

Biology and Integrated Management of Navel Orangeworm in Almonds

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NSJV Almond Day, Modesto

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Agriculture and Natural Resources

Navel Orangeworm Biology



- Overwinters as a larva inside the mummy nuts on the tree
- Moths emerge in the Spring, and females lay eggs on mummy nuts
- In summer, 2nd - 4th generations larvae infest the hullsplit nuts
- Direct feeding damage, plus increase the risk of 'aflatoxin' contamination

Navel Orangeworm: Infestation History

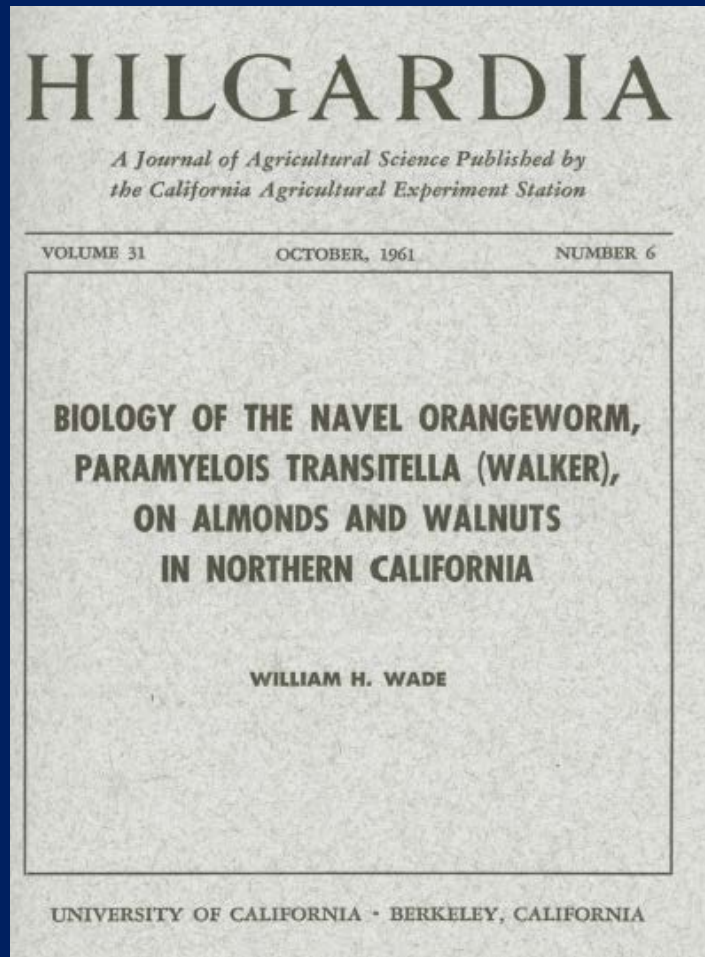


Navel orangeworm origin: Mexico

- ❑ **1920:** First reported in the USA (AZ): an adult in a light trap
- ❑ **1921:** NOW Infested nearly 100% of *Alternaria* infected **navel oranges** in Salt River Valley, AZ
 - Larvae infested only diseased or split oranges
 - Hosts expanded: grapefruit, lemon, fig, pear, pomegranate, and all varieties of orange



Navel Orangeworm: Infestation History



In California

- ❑ **1942:** First detected in oranges in Orange, San Bernardino, LA counties
- ❑ **1946:** Infestation found in walnut (infested with CM) packing house in So Cal (LA, Ventura counties)
- ❑ **1949:** Spread as far north as Tehama County, and found infesting on almonds, pistachios, etc.

Navel Orangeworm: Survival Strategy

R-selected species (i.e., produce many 'cheap' offspring)

- ❑ **Favored environment:** Often pioneer, variable environment
- ❑ **Reproduction:** Early in life cycle, produced frequently with many offspring
- ❑ **Life span:** Short life span
- ❑ **Immigration/emigration:** Frequent movement
- ❑ **Mortality:** High mortality
- ❑ **Survival:** variable survival qualities

High rate of reproduction



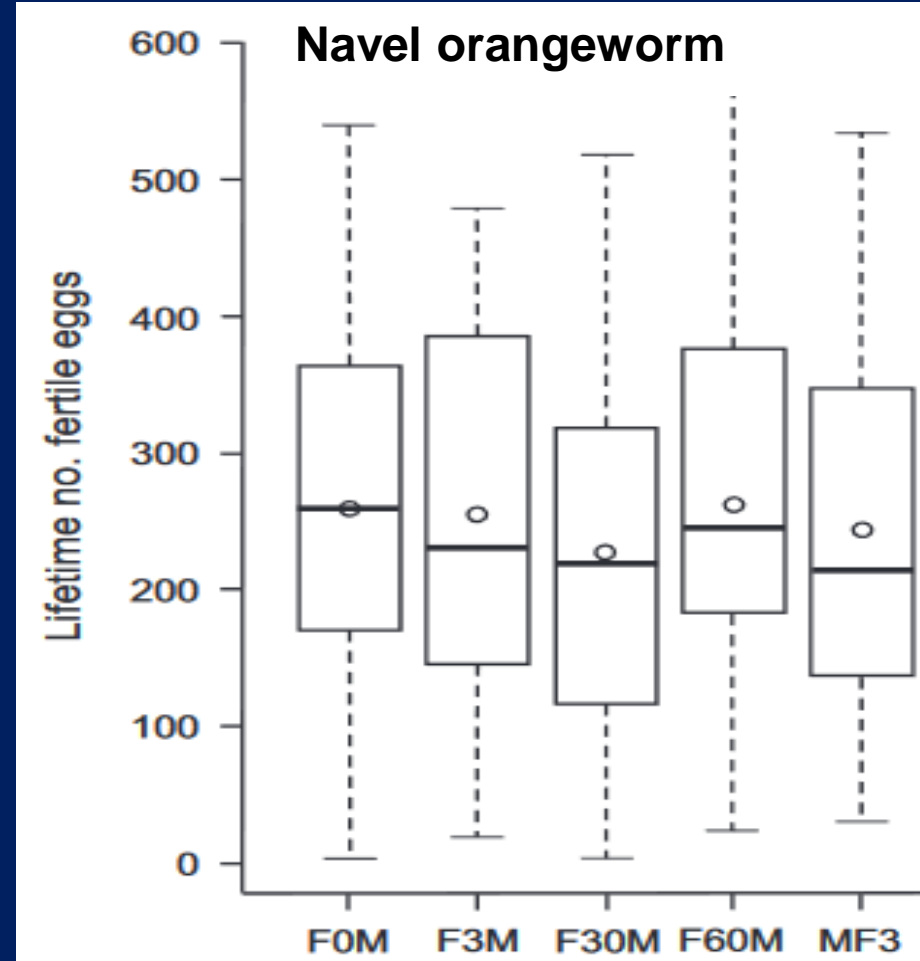
Navel orangeworm

170-400 eggs

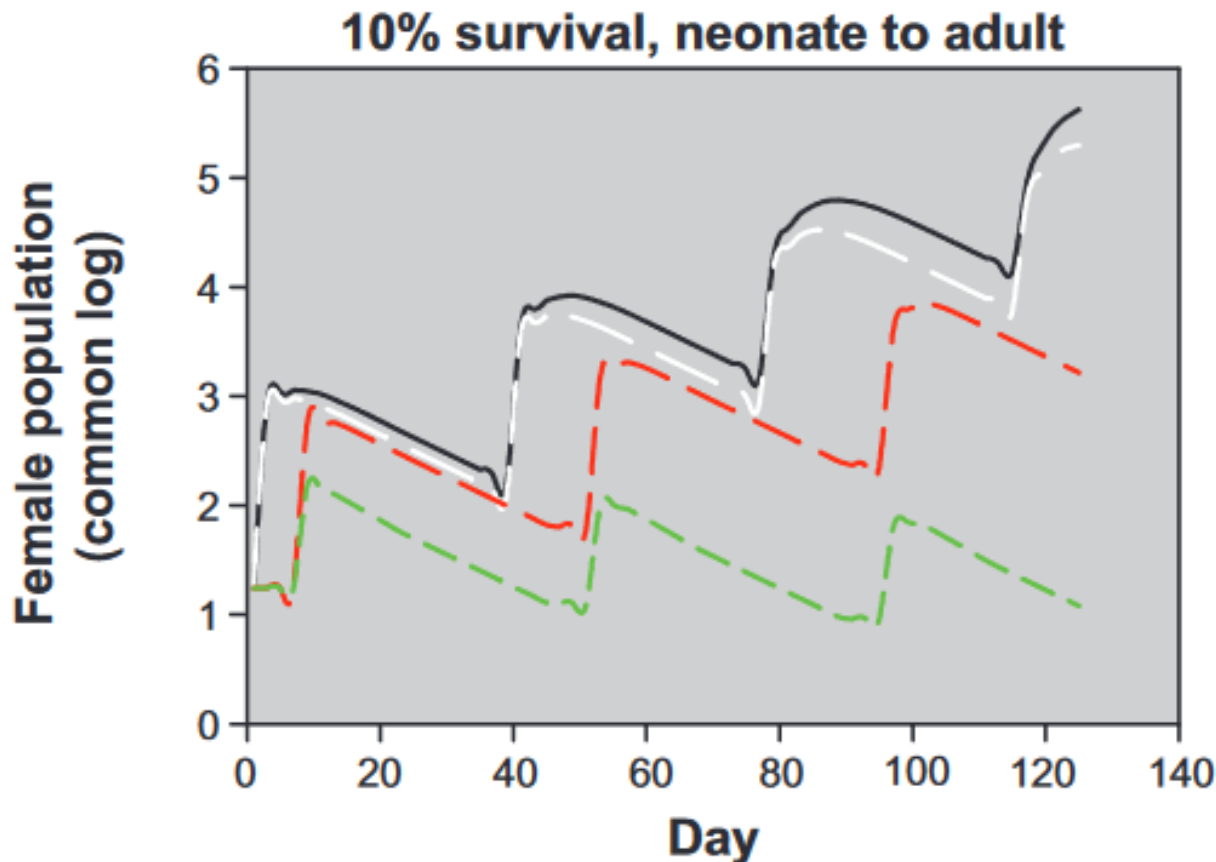
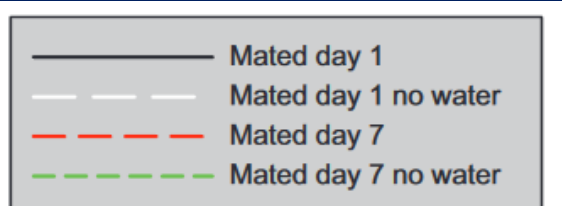


Codling moth

30-60 eggs



High rate of reproduction, short life span



Leslie matrix projections of the population of *NOW* over 125 days, assuming 10% survival from neonate to adult

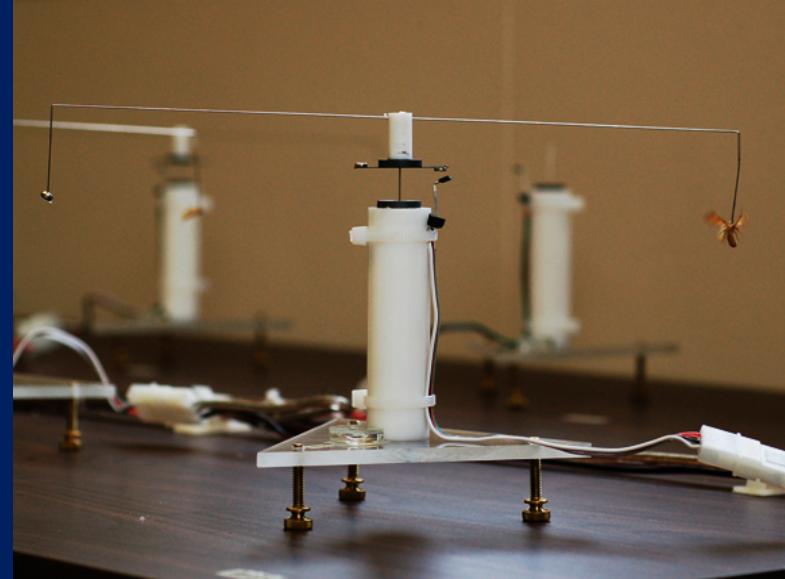
- NOW survival is probably ~10% under most field circumstance
- Mating at day 7 vs. day 1 makes a significant difference in population abundance

Survive in variable environment



High tendency for immigration/emigration

- NOW moths are capable of flying over **9 miles** in flight mills
- Based on field and laboratory-based studies, mated NOW females can fly within the radius of **2-3 miles** for oviposition (Higbee and Siegel 2009; Rovnyak et al. 2018)
- However, most females mate and oviposit in or near their natal habitat, some may disperse potentially long distances to oviposit elsewhere

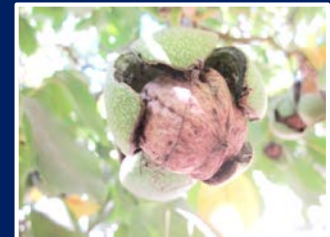
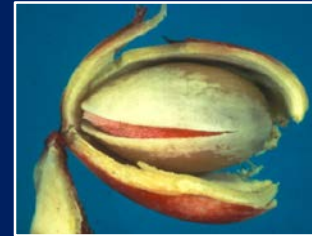


Insect flight mill



High potential of NOW movement among hosts

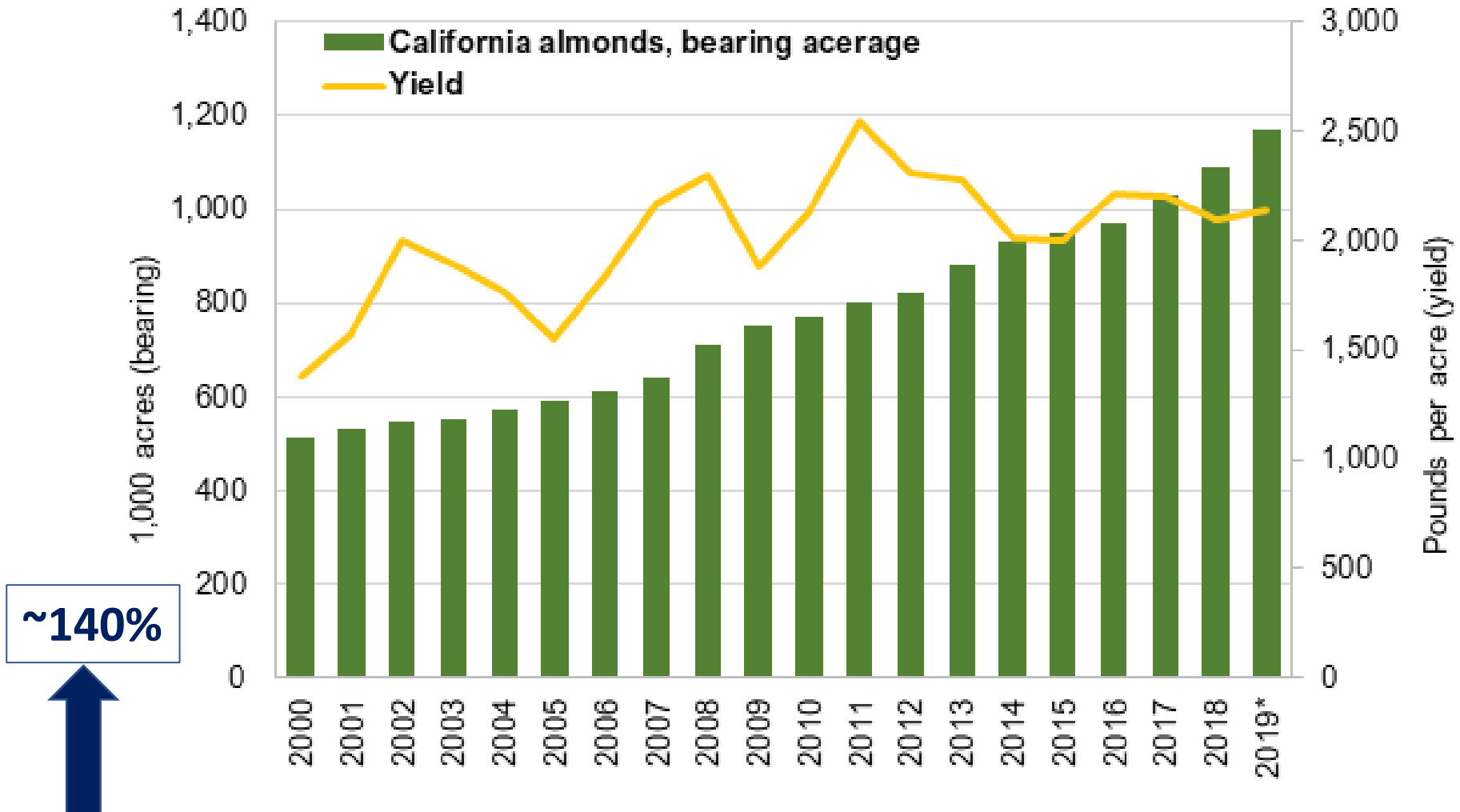
Multiple hosts, staggered crop phenology, contiguous hosts



Time

High potential of NOW movement among hosts

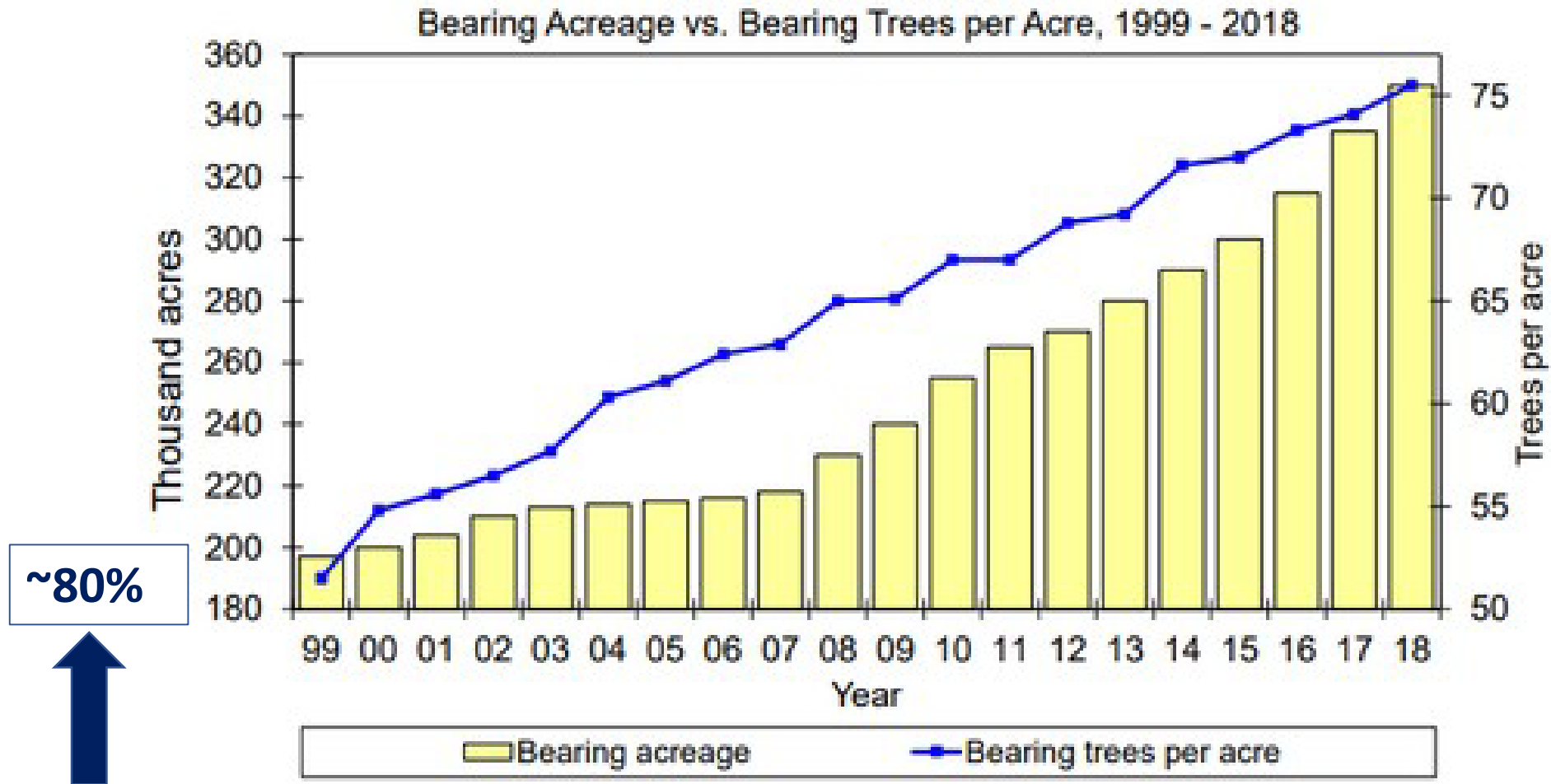
Almond bearing acreage (2000-2019)



Source: USDA-NASS

High potential of NOW movement among hosts

Walnut bearing acreage (1999-2018)



Migration Between Almonds and Walnuts

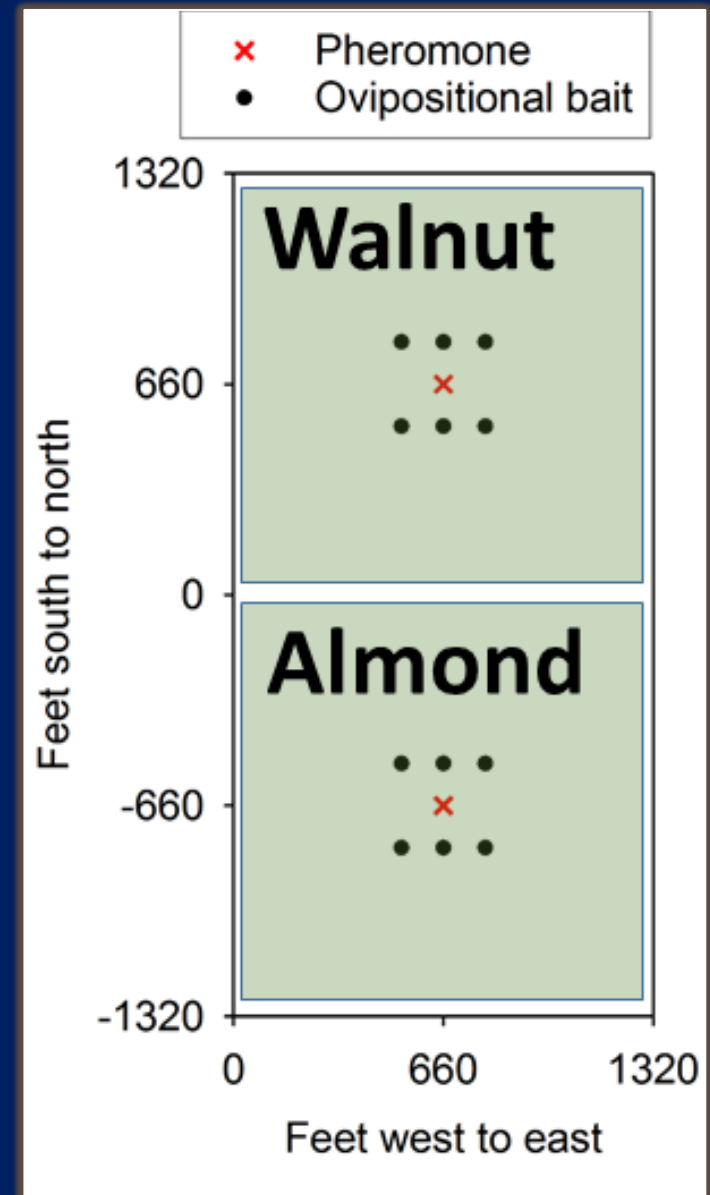
- Adjacent walnut-almond paired sites (total 9 sites; 3 in each of Sac, North SJ, and South SJ Valleys)
- 6 kairomone (Ovipositional trap)
- 1 Pheromone trap
- Moths collected weekly for **fatty acid analysis**



Wing trap

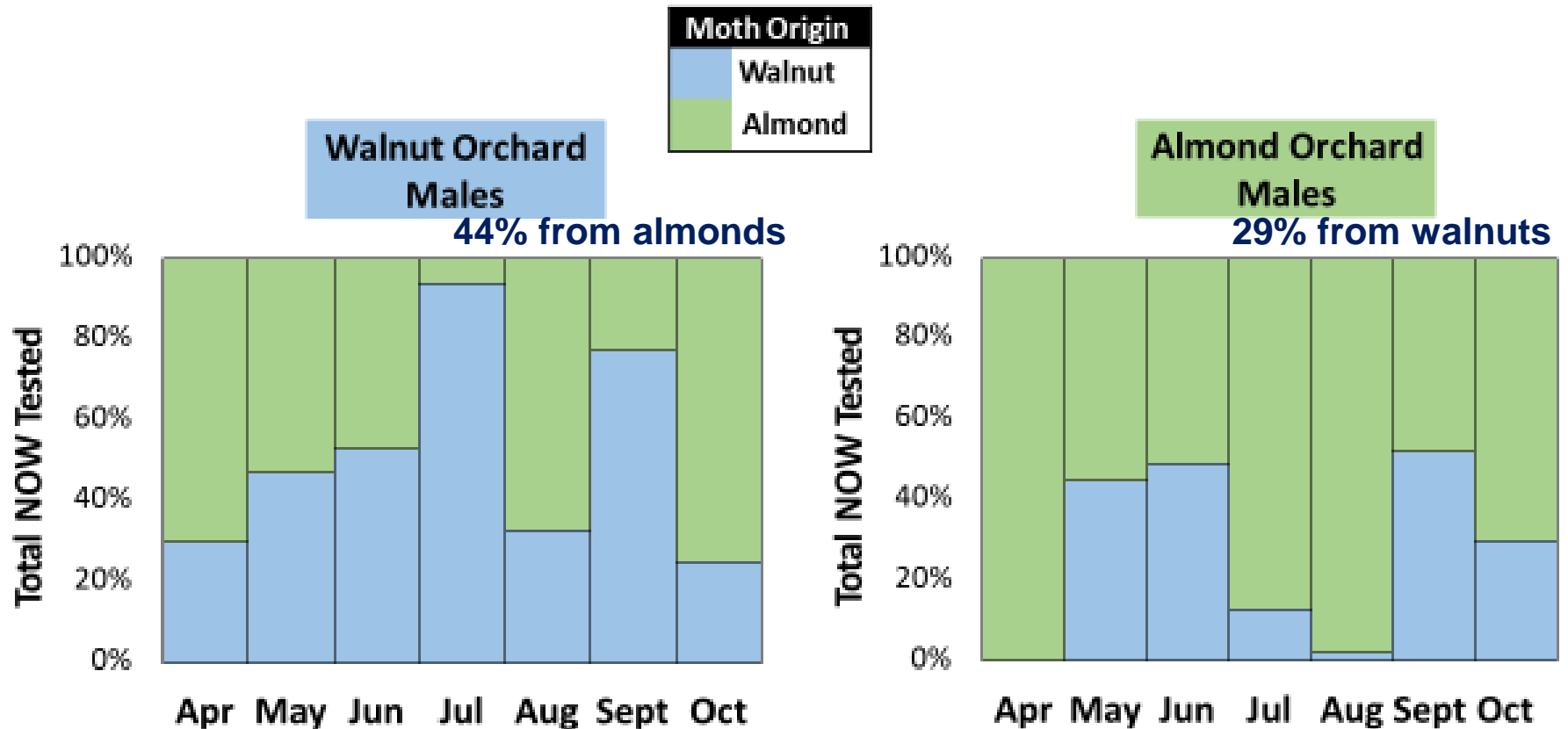


Peterson bait bag



Migration Between Almonds and Walnuts

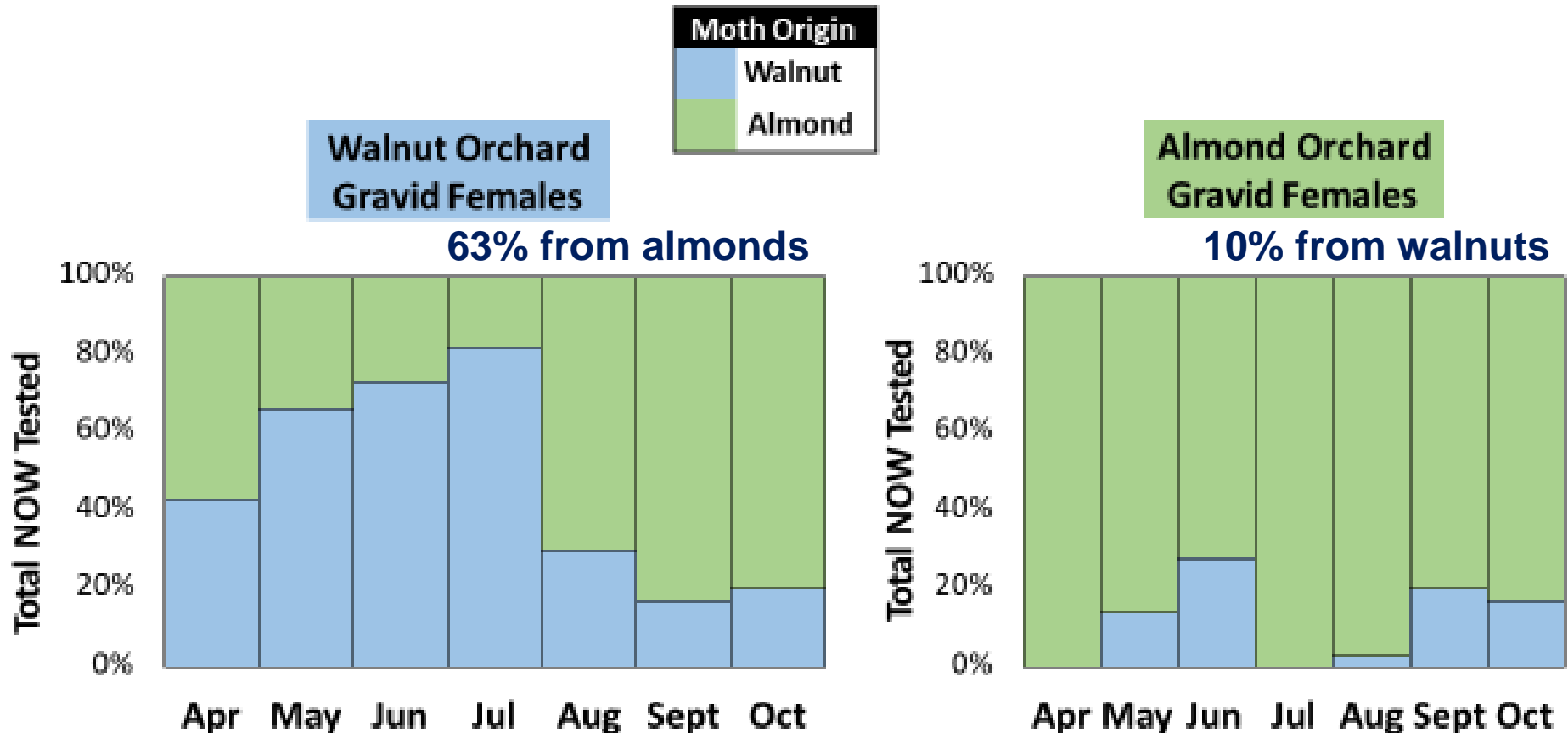
Fatty Acid Analysis to Determine Moth Origin



2018 Study: n = 280 male moths evaluated (walnut); 229 (almond)

Migration Between Almonds and Walnuts

Fatty Acid Analysis to Determine Moth Origin



2018 Study: n = 170 female moths evaluated (walnut); 187 (almond)

Summary of NOW Biology

Opportunistic pest

Highly temperature dependent

Multiple generations (3-4 generations)

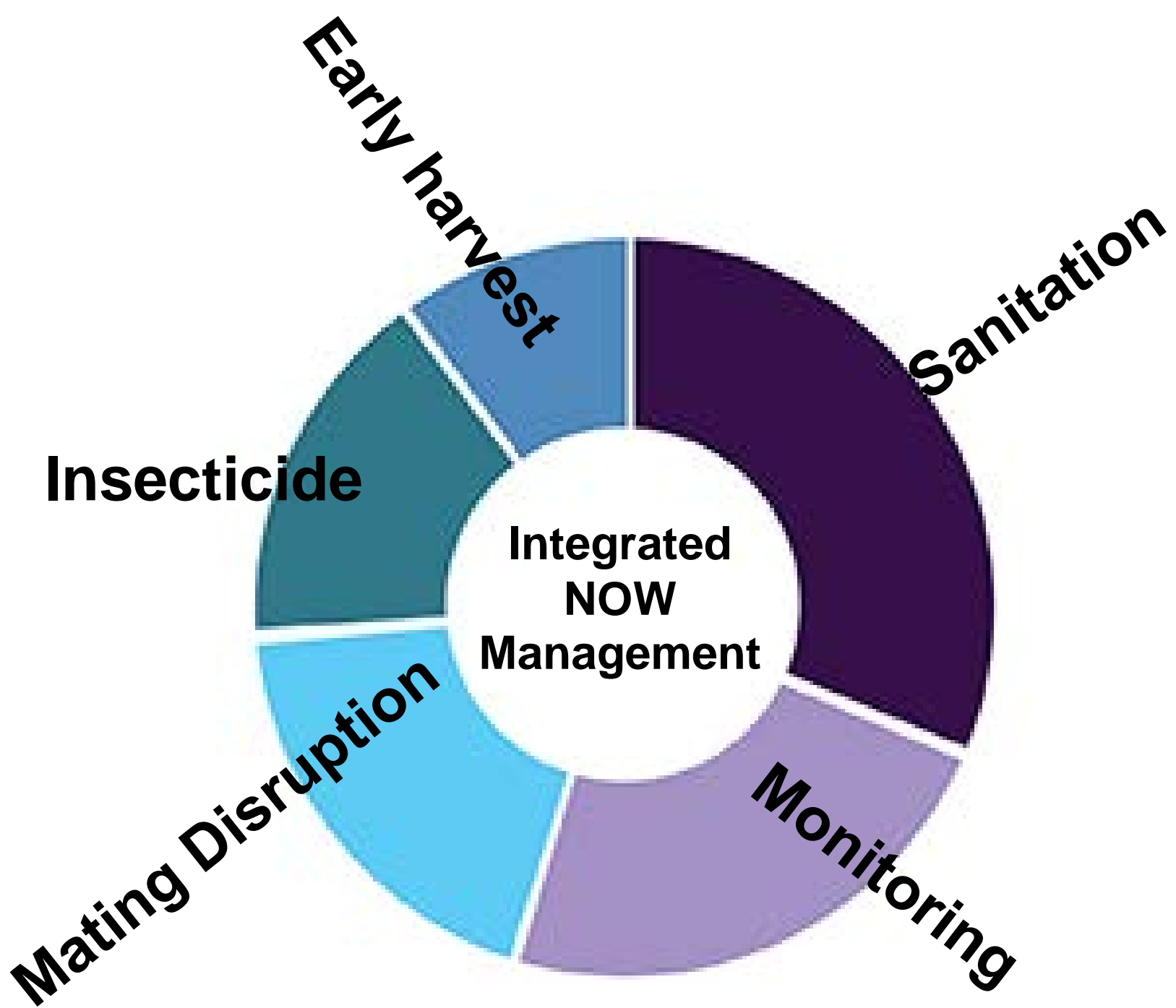
A prolific organism with high oviposition and reproduction rates

Well adapted to variable environmental conditions (host type, host nutritional status, host susceptibility)

Capable to migrate among multiple hosts



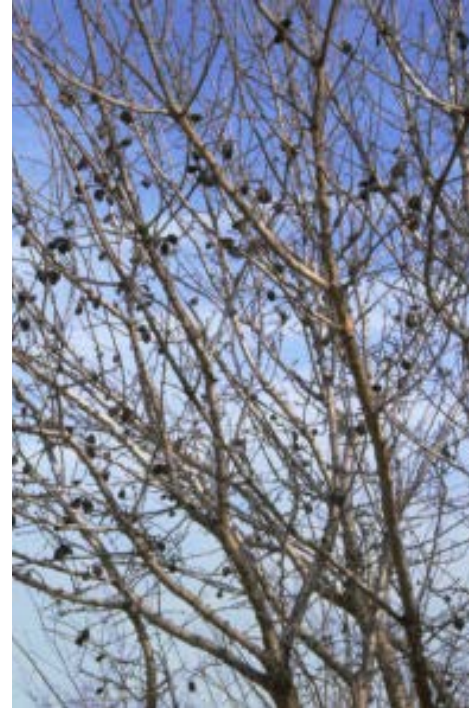
Difficult to predict, and control NOW



Navel Orangeworm Control

1. Effective monitoring
2. Mummy sanitation
3. Early harvest
4. Mating disruption
5. Insecticides





UC Statewide IPM Project
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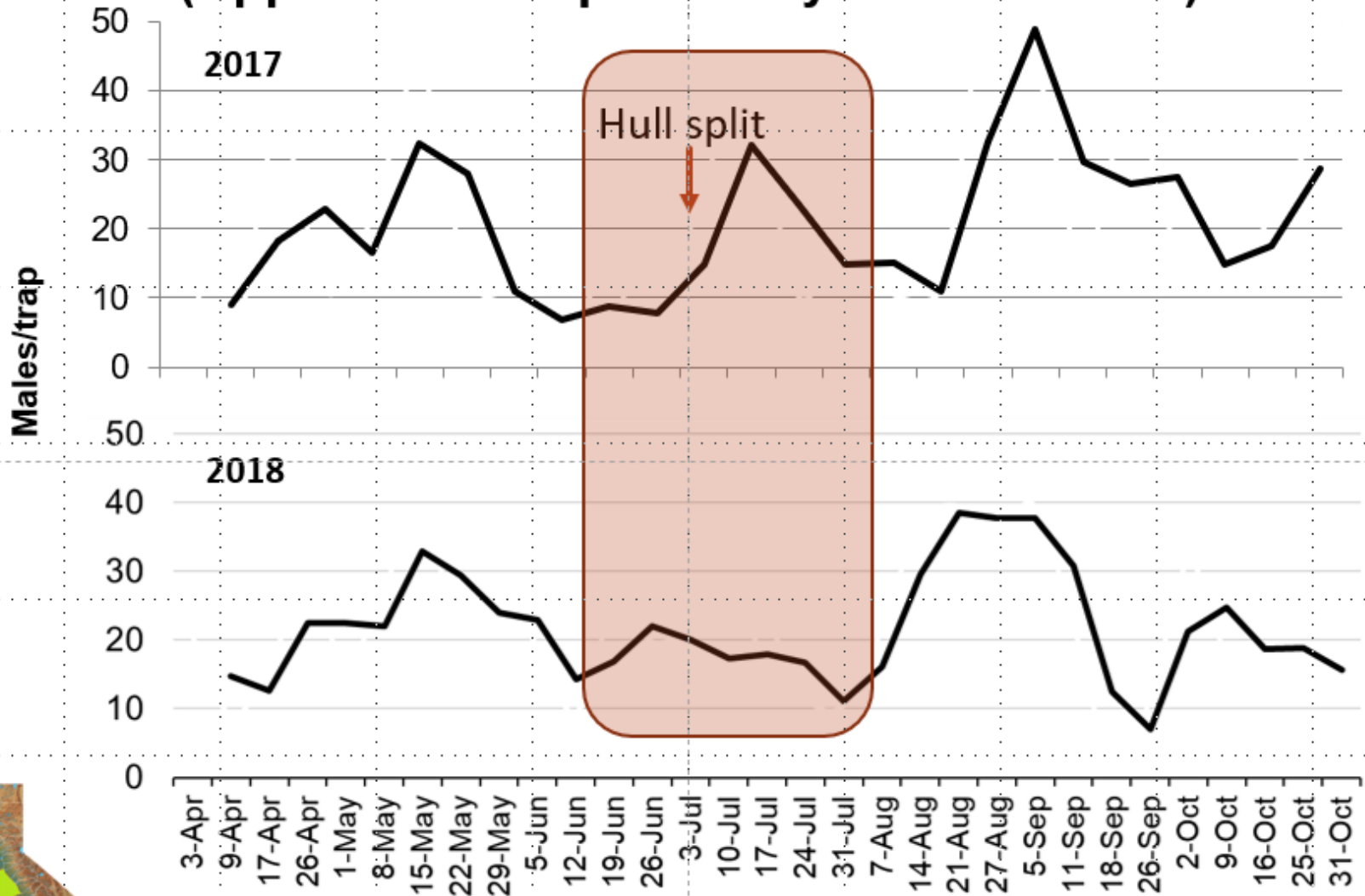


NOW Monitoring

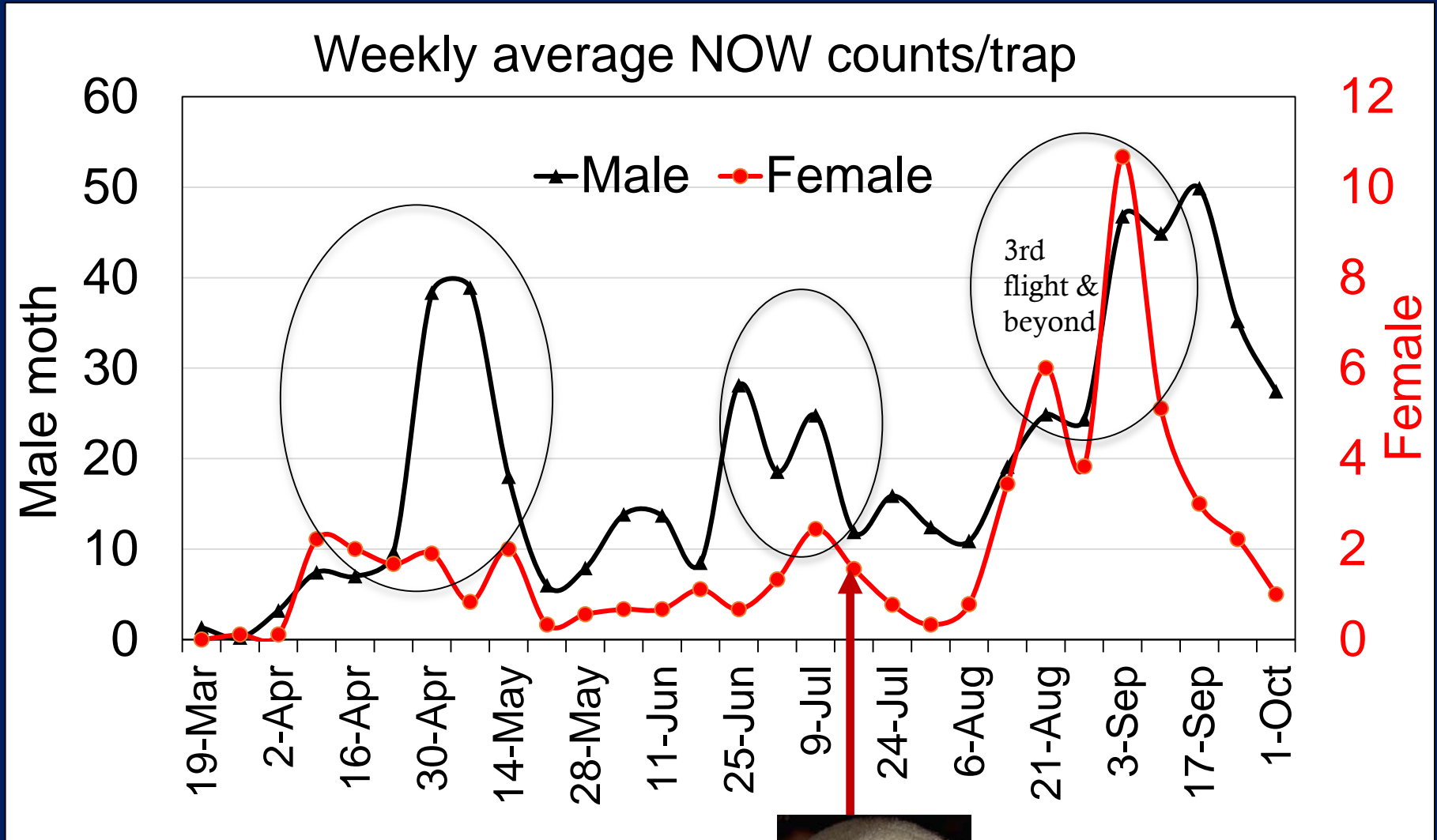
- Egg trap
- Ovibait (Peterson) traps
- PPO trap
- Pheromone trap
- Harvest sampling
- Mummy nut sampling

NOW Activity in Pheromone Trap

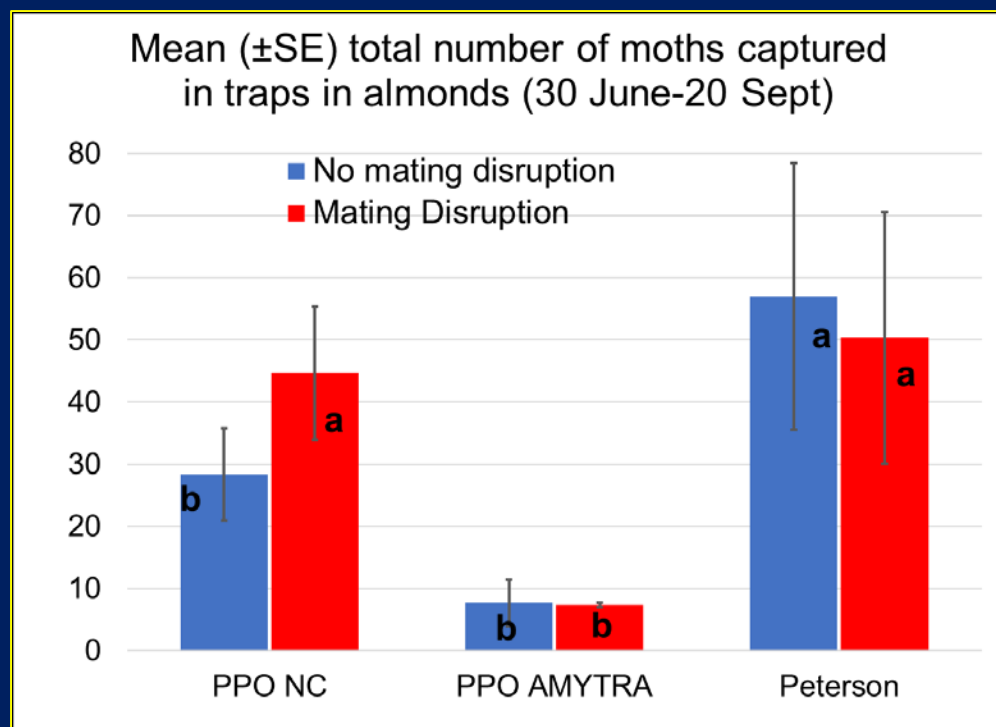
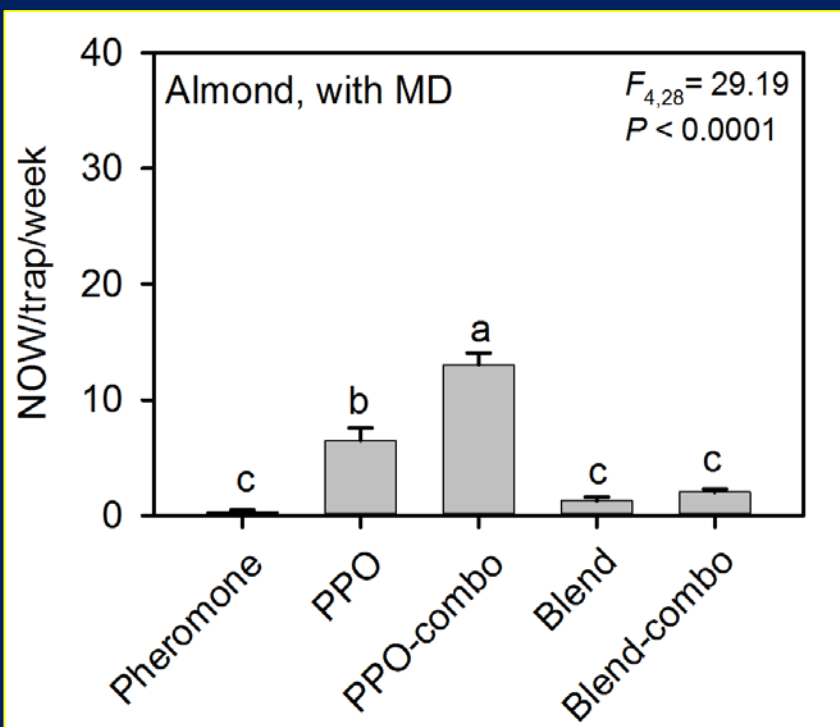
(Upper San Joaquin Valley-Modesto area)



2019-Navel Orangeworm Seasonal Activity (Modesto)



NOW Trap/Lure under mating disruption



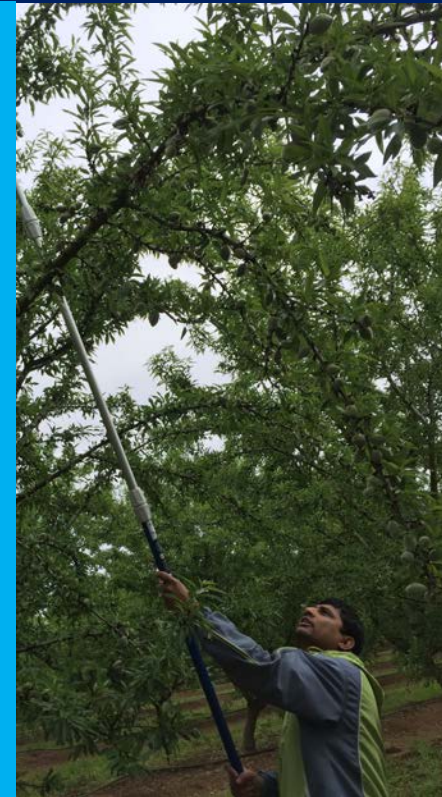
Source: C. Burks, USDA

J. Rijal

- Both Peterson bait and PPO lures showed effectiveness in trapping NOW under mating disruption (Fig. right)
- PPO + pheromone (PPO-Combo) performed better than PPO alone (Fig. left)
- PPO lures are commercially available from AlphaScents and Trece

Navel Orangeworm Control

1. Effective monitoring
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Mummy Sanitation

-Foundation of a successful NOW management



Mummy nuts :

- Harbor the overwintering larvae
- Serve as the only resource for egg laying by first generation moths



Orchard Sanitation



Removal and flail mowing of mummy nuts is critical

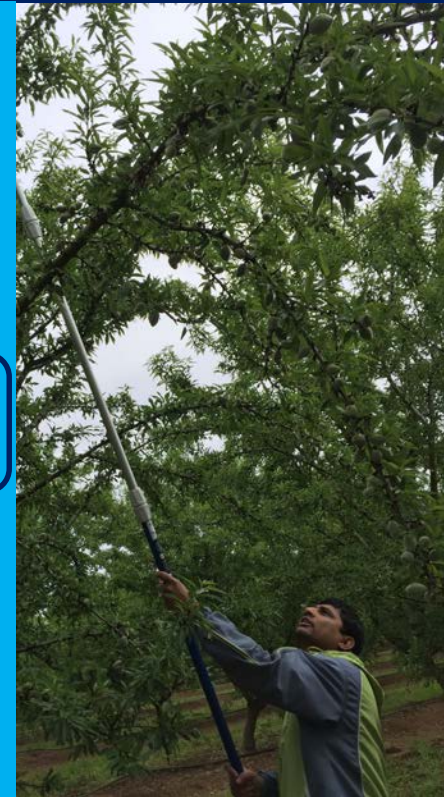
Mummy nut threshold

- Removal of mummy nuts from trees **by Feb. 1**
- Destroy the nuts by **March 15**
- **<2 mummies/tree**
(Sacramento and upper San Joaquin Valleys)

- **0.2 (tree mummies/tree) and 8 (ground mummies/tree)**
(lower San Joaquin Valley)

Navel Orangeworm Control

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2. Early Harvest

- Harvest early before the 3rd generation eggs hatch.
- Harvest when 100% of nuts at 6-8 ft height are at hullsplit

NOW male captures in traps

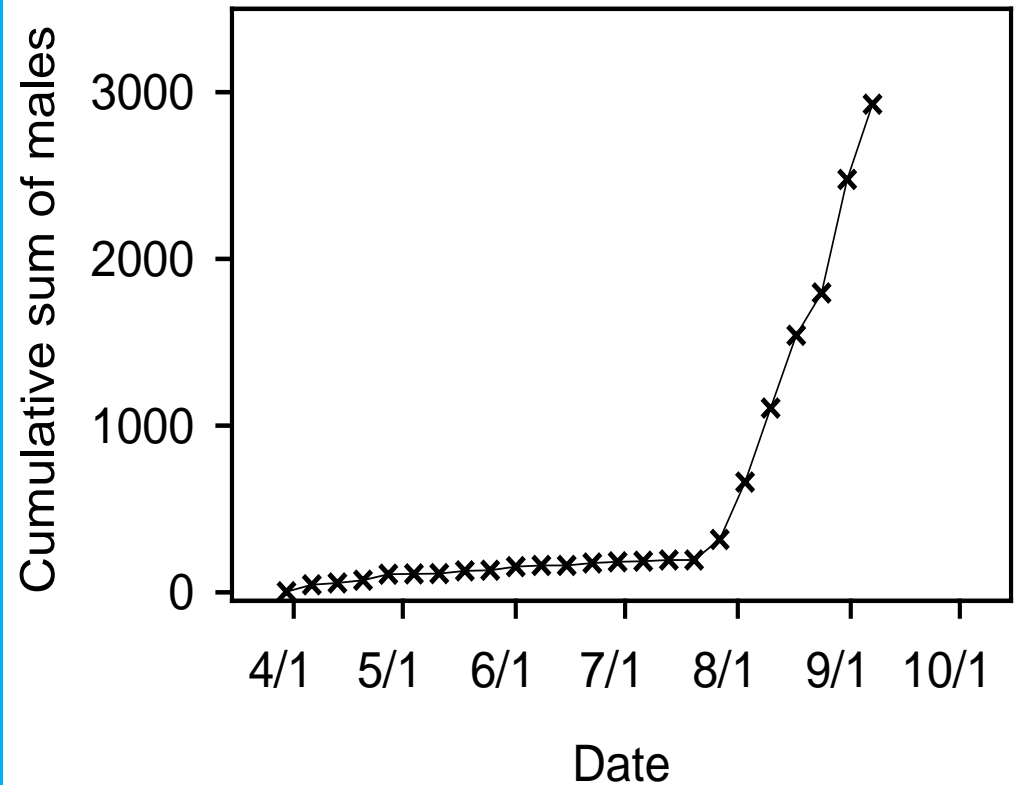
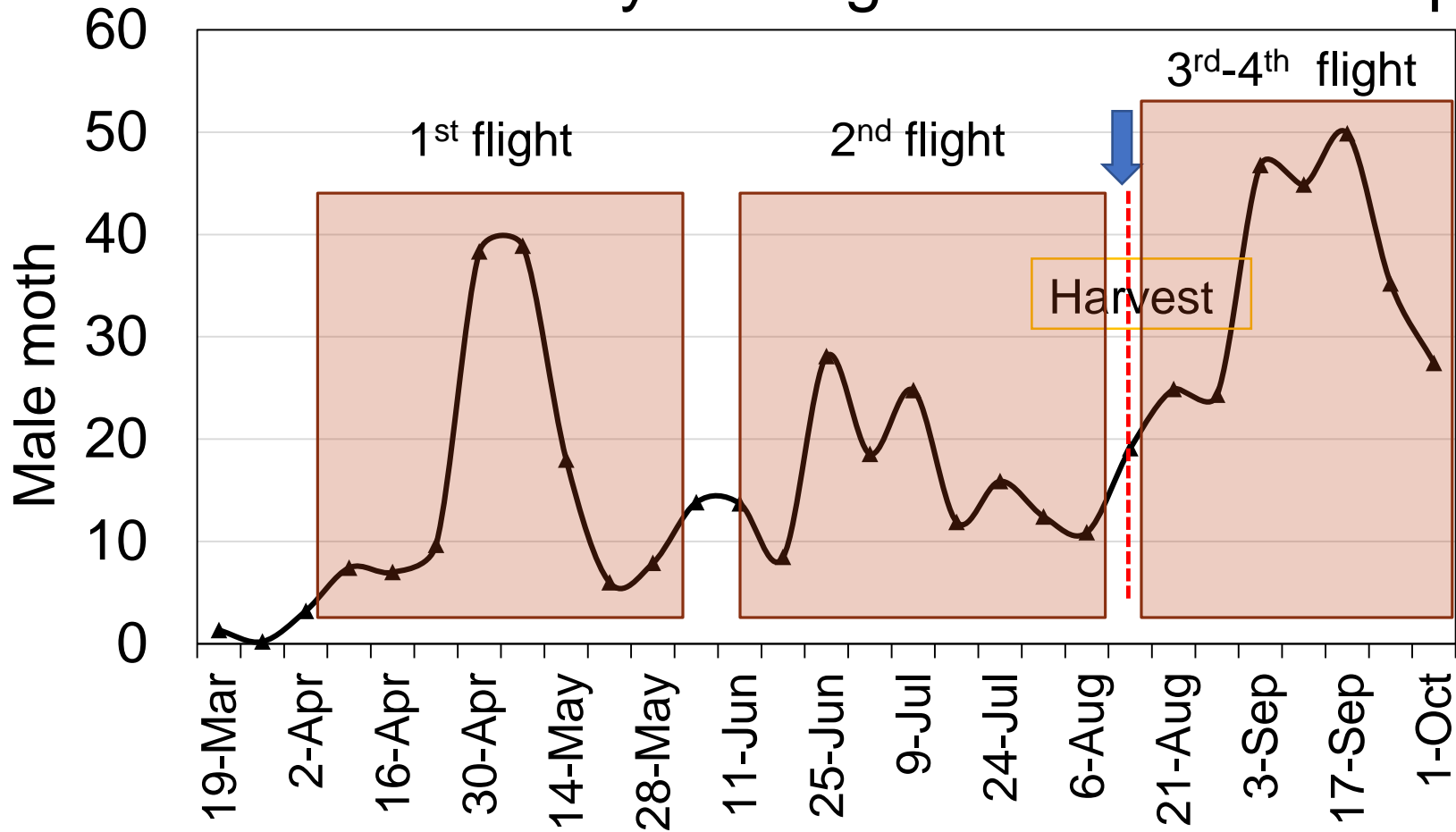


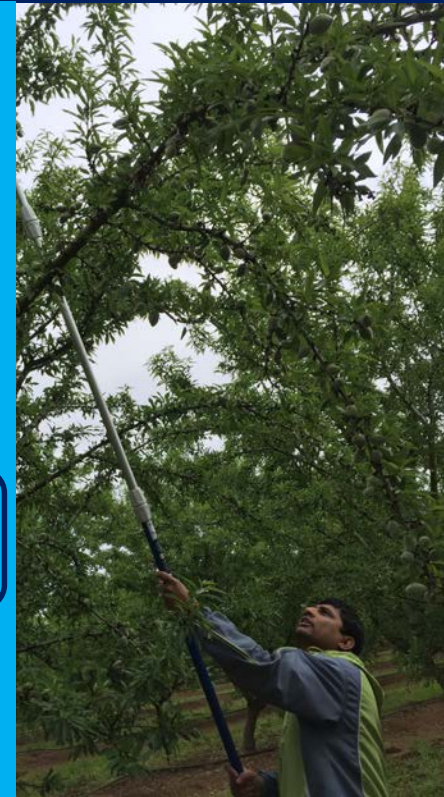
Fig. from Chuck Burks

2019-Weekly average NOW counts/trap



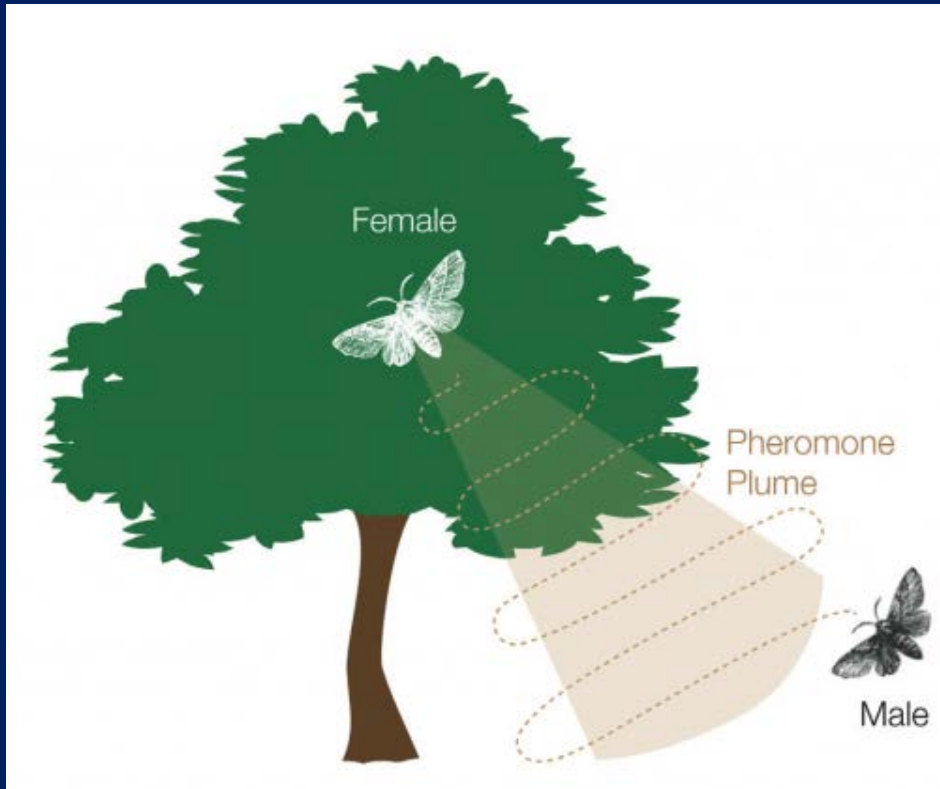
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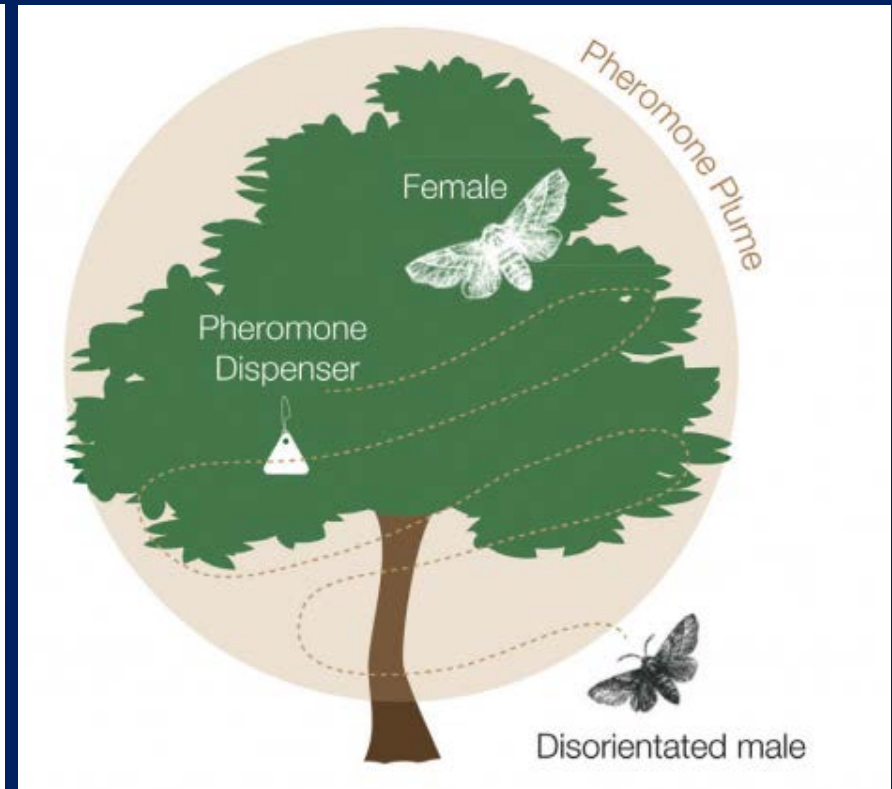


Insect Mating Disruption

Release of the synthetic pheromone (into the orchard) inhibits the male's ability to locate and mate with the female



No mating disruption



Under mating disruption

NOW Mating Disruption Products



Puffer NOW (Suterra)
@2 units/A; 7.48 g a.i./A



Semios NOW Plus (Semios)
@1 unit/A; variable a.i.



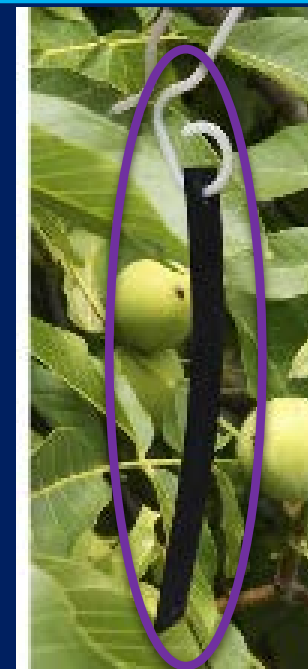
**Semios
NOW
Eco
(Semios)**



**ISOMATE NOW Mist
(Pac. Biocotrol)**
@1 unit/A; 7.1 g a.i./A



**Cidetrak NOW Meso
(Trécé)**
@20 dispensers/A



Efficacy of 4 MD Products in reducing damage by NOW - Southern SJV

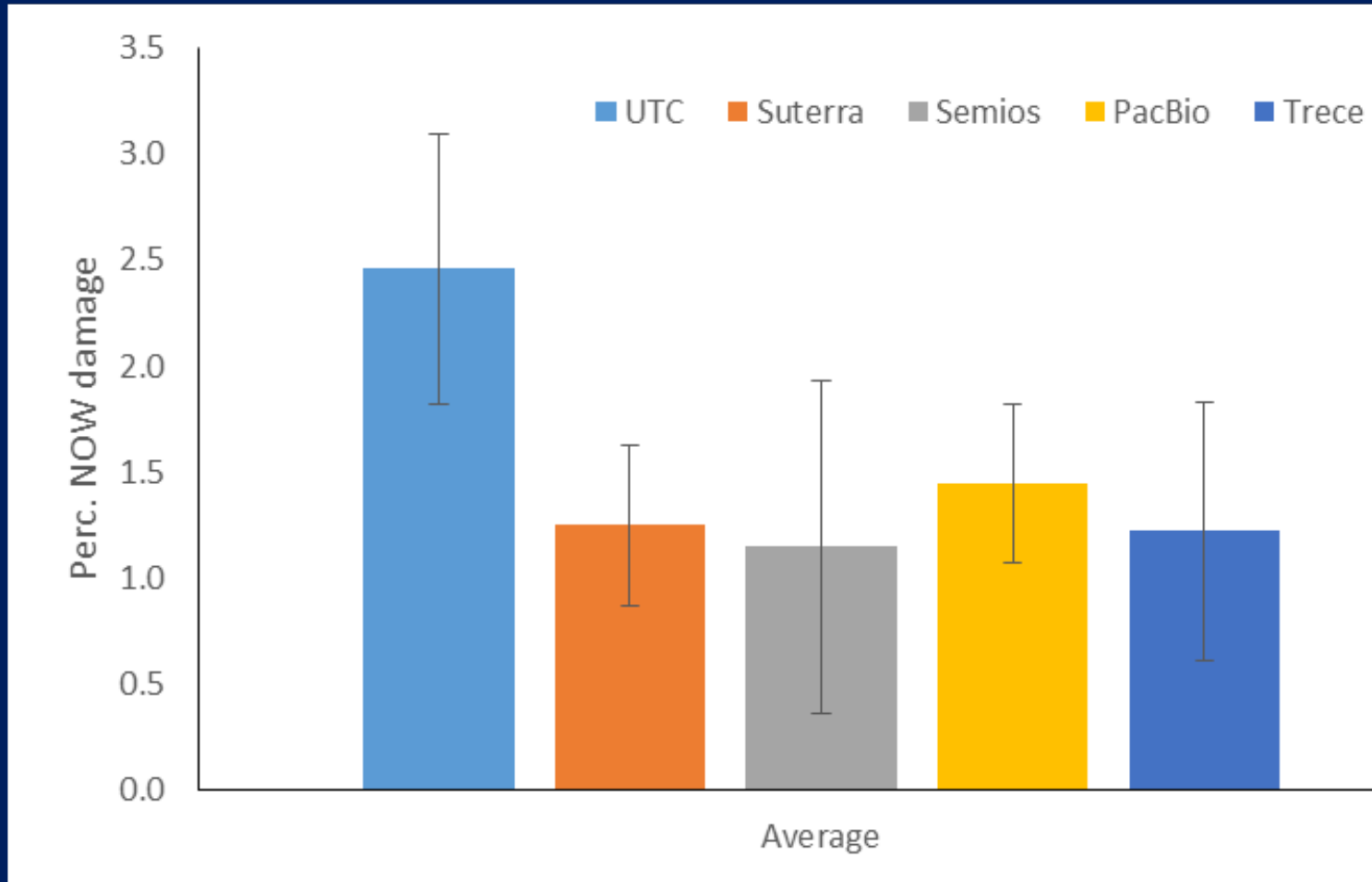
Damage Reductions

Wasco
62%

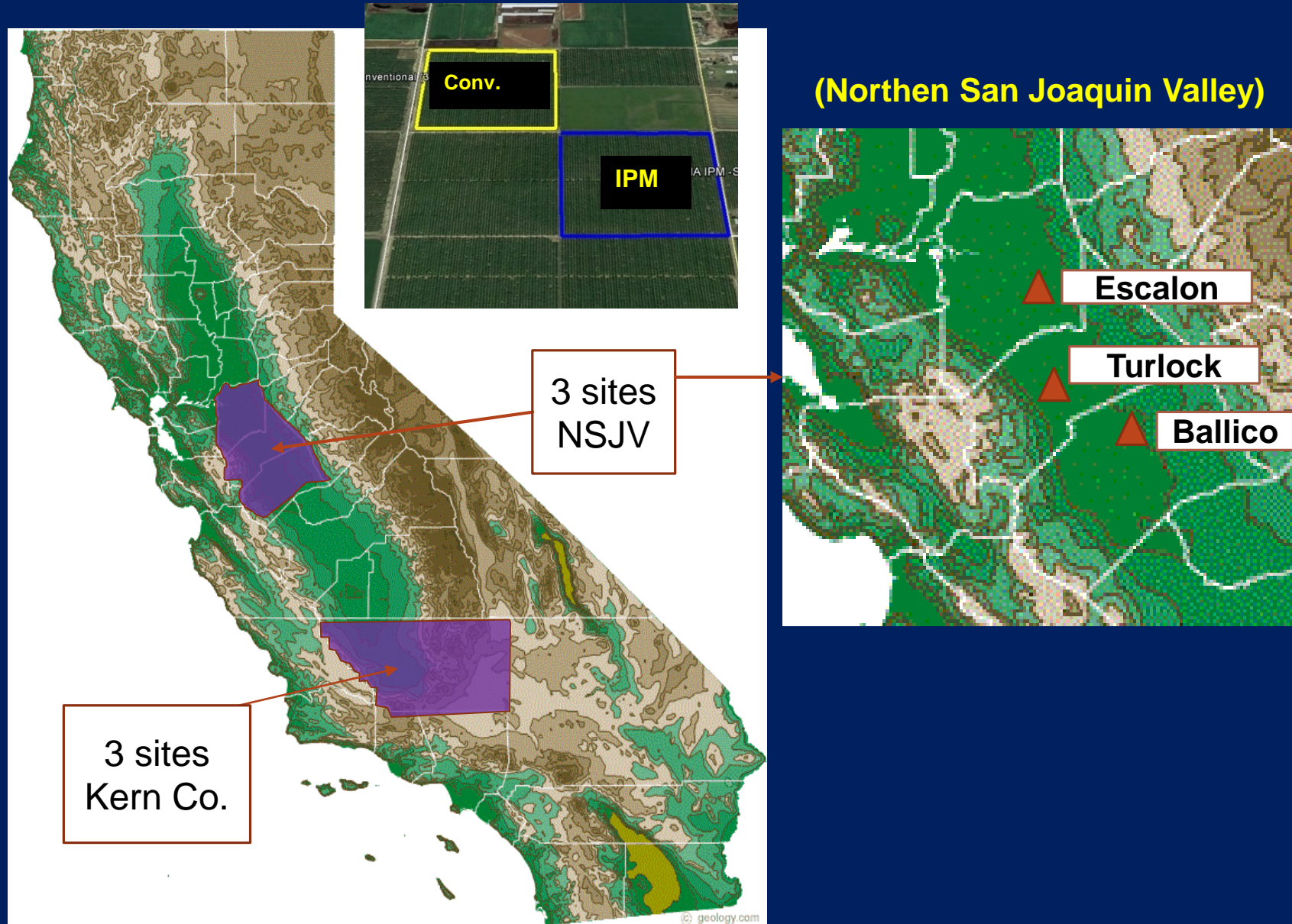
Maricopa
45%

Buttonwillow
20%

Average
46%

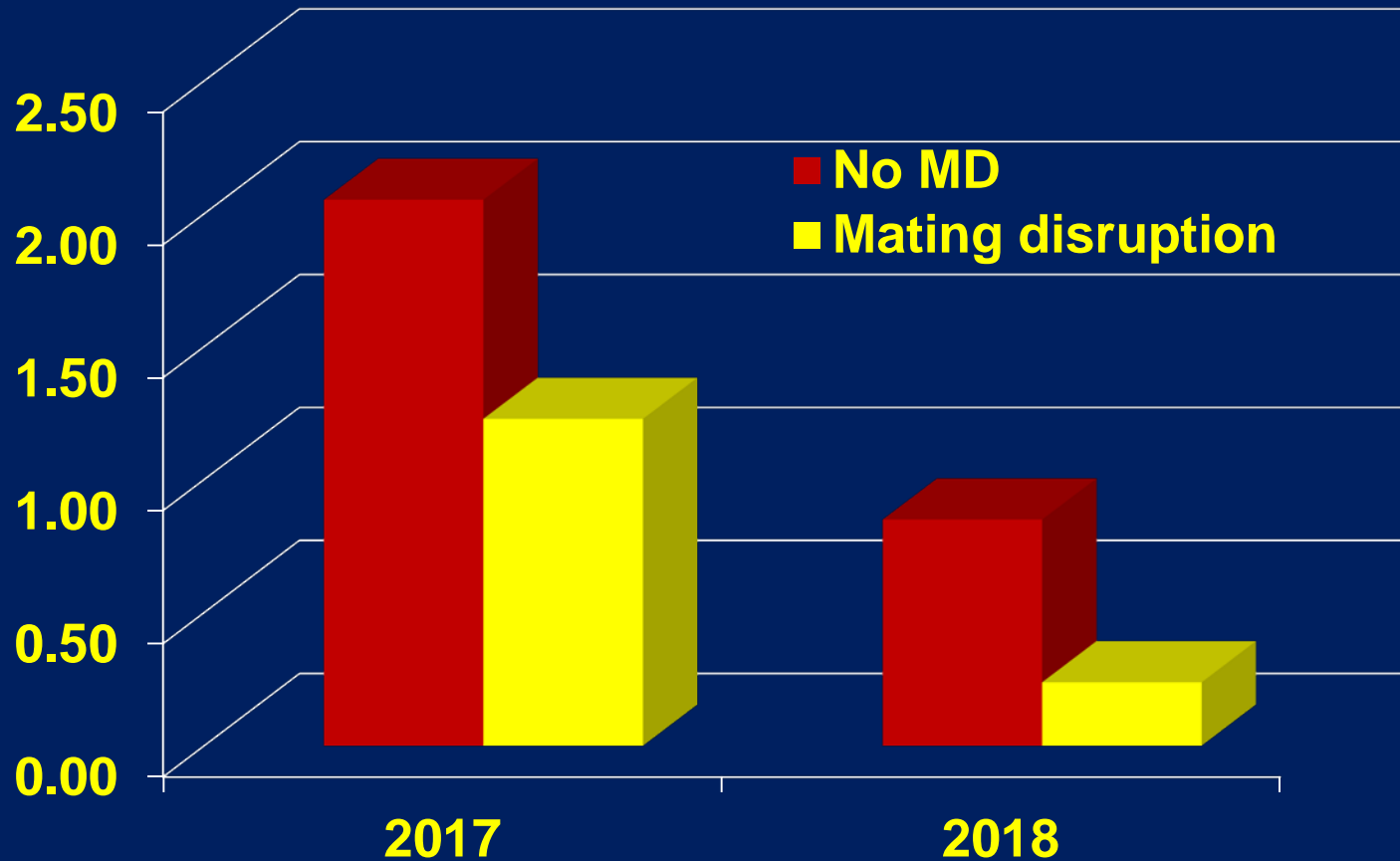


Pest Management Alliance (PMA) Grant from DPR -Project Sites



All 3 North SJV Sites Combined (2017-2018), Navel Orangeworm

% NOW damage in 3 PMA sites



**Reduction
in damage**

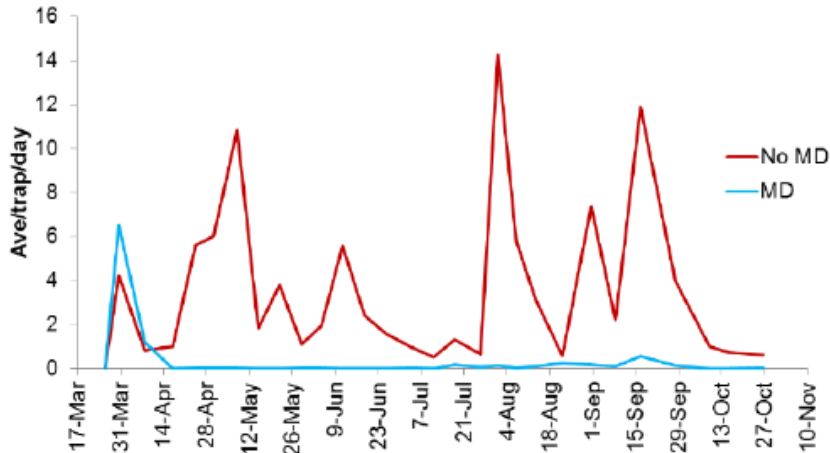
2017: 72 %

2018: 63 %

**Combined:
~67%**

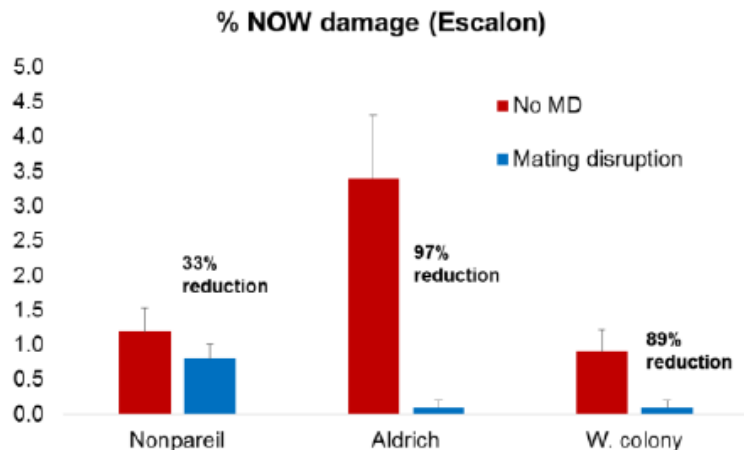
2017-2018 Summary (North & South SJV)

- Consistent reduction in moth captures (down 95%)



| Kern 2017 | SSJV 2017 | SSJV 2018 | NSJV 2017 | NSJV 2018 |
|-----------|-----------|-----------|-----------|-----------|
| 89 | 97 | 100 | 95 | 100 |
| 95 | 93 | 97 | 97 | 98 |
| 91 | 94 | 99 | 83 | 97 |

- Consistent reduction NOW damage (down 48%)



| Kern 2017 | SSJV 2017 | SSJV 2018 | NSJV 2017 | NSJV 2018 |
|-----------|-----------|-----------|-----------|-----------|
| 62 | 84 | 50 | 57 | 46 |
| 45 | 5 | 50 | 70 | 73 |
| 20 | 73 | 42 | up | 53 |

Nonpareil Reject Levels

| Comparative Values at Varying Reject Levels | | | | | | | | | | |
|---|---------------|--------------------------------------|------------|--------|-------------|---------------|------------|-------------|----------------------|------------------|
| | | Yield | 2,500 | | | | | | | |
| | | Price | \$ 2.50 | | | | | | | |
| TMS | RJS% | RJS Wt | Field Loss | TGM | Base | Total Premium | | Total Value | Loss | Incremental Loss |
| | | | | | | Rate | Amount | | | |
| 2,500 | 0.00% | 0.0 | 0.0 | 2500.0 | \$ 6,250.00 | \$ 0.1850 | \$ 462.50 | \$ 6,712.50 | | |
| 2,500 | 1.00% | 25.0 | 25.0 | 2450.0 | \$ 6,125.00 | \$ 0.1750 | \$ 428.75 | \$ 6,553.75 | \$ (158.75) | |
| 2,500 | 2.00% | 50.0 | 50.0 | 2400.0 | \$ 6,000.00 | \$ 0.1150 | \$ 276.00 | \$ 6,276.00 | \$ (436.50) | \$ (277.75) |
| 2,500 | 3.00% | 75.0 | 75.0 | 2350.0 | \$ 5,875.00 | \$ 0.0500 | \$ 117.50 | \$ 5,992.50 | \$ (720.00) | \$ (283.50) |
| 2,500 | 4.00% | 100.0 | 100.0 | 2300.0 | \$ 5,750.00 | \$ 0.0450 | \$ 103.50 | \$ 5,853.50 | \$ (859.00) | \$ (139.00) |
| 2,500 | 5.00% | 125.0 | 125.0 | 2250.0 | \$ 5,625.00 | \$ 0.0350 | \$ 78.75 | \$ 5,703.75 | \$ (1,008.75) | \$ (149.75) |
| 2,500 | 6.00% | 150.0 | 150.0 | 2200.0 | \$ 5,500.00 | \$ 0.0250 | \$ 55.00 | \$ 5,555.00 | \$ (1,157.50) | \$ (148.75) |
| 2,500 | 7.00% | 175.0 | 175.0 | 2150.0 | \$ 5,375.00 | \$ 0.0150 | \$ 32.25 | \$ 5,407.25 | \$ (1,305.25) | \$ (147.75) |
| 2,500 | 8.00% | 200.0 | 200.0 | 2100.0 | \$ 5,250.00 | \$ 0.0050 | \$ 10.50 | \$ 5,260.50 | \$ (1,452.00) | \$ (146.75) |
| 2,500 | 9.00% | 225.0 | 225.0 | 2050.0 | \$ 5,125.00 | \$ (0.0050) | \$ (10.25) | \$ 5,114.75 | \$ (1,597.75) | \$ (145.75) |
| 2,500 | 10.00% | 250.0 | 250.0 | 2000.0 | \$ 5,000.00 | \$ (0.0150) | \$ (30.00) | \$ 4,970.00 | \$ (1,742.50) | \$ (144.75) |
| Assumes | 10.00% | Broken and Foreign Material = \$.055 | | | | | | | | |
| Assumes | | very. | | | | | | | | |
| | | | | | | | | | \$ (1,742.50) | |

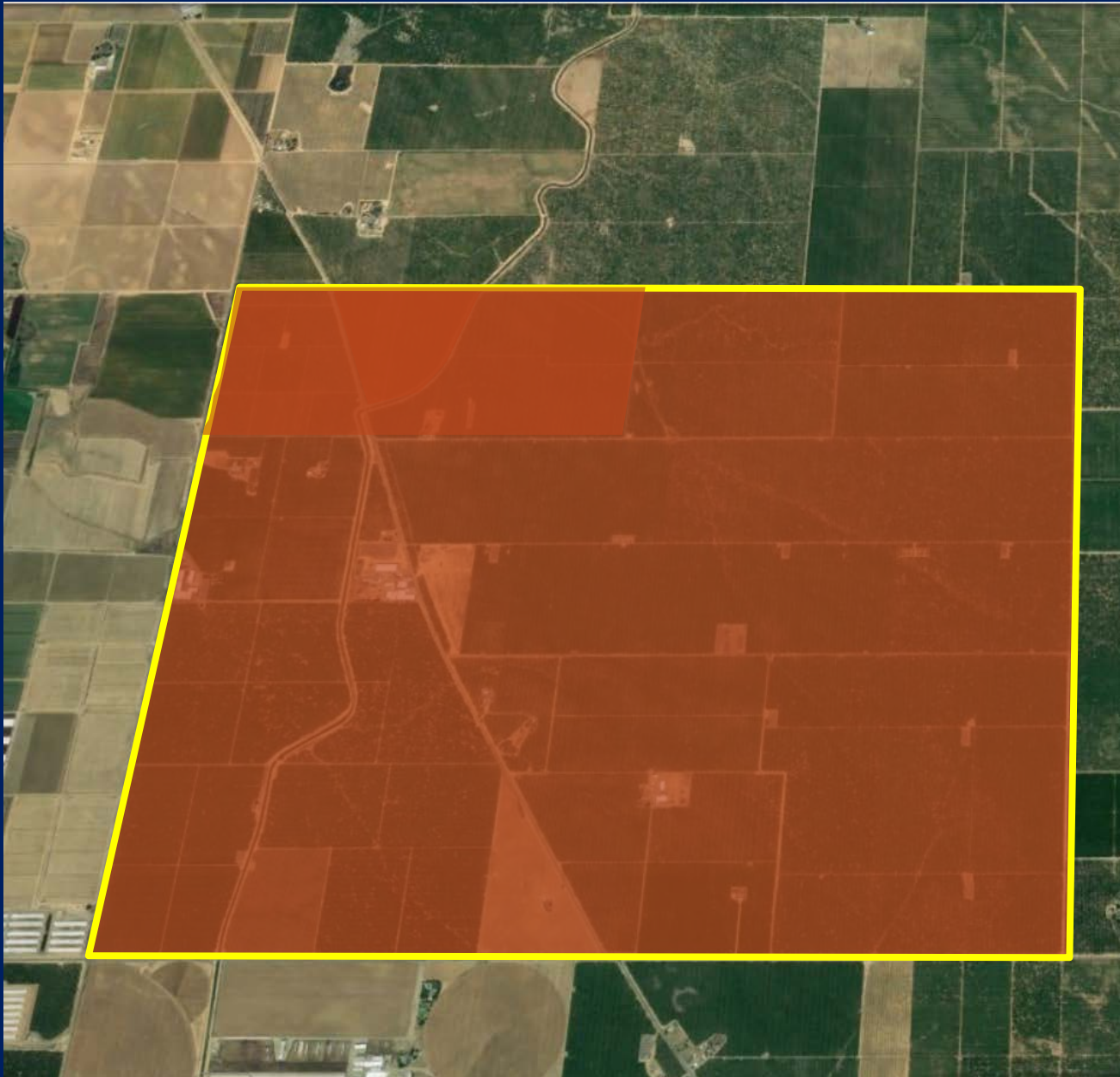
Source: Mel Machado



Benefits: NOW Mating Disruption

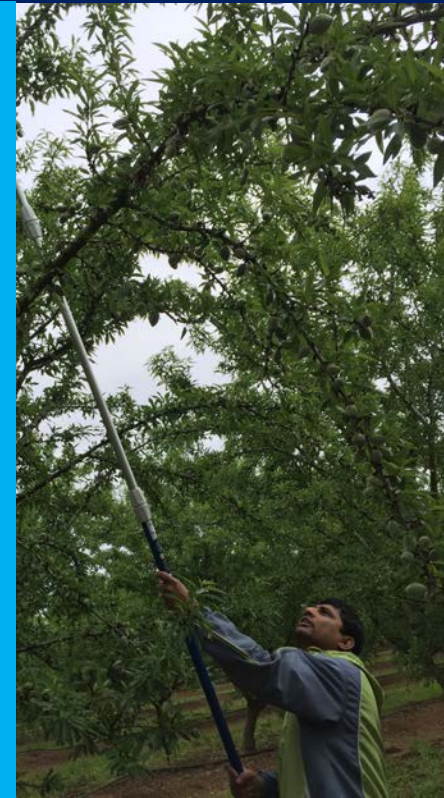
- ~48% damage reduction used with insecticide(s)
- Reduced aflatoxin contamination
- Non-toxic to the labor, no REI, PHI; no residue on fruit
- Less likely that NOW develops resistance to the product
- One-time application beginning of the season, and at a time when there is the less labor demand for other tasks
- Cumulative effect of population reduction by repeated use over the years
- Benefit higher with higher pressure and bigger blocks
- A strong candidate tool for sustainable production

Areawide (neighborhood??) Mating Disruption

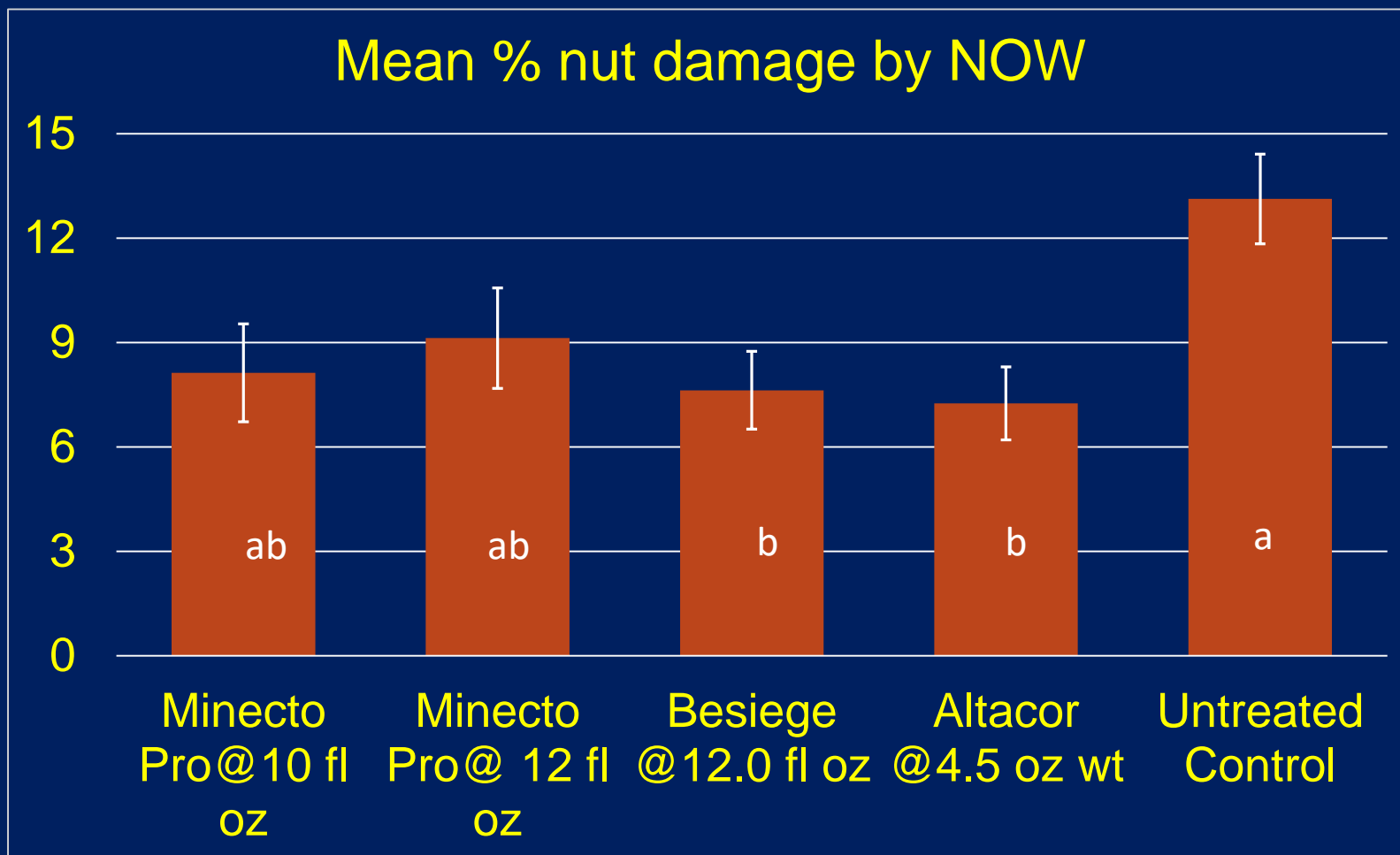


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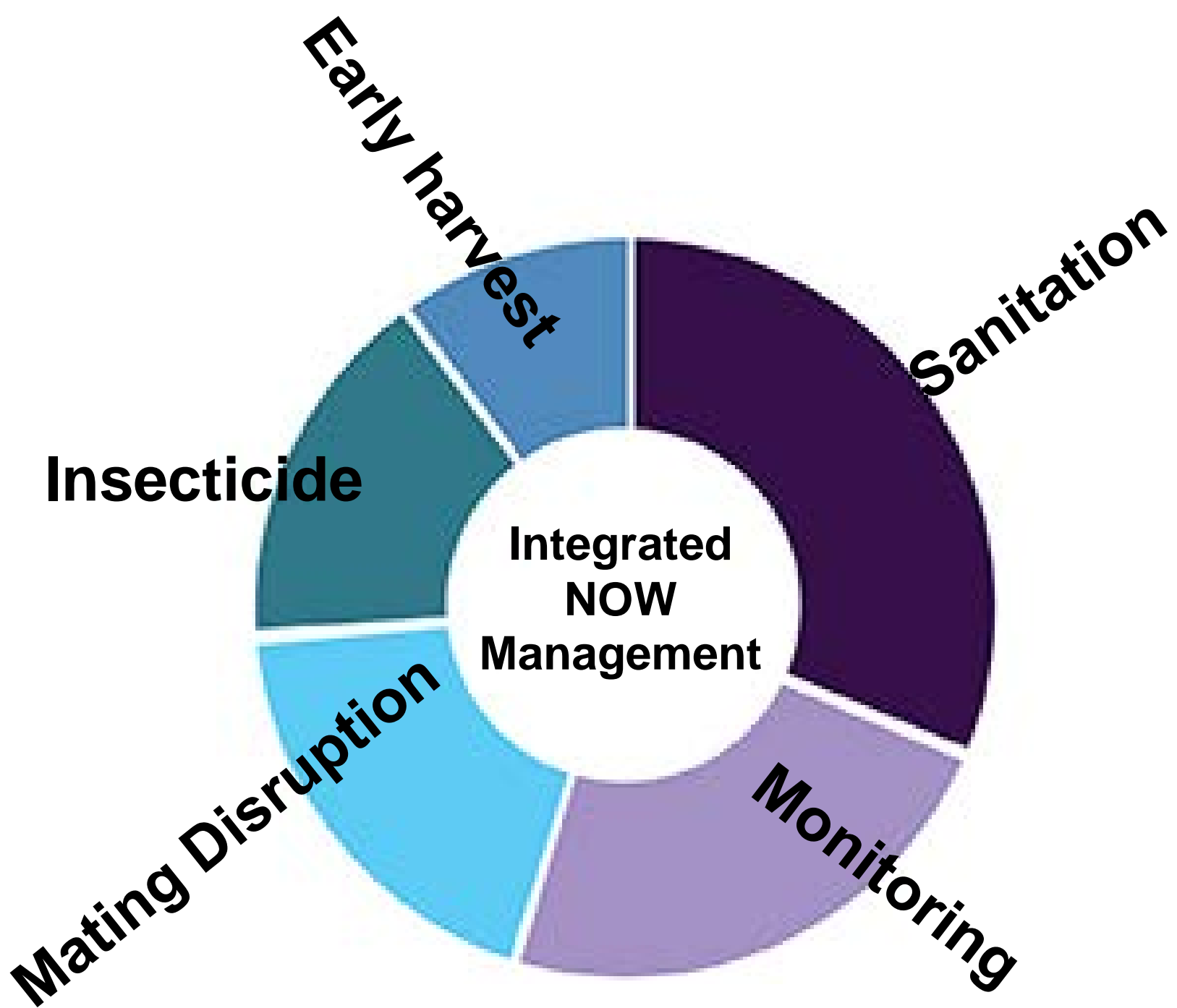


Insecticides for NOW-2017



Minecto Pro: cyantraniliprole, abamectin
Besiege: chlorantraniliprole, lambda-cyhalothrin
Altacor: chlorantraniliprole

Single tree treatment, 100g water vol.
Replication = 4; Design = CRD
2 applications (1% HS, 14 days after)



Thanks to:

- Cooperator Growers/Pest Control Advisors
- Tania Herrera, Dan Rivers, Daniel Green



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