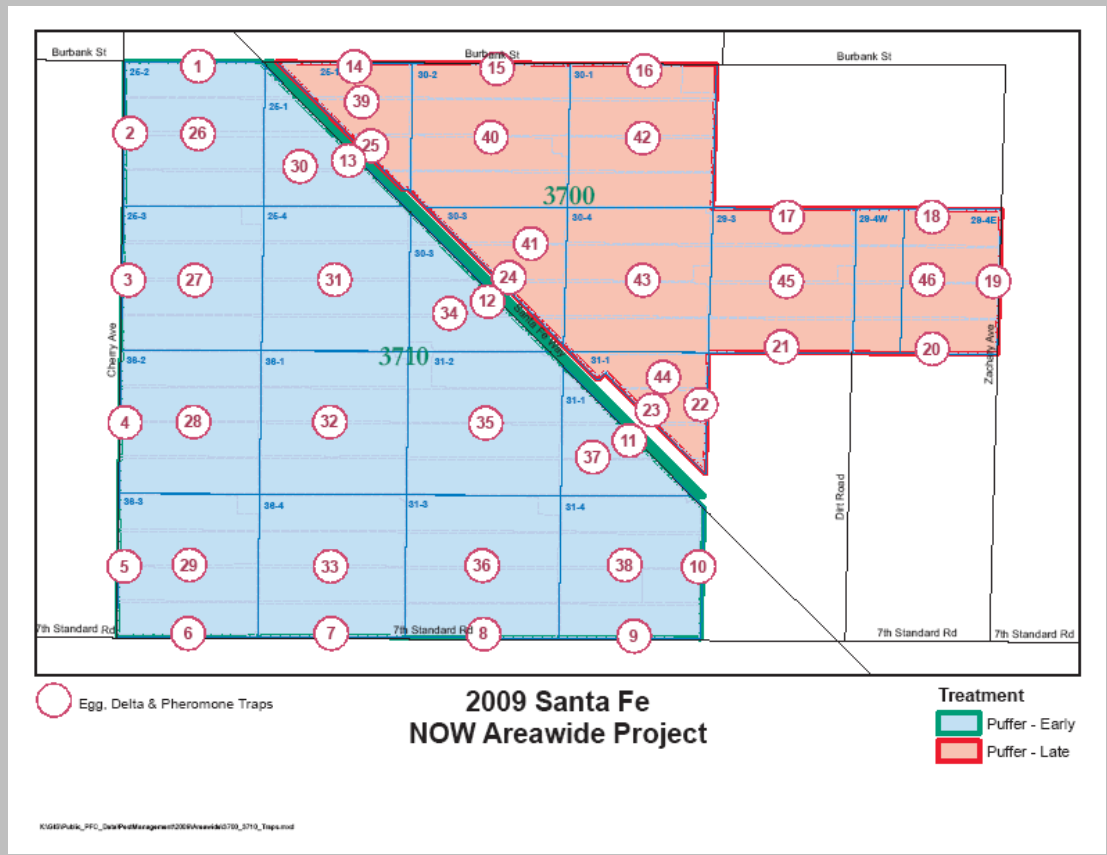
# The Monitoring Site Approach
## Making informed NOW management decisions

- Precision:
  - Is treatment needed?
  - What areas are at the greatest risk?
- Relative rather than absolute
  - Are there areas where counts are elevated?
  - Is there agreement among metrics?
- Experience breeds confidence

# Monitoring Site approach




1. Pheromone trap
2. Egg and/or oviposition attractant trap
3. Pre-harvest or early split examinations
4. Harvest sample evaluations



# NOW Management

- History of insect damage
  - Dictates program intensity
  - May need to plan for worst case scenario – but new predictive capabilities exist
  - Monitoring – crucial for guiding management decisions
- Sanitation
  - Solid benefit in almonds, should be foundation of any program
- Insecticides – Ovi-larvicides + Pyrethroids
  - Load up residues prior to harvest
- Mating Disruption
  - Greatest value has been in more challenging settings
- Biocontrol – limited potential

# Sanitation

- Established benefit in almonds
- Ground *and* tree mummies influence damage : Reducing mummy load results in lower NOW damage
- The impact is greater as pressure (damage) increases
- NOW is highly mobile (able to travel 0.5+ mile in one night) – Larger adjacent acres will benefit most
- Can we make up for a deficit in mummy destruction with other tactics?

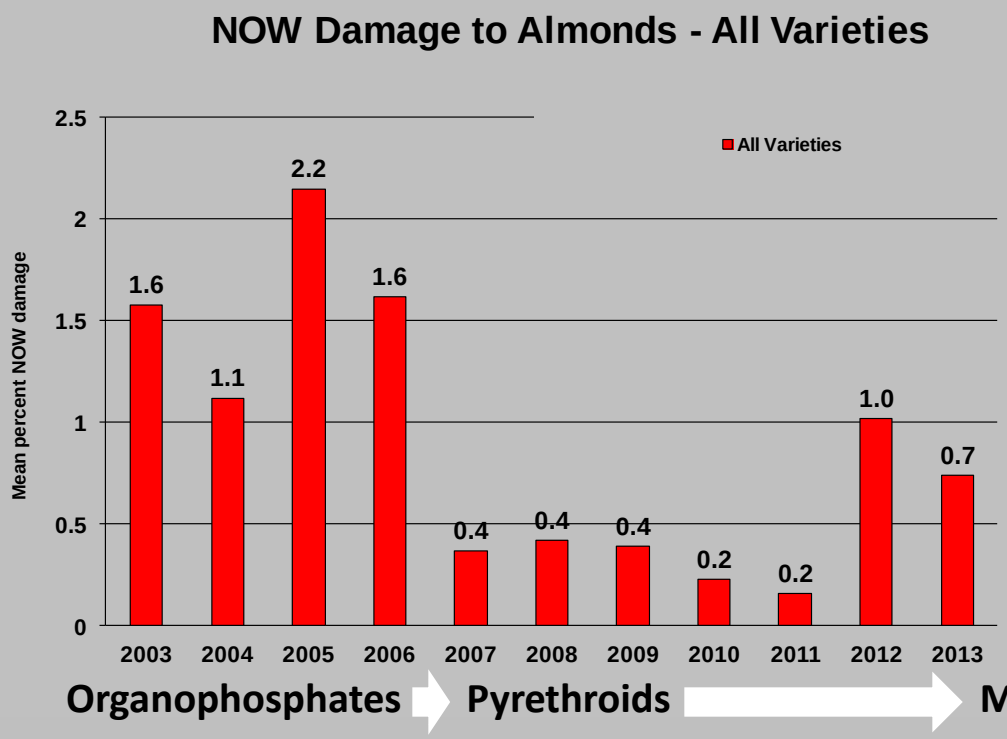
# Insecticides

- Limited Arsenal
  - Pyrethroids
    - Bifenture, others (bifenthrin)
    - Warrior (lambda-cyhalothrin)
    - Danitol (fenpropathrin)
    - others
  - IGRs
    - Intrepid (methoxyfenozide)
    - Dimilin (diflubenzuron)
  - Anthranilic diamides
    - Altacor (chlorantraniliprole)
  - Organophosphates
    - Lorsban, not registered in pistachios (chlorpyrifos)
    - Imidan (phosmet)
  - Bacterial fermentation products and derivatives
    - Delegate (spinetoram)
- Coverage limiting – 50% damage reduction per spray

Adulticide plus ovi-larvicidal action
Highly effective after initial introduction

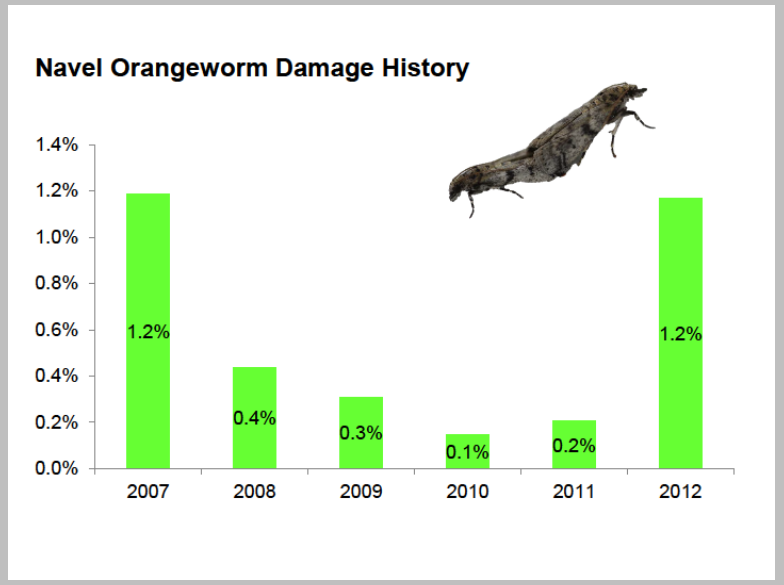
# Pyrethroid Performance in large scale field trials

- 2007 – bifenthrin included in one application: typically 80-95% damage reduction
- 2014 – bifenthrin included in 2-3 applications: 45-55% damage reduction
- Lab assays have confirmed a degree of resistance development

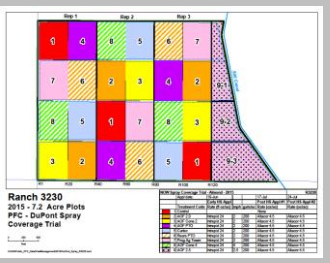



# NOW damage to Almonds

# NOW damage to Pistachios

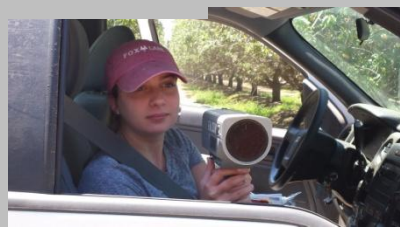


# 2015 Spray Coverage Trial

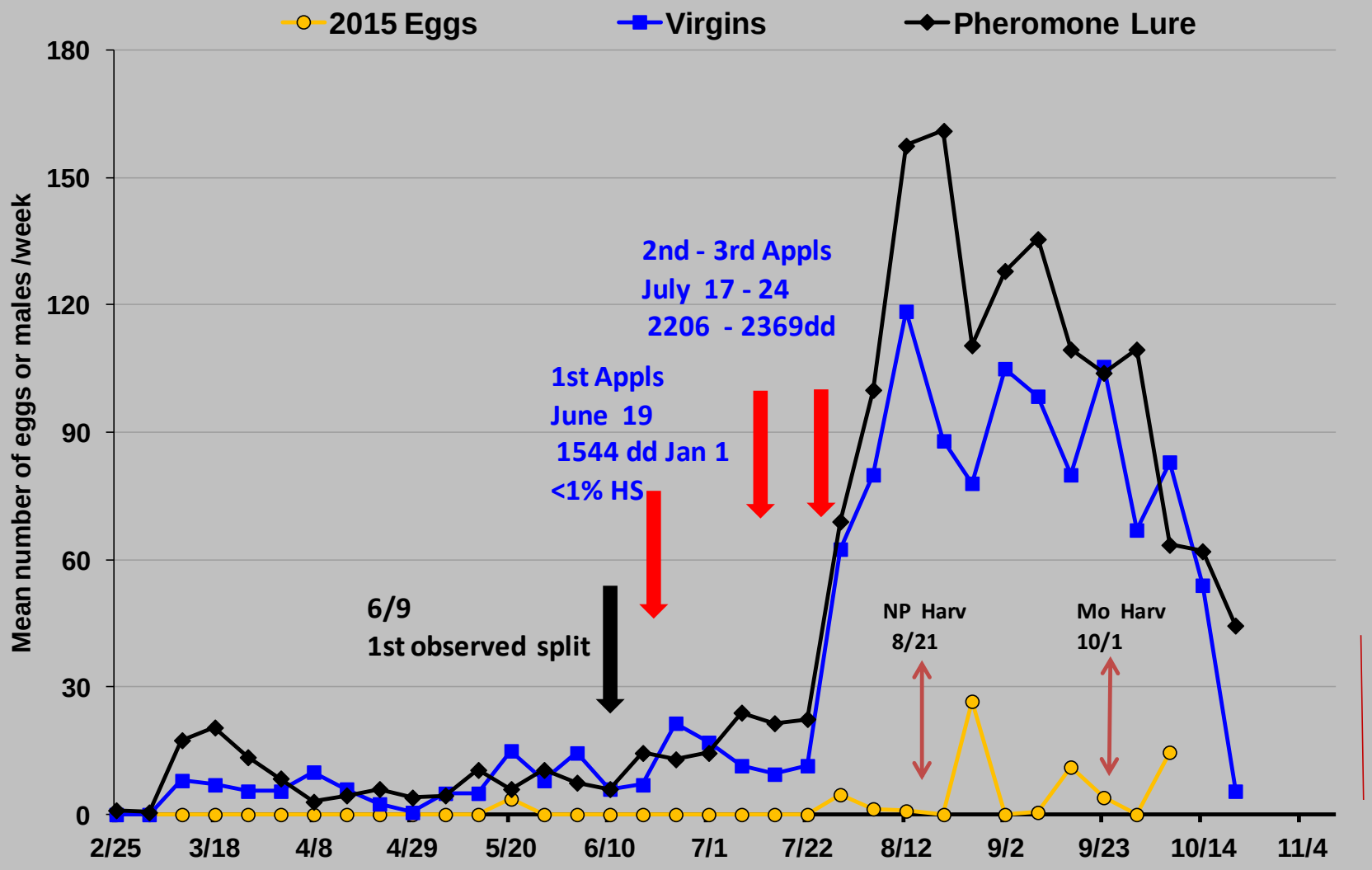



## Treatment Regimes

| | NOW Spray Coverage Trial - Almond - 2015 | | | | | |
|---|---|---|---|---|---|---|
| | R3230 | | | | | |
| | | **Early HS appl** | **HS Appl** | **Post HS Appl** | | |
| | **Product (fl oz/ac):** | Intrepid (24) | Altacor (4.5) | Altacor (4.5) | | |
| | Appl date: | 19-Jun | 17-Jul | 24-Jul | | |
| | **DD from Jan 1:** | 1545 | 2206 | 2370 | | |
| | | **Targets** | | **Actual** | | **Avg (MPH)** |
| | **Treatment Code** | **mph** | **gals/ac** | **mph** | **gals/ac** | **Airspeed** |
| 2 | AOF 2.0 | 2.0 | 200 | 2.0 | 172 | 100 |
| 3 | AOF Cone 2 | 2.0 | 200 | 2.0 | 212 | 125 |
| 4 | AOF PTO | 2.0 | 200 | 1.9 | 212 | 120 |
| 5 | Curtec | 2.0 | 200 | 1.9 - 2.1 | 200 | 50 |
| 6 | Rears PTO | 2.0 | 200 | 1.9 | 172 | 130 |
| 7 | Prog Ag Tower | 2.0 | 200 | 2.1 | 200 | 180 |
| 8 | AOF Cone 4 | 4.0 | 200 | 3.9 - 4.0 | 200 | 130 |

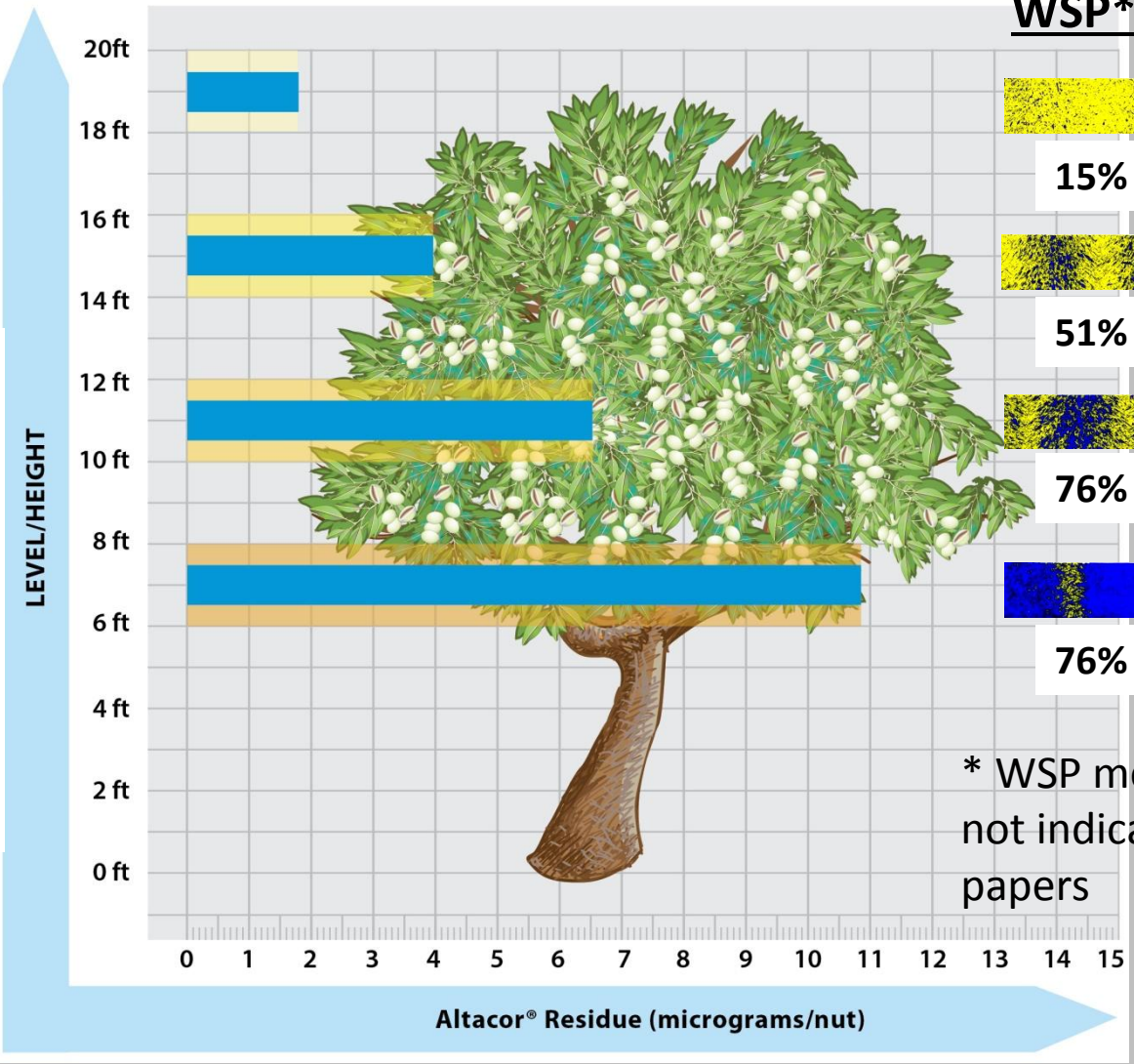


# Almond Insecticide Spray Coverage Trial 2015



# Air-O-Fan Spray Coverage (2 sprays)

- Extremely rugged design
- 100 mph, Hi Volume air
- Nozzle flexibility a plus
  - Multi-Boom




| WSP* | % infested |
|---|---|
| 20 | 15% |
| 8 | 51% |
| 5.8 | 76% |
| 5.7 | 76% |

* WSP mean values do not indicate individual papers

2013 Trial

B. Higbee, TRECE Inc

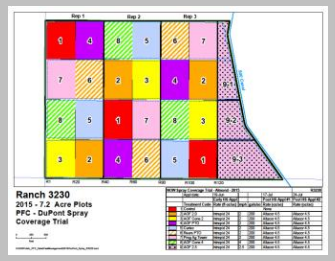
# Almond Spray Coverage Trial- 2015

## NOW Infested nuts from Tree/level samples - NP+Mo

Sampled Aug 17-Sept 25

*% Reduction*

F = 19.99
p < 0.001
Fisher's LSD




Percent infested

30
25
20
15
10
5
0

| Control | AOF 2.0 | AOF Cone 2 | AOF PTO | Curtec | Rears PTO | Prog Ag Tower | AOF Cone 4 |
|---|---|---|---|---|---|---|---|
| 22.3 | 7.0 | 9.4 | 8.3 | 9.6 | 7.0 | 6.0 | 10.0 |
| a | bc | b | bc | b | bc | c | b |
| | *69%* | *58%* | *63%* | *57%* | *69%* | *73%* | *55%* |

# 100% Coverage by Dipping Nuts

Each nut numbered

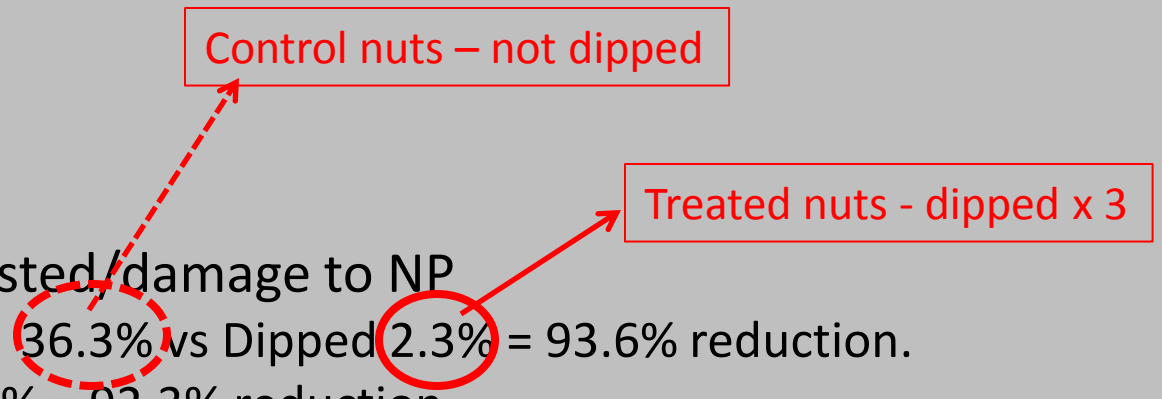

Mix spray solution

Determine maturity status

Dip nut for
5 secs

# Nut Dipping

- At each of the 3 spray application timings, 300 NP nuts were dipped in situ for 5 secs in the spray tank solution.
- Interior trees, 5-6’ from ground.
- % NP split:
  - June 19 = 0%
  - July 17 = 66%
  - July 24 = 94%
- Aug 17 - % NOW infested/damage to NP
  - Infested: = Control 36.3% vs Dipped 2.3% = 93.6% reduction.
  - Damage = 26% vs 2% = 92.3% reduction
- Many dead neonates on treated nuts (96.4% vs 7.4% of larvae were dead)
- Therefore: Under heavy pressure, the best this 3 spray program can achieve is 2% damage, or a reduction of 92%!



# Spray Coverage

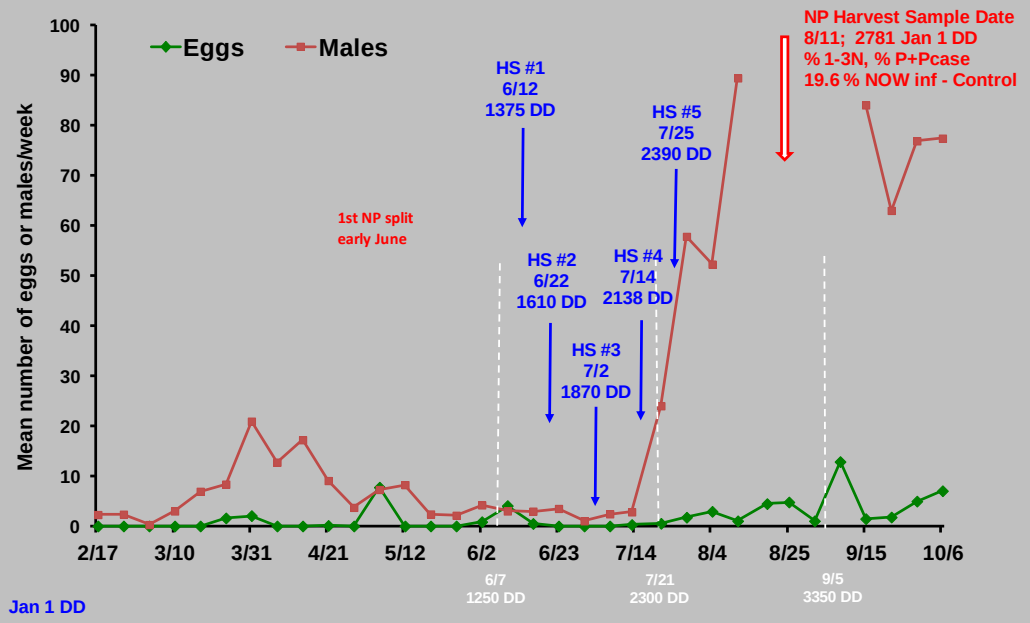
- Under the conditions of this trial (≈ 30% infested, 3 sprays) max potential is 92% damage reduction
- PTO based machines look as effective as engine driven – operational advantage
- Cone-jet nozzles do not provide any significant advantage at 2 mph, but may have potential at higher speeds (4 mph in this trial)
- The Progressive Ag tower continues to be a top performer, *but not sig better than the standard AOF machines*

# NOW Insecticide Control Trial 2 - Almond - 2015

| No MD | | Timing | | | |
|---|---|---|---|---|---|
| Jan 1 DD | 1400-1600 DD | 1650-1850 DD | 1900-2100 DD | 2150-2350 DD | 2400-2600 DD |
| Treatments | Early HS | 2nd Early HS | HS | 1st Late HS | Late HS |
| 1 | No Treatments | | | | |
| 2 | Warrior+Intrepid | | Warrior+Intrepid | | Brig+Altacor |
| 3 | Intrepid | | Intrepid | | Altacor |
| 4 | Warrior | | Warrior | | Brig |
| 5 | Intrepid | Intrepid | Altacor | Danitol | Danitol |
| 6 | Altacor | Altacor | Lorsban | Lorsban | |
| 7 | Intrepid | Intrepid | | Altacor | Altacor |
| **Estimated date** | June 12- June 19 | June 22- June 29 | July 2- July 9 | July 12- July 19 | July 22- July 29 |
| **Actual date** | June 12 | June 22 | July 2 | July 14 | July 25 |
| **DD (Jan 1)** | 1375 | 1610 | 1870 | 2138 | 2390 |

## NOW Insecticide Trial 2 - Almond

### Pheromone and oviposition attractant traps - 2015




B. Higbee, Paramount Farming Co.

# NOW Insecticide Programs -Almond

| Program | Products | NP | Pollenizers | All Var | % Reduction |
|---|---|---|---|---|---|
| #2 - 3 sprays | Warrior or Brigade + Intrepid or Altacor | **4.4** | **2.5** | **3.1** | **81** |
| #5 – 5 sprays | Intrepidx2-Altacor-Danitolx2 | **5.8** | **3.1** | **4.0** | **75.4** |
| #3 – 3 sprays | Intrepid x 2 - Altacor | **7.6** | **4.8** | **5.7** | **65** |
| #4 – 3 sprays | Warrior x 2 - Brigade | **14.4** | **5.8** | **8.8** | **47** |
| Control | None | **19.6** | **14.7** | **16.3** | **0** |

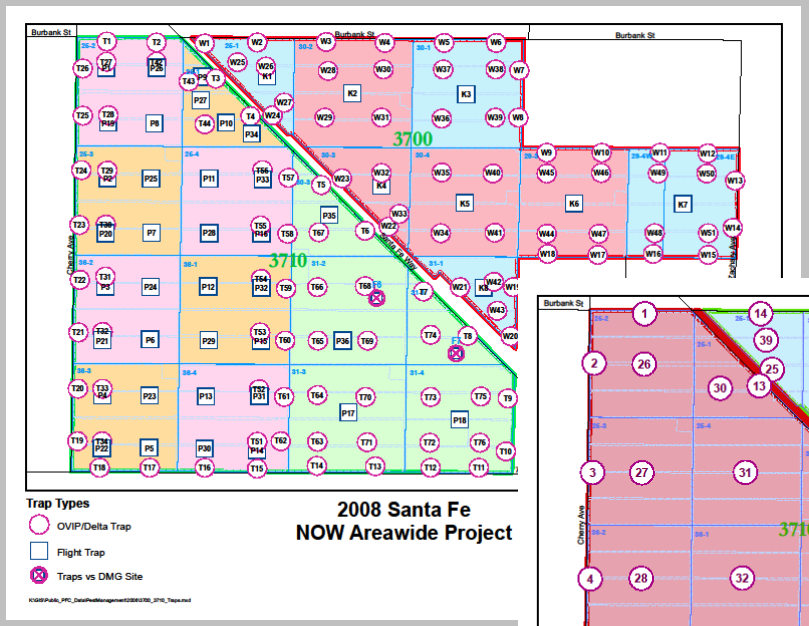
# Insecticides

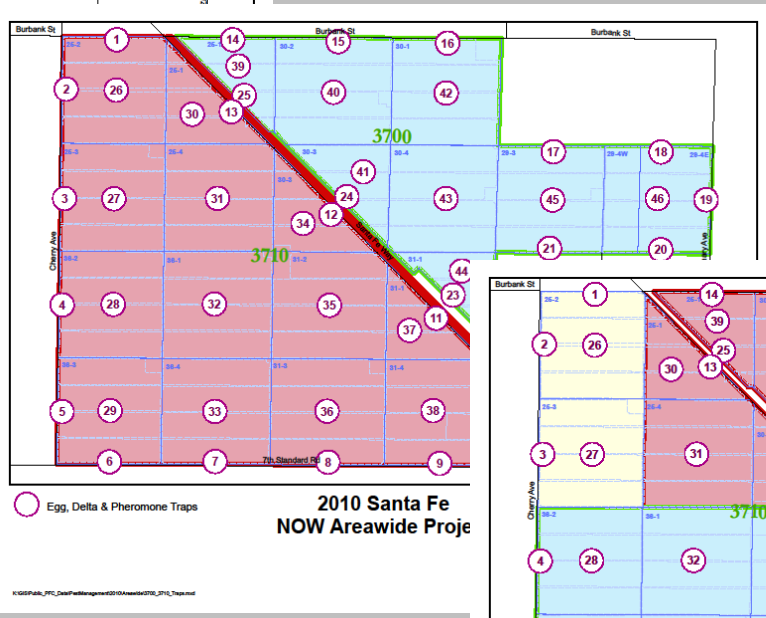
- Pyrethroid tank mixes are now required for the most impact
- Residue loading prior to harvest is the most effective strategy. The earlier timings, prior to beginning of the 2nd flight (mid-late June in Kern), do not seem to contribute as much to damage reduction
- The later the spray, the greater the impact. The window of time about 10-60 days prior to harvest are primetime for applications
- There has not been a new worm insecticide in 10+ years

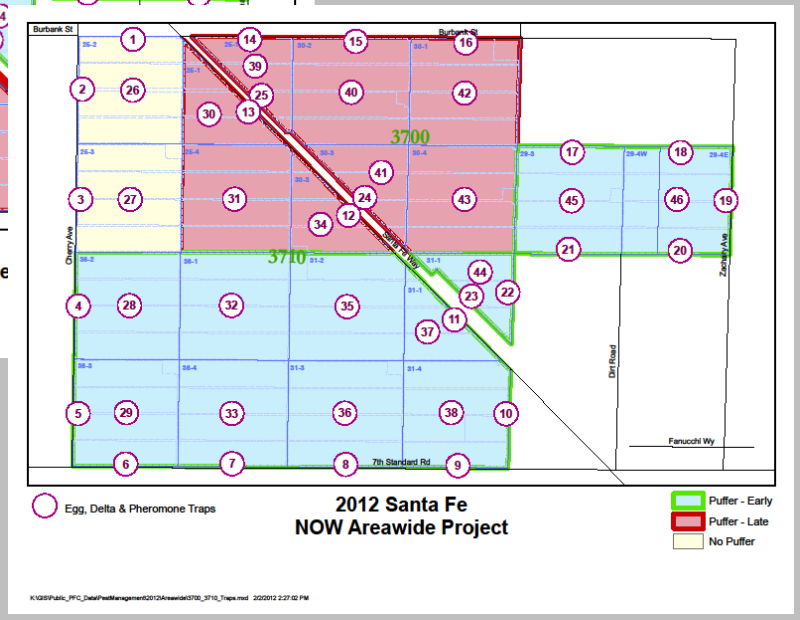
# Mating Disruption

# Santa Fe Areawide Project - 2500 acres 2007-2012

"Puffer"
Mating Disruption



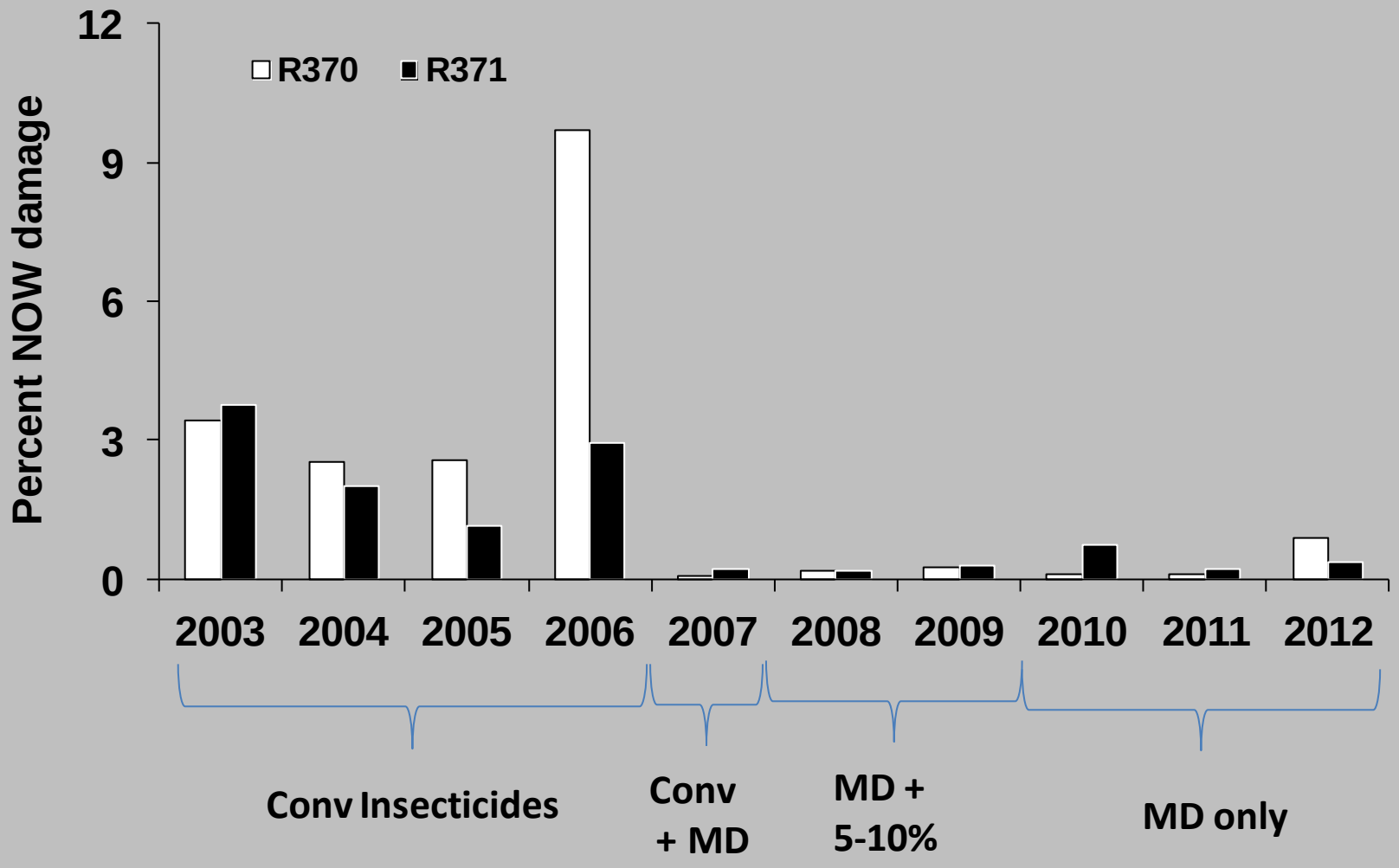




Development of Monitoring System
46 monitoring sites, 1 per 54 ac

# Santa Fe NOW Areawide Project

Historical NOW Damage - All varieties

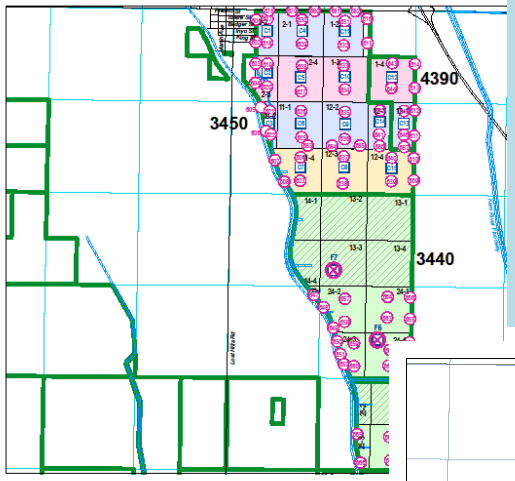


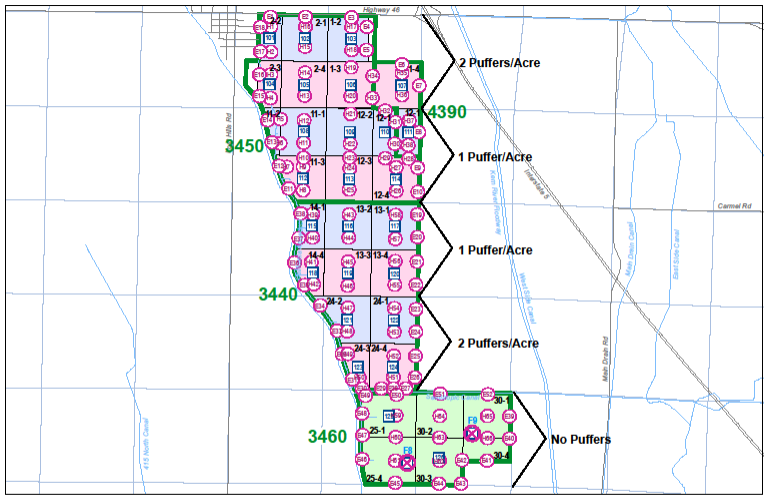

** After 2007: 75-100% reduction in insecticide applications for NOW

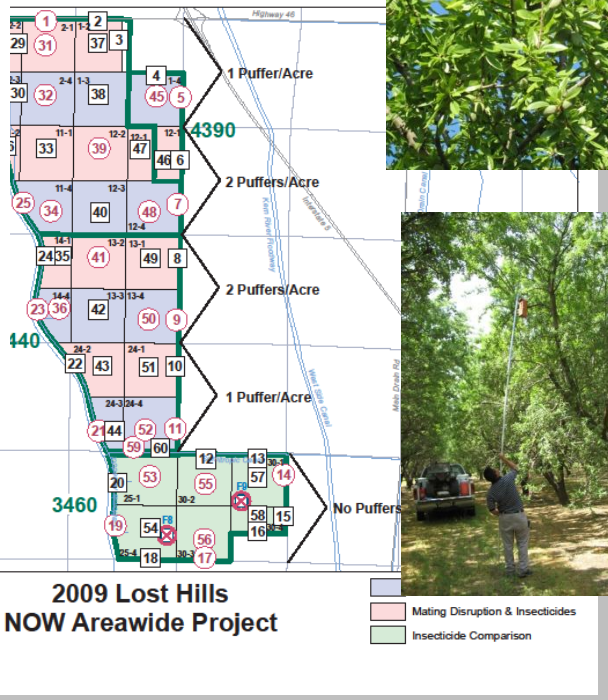
# Areawide MD for NOW compared to :

## Conventional Insecticide program

## Combination

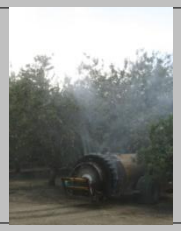


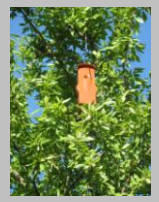



# Lost Hills Areawide NOW MD Project

Processor/huller samples - All Varieties





Conv  Conv+MD  MD only

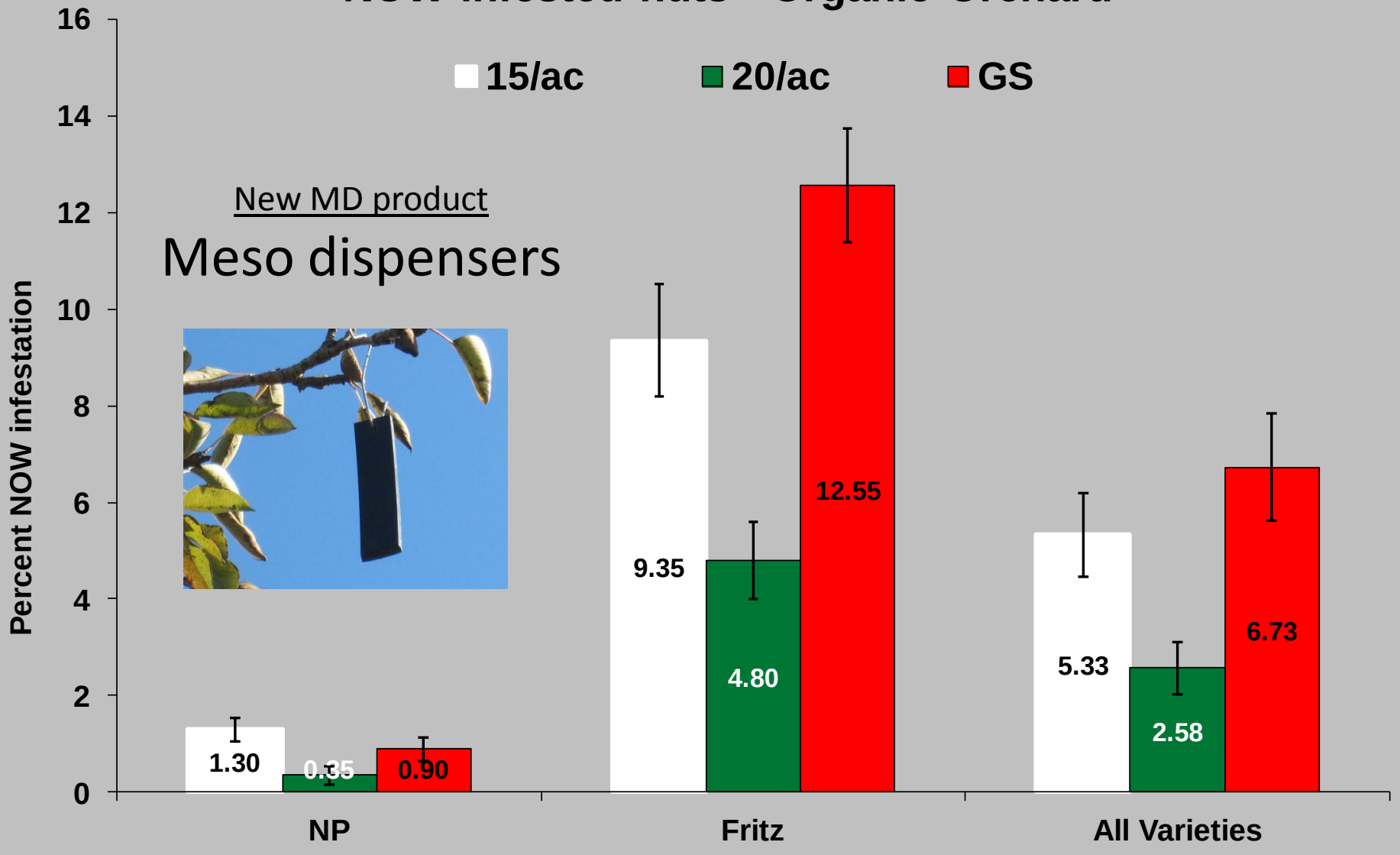
Mean percent NOW damage

2
1.5
1
0.5
0

| 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|
| 1.0 | 0.4 | 1.5 | 1.0 |
| 0.4 | 0.2 | 0.4 | 0.2 |
| 1.0 | 0.3 | 0.9 | 0.4 |

# TRECE NOW MD Mesos - 2017

## NOW infested nuts - Organic Orchard




B. Higbee, TRECE Inc

# Mating Disruption

- Proven benefit in almonds and more recently pistachios – 50% damage reduction is the expectation
- Adoption on steep incline in last 5 years
- Economics a factor
  - $120-160+/ac for MD
  - $40-60 per insecticide application
- New delivery technologies could add efficiency and flexibility to current puffer systems

# NOW control in Almonds

- Foreign markets are driving down acceptable damage levels (aflatoxin)
- Pyrethroid performance is waning
- Coverage is problematic for ovi-larvicides
- Heavy pressure areas will require multiple appls of ovi-larvicides (3-5) + MD
- Lower pressure areas can be controlled with MD alone, or 1-2 sprays
- Combining insecticides with MD results in lowest damage in all situations

# Bottom Line

- No new developments are on the horizon.
- We must use the tools we have as effectively and efficiently as possible.
- Low to moderate pressure situations can still be managed, but High pressure situations will require the most control inputs and there is no guarantee that an expectation of 1-2% NOW damage can be achieved.

# What is the future for NOW management?

- Sanitation – Costly, but likely will be most effective intervention until futuristic technologies overcome the need
- Insecticides – Little if any in the pipeline
- Mating Disruption – is it optimized? Competition may impact cost
- SIT – Proven in other systems
  - Mass release of sterilized moths
  - RIDL – Looks promising for mosquito control
- Molecular Approaches
  - CRSPR – **C**lustered **I**nterspersed **S**hort **P**alindromic **R**epeats
    - Gene Editing – no foreign DNA introduced
  - RNAi – **R**ibo**n**ucleic **A**cid **I**nterference
    - Gene silencing via interfering with mRNA
  - 5-10 yrs until seen in the field?

# Thank you for your kind attention

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