Navel Orangeworm Biology and Management

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2017 American Pistachio Growers Conference

Navel orangeworm (NOW)

- First Identified in Mexico in 1915
- Found in CA in 1942
  - Quickly spread to the SJV
- In Tehama Co. by 1949
- Predominantly found in almonds, pistachios and walnuts
- Many alternate hosts
  - Figs, nuts, pomegranate, citrus, stone fruit, pome fruit
- Always associated with nuts or fruit

Identification

- Adults
  - gray with narrow, wavy black bands on wings
  - Females up to 1 inch wingspan
  - Male slightly smaller
  - Pointed palps at 30° upward angle
- Eggs
  - Creamy white, reticulated, flat
  - Becomes orange to red as it matures
  - ~85 eggs per female over a period of 1 week
  - Eggs hatch in 3 days (summer) to 30 days (winter)
  - Eggs are the size of a pinhead

Identification

Larvae

- 1st instar 1mm long
- Typically creamy to orange to pale red
- Pass through 6 instars
- All similar in appearance
- Large larvae ~3.4 in long
- C-shaped crescent present above middle legs on thorax

Injury

- NOW must feed on the kernel
  - Do not attack almond before shells split
  - Must feed on last year's crop until new crop splits
- Lay eggs when shell is split
- Larvae feed on the kernel
  - Reductions in yield and quality
- NOW associated with fungi (Aspergillus sp.) that can produce aflatoxins

Management Pressures Increasing

- Huller thresholds
  - Pre-aflatoxins = goal of 2%, but often higher
  - Post-aflatoxins- nothing over 2% (goal of less than 0.5%)
- Climate change
  - Dry winters, no fog- increased overwinter survival
  - Warm springs, increased degree days- earlier start for NOW, 4 generations in places that usually have 3
- Increases in grower returns
  - Pesticides appear cheaper
  - Increased crop value means more to protect
- Increased acreage, nuts over 1.5 million acres in CA
  - Many new PCAs and PCAs covering too much territory
- Shifts in pesticides
  - OPs and Pyrethroids shifting to ‘greener’ products

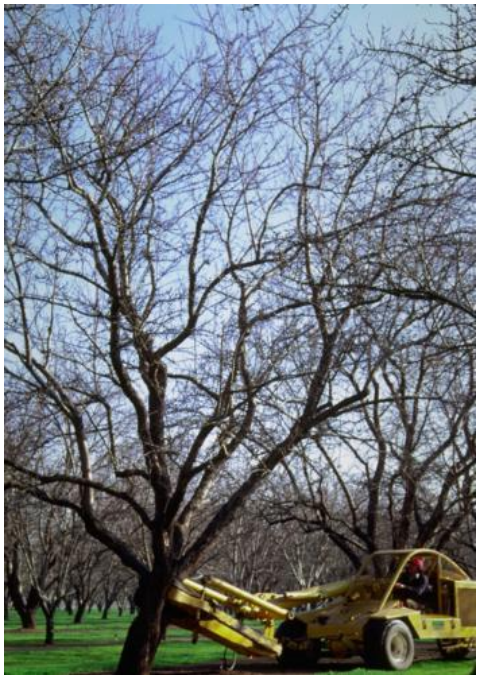
Seasonal development

- Overwinter in mummies as large larvae
- 1st flight from March to May
- Complete a generation in mummies
- 2nd flight in late June and July
- Eggs laid on mummies, then early splits
- 3rd flight mostly in August
- Eggs laid on new crop
- 4th flight mostly in September
- Development time in each stage dependent on host quality (1050DD in mummies, ~700DD in fresh almonds, ~500-600DD in fresh pistachios)

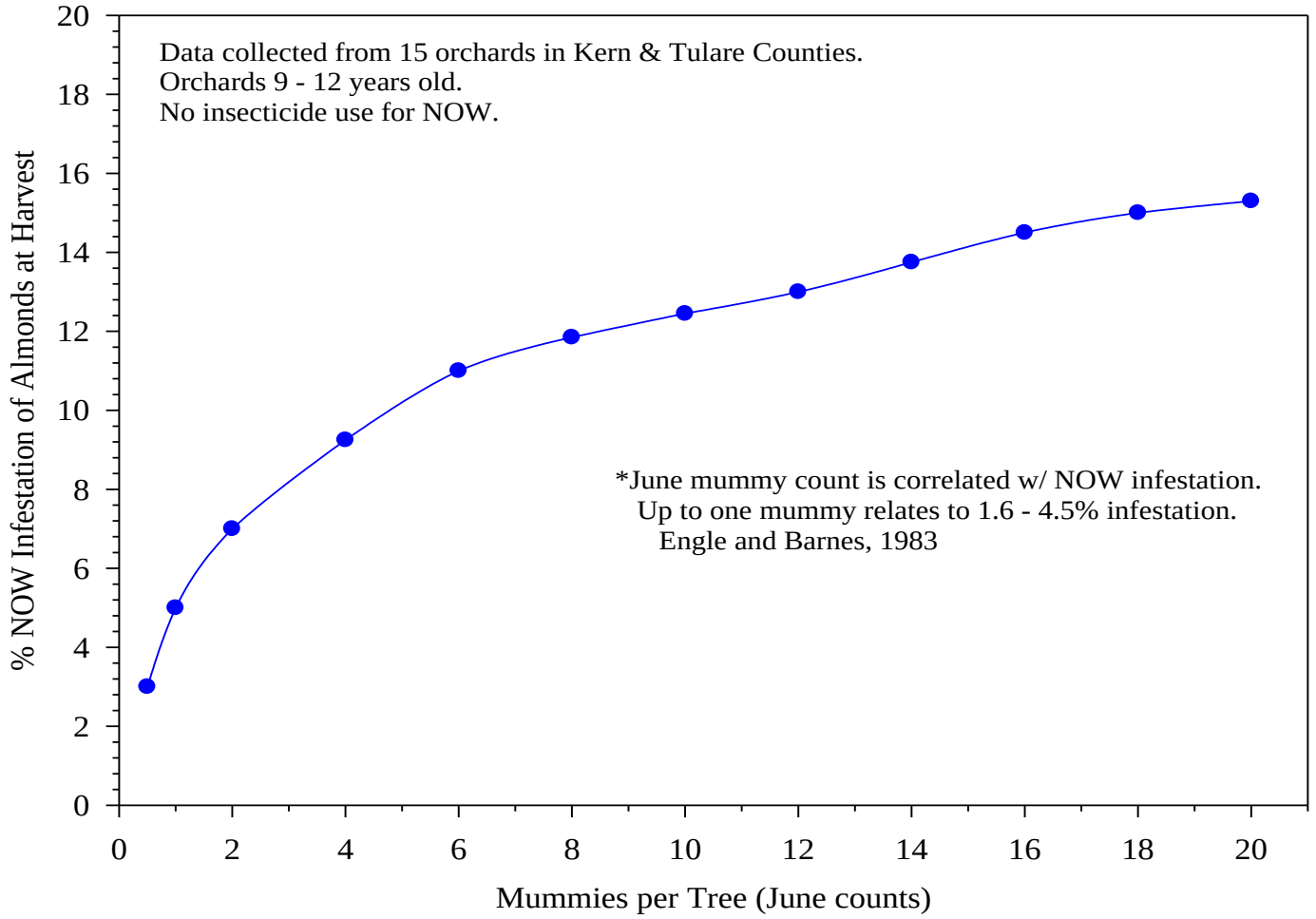
TOOL #1- SANITATION

Sanitation

- Backbone of NOW management
  - NOW overwinter in mummies
  - 1st flight of adults must lay eggs in mummies
  - 2nd flight adults must also lay eggs in mummies if early splits are not available
- Remove all mummies possible
  - 50% of nuts not removed are still available for NOW
- Help nature destroy nuts
  - Rain, dew in ground cover, fungi, sprouting
- Much easier in almonds than pistachios



Winter Orchard Sanitation



Orchard Sanitation

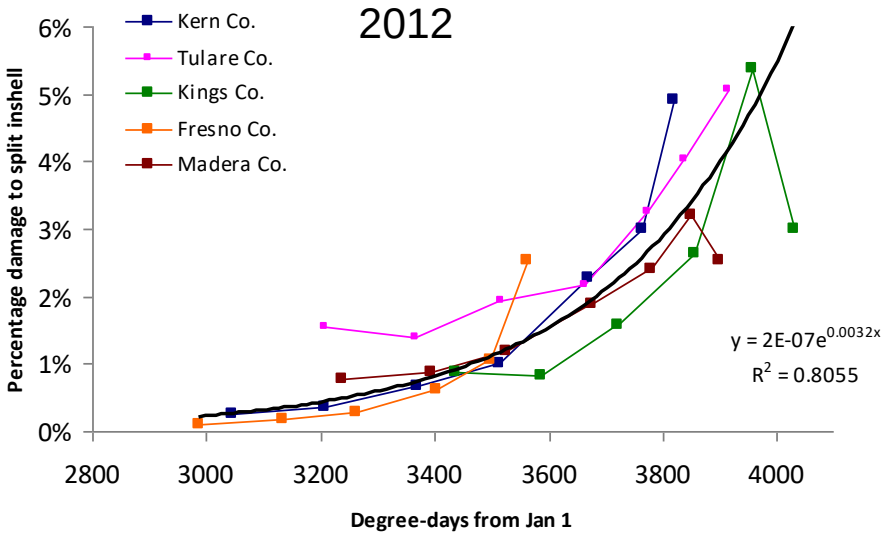
- Shaking
- Poling
- Cleaning tree crotches
- Blowing off berms
- Disking
- Flail mowing
- Crows
- Floor management
- Winter flooding

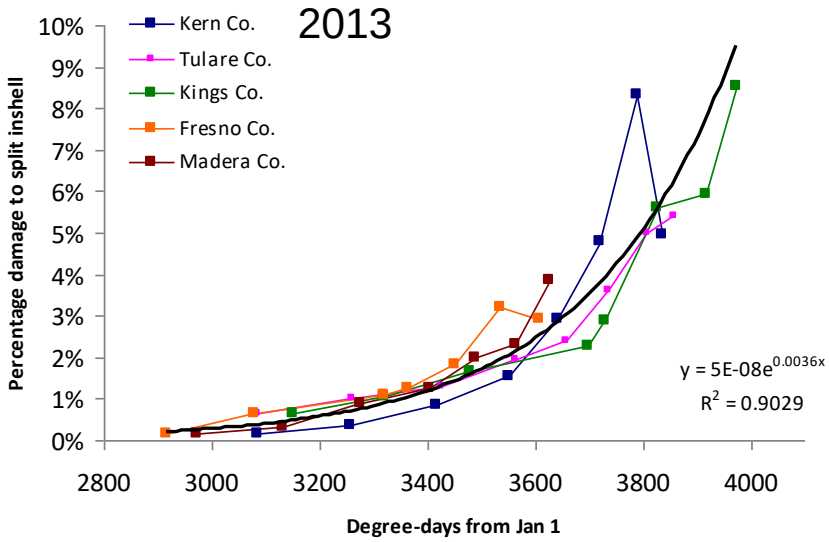
TOOL #2
EARLY/TIMELY HARVEST

Early/Timely harvest

- Damage increases over time
  - Low during 3rd flight
  - Increases exponentially with 4th flight
  - Second shake all bets are off
- Harvest as soon as possible
  - Too early results in a poor shake and need to reshake
  - Too late may result in one pass to harvest, but increased damage to NOW
- Two shakes becoming very common
  - 100 lbs/ac of nuts justifies the cost at $2/lb
  - Second shake has value for sanitation

Harvest damage over time



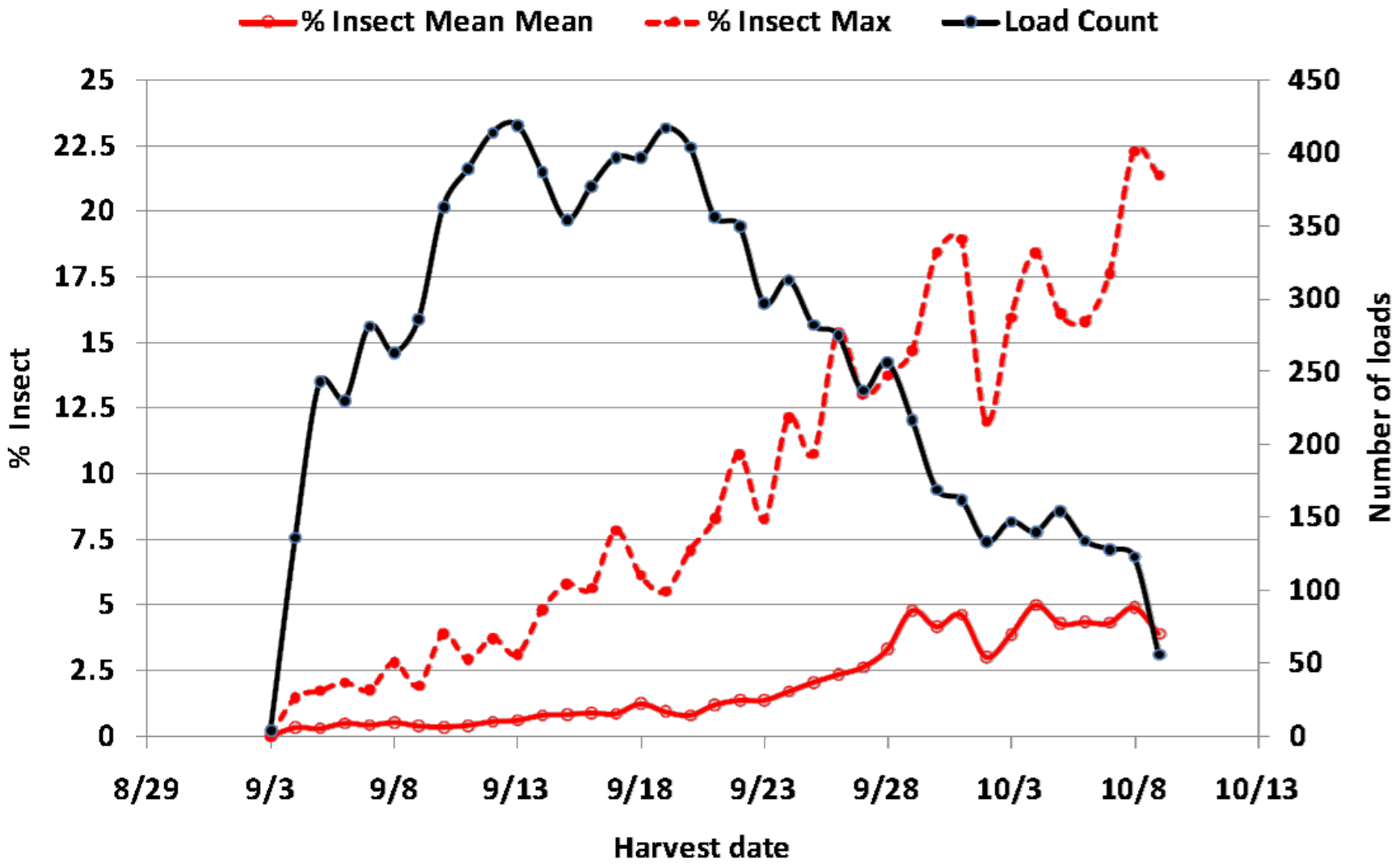


	1.5%	2%	Damage doubling time
2012	3508	3598	215 dd = ~10-11 days
2013	3547	3624	191 dd = ~9-10 days

Note: Data are from orchards using insecticides. Rate of damage increase in untreated orchards may differ

Kern County - 2012

9690 (10/11) loads



B. Higbee, Paramount Farming Co.


TOOL #3
BIOLOGICAL CONTROL
UC Statewide IPM Project
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Biological Control

- Parasitoids
  - *Goniozus legneri* and *Copidosoma plethorica*
  - Rare at low NOW densities
- Predators
  - *Phytocoris*
  - Lacewings, other general predators
- Vertebrates
  - Birds, mice, crows that eat mummy nuts, eat larvae in mummies, or that knock mummies to the ground

Phytocoris

(Phytocoris relativus and *Phytocoris californicus)*

Predator of NOW eggs

and European fruit lecanium

and young pistachios

Conserving Phytocoris

- Monitor for small bugs
- Recognize tolerance for *Phytocoris* compared to *Lygus* and *Calocoris*
- Acknowledge compensation
- Don't treat unless needed
  - Avoid 'throwing in a pyrethroid' because it is cheap.
- Consider permethrin instead of Brigade or Warrior II
- Avoid May sprays with pyrethroids for NOW

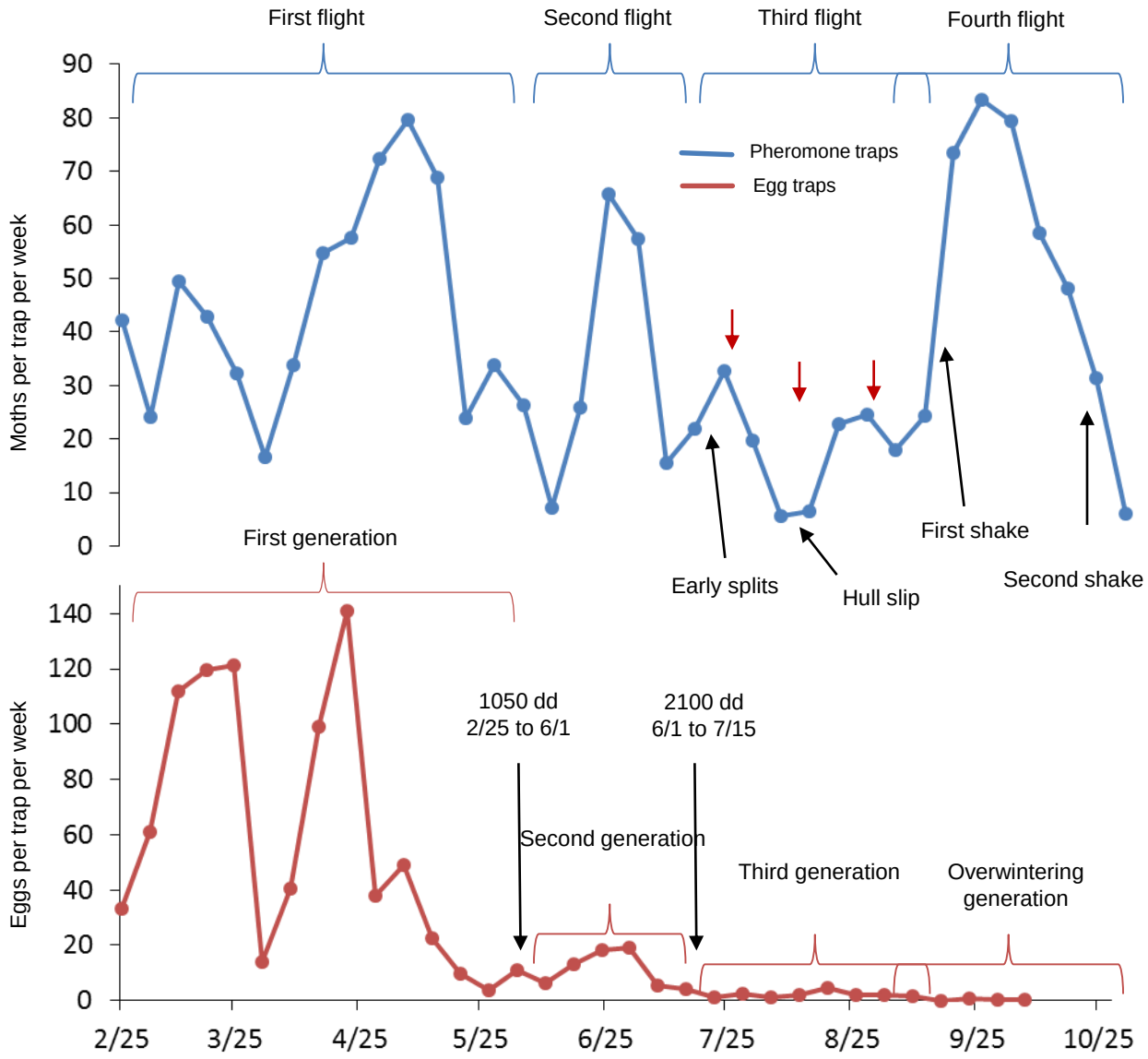
TOOL #4
EGG AND
PHEROMONE TRAPS

Egg traps

- Black cylinder
- Almond meal and oil
- Start in March
- Most effective during the first flight
- Most effective with good sanitation
- Traditionally used to set a biofix for degree-day models

Monitoring adults

- Pheromone traps
  - Captures adult males
  - Start in March or April
  - Difficult to interpret before June
  - Better that egg traps after June
- Peterson trap
  - Ground mummies in a bag
  - Placed on wing trap
  - Captures adults
  - Advertised as a way to trap out adult females

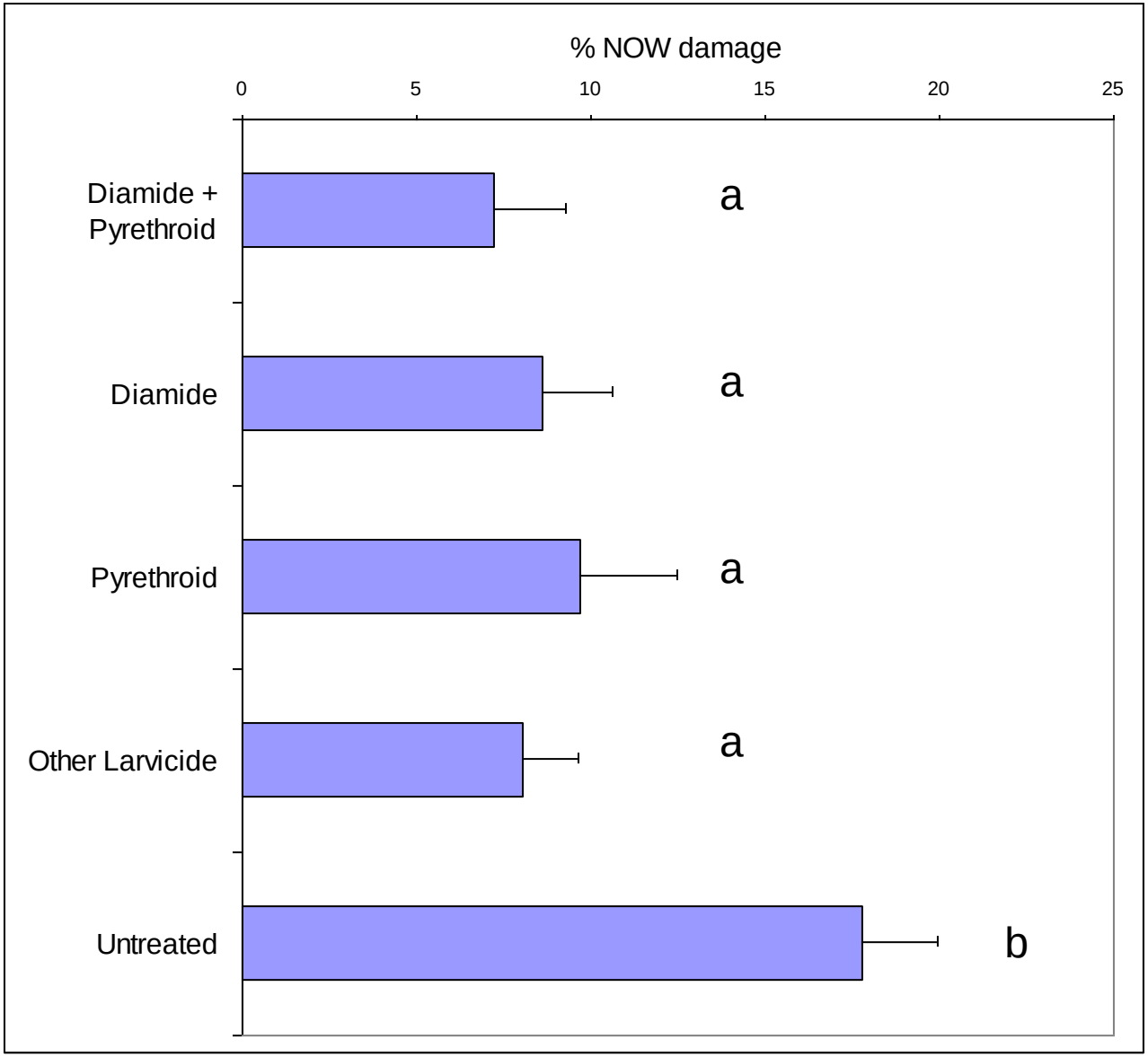


18.5. Navel orangeworm captures in a 640-acre commercially sprayed pistachio orchard in Kern County during 2014 using A) pheromone traps and B) egg traps. Flight periods shown are approximately 2 weeks earlier than normal due to an above-normal accumulation of degree-days during 2014. Red arrows indicate insecticide applications on 27 July, 12 August and 30 August. *Source*: B. Higbee, Paramount Farming Company

TOOL #5
INSECTICIDES

Insecticides for Navel Orangeworm

- Intrepid (methoxyfenozide)
  - Ecdysone Receptor Agonists
  - IRAC Group 18
  - Larvicide
  - Toxin is ingested, larvae don't develop
- Altacor (chlorantraniliprole)
  - Also referred to as rynaxypyr
  - Anthranilic Diamide
  - IRAC Group 28
  - Ovi-larvicides
  - Affects calcium channel in muscles, jaws won't work
- Pyrethroids (multiple)
  - Broad spectrum
  - Also kill beneficial parasitoids and predators
  - Issues with off-site movement in to waterways
  - EPA re-review ongoing
- Delegate (spinetoram)
  - Fungal fermentation product
  - Contact and ingestion toxin
  - Primarily a larvicides, can kill adults
  - Intrepid Edge = Intrepid + Delegate



Insecticide Efficacy

1 application- typically ~50% reduction in damage

2 applications- typically ~65% reduction in damage

3+ applications- ~70-75% reduction

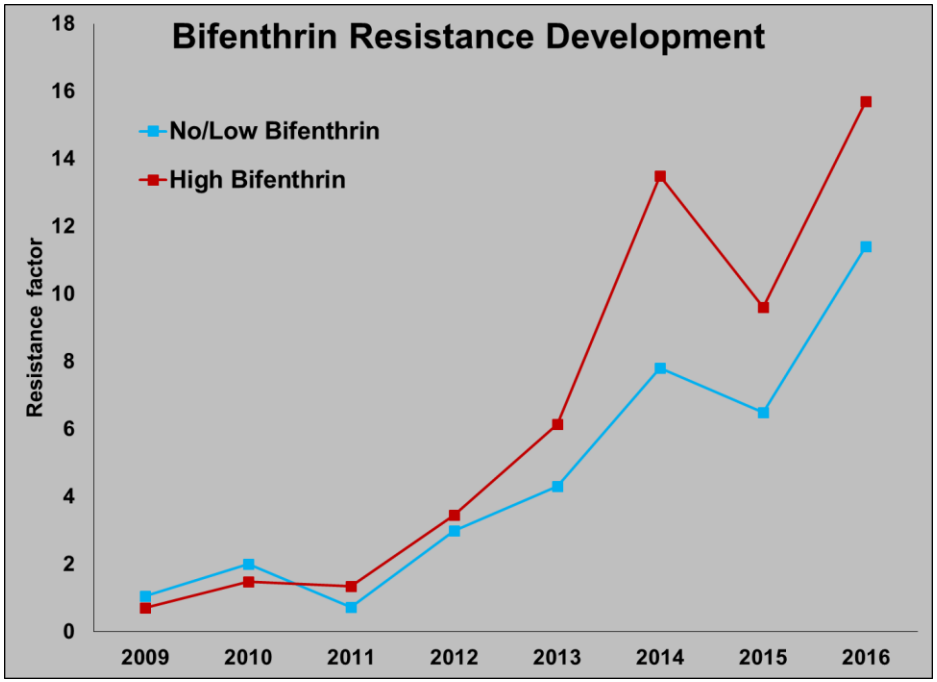
2012, Almond, UC West Side Research and Extension Center, nonpareil, individual tree plots, sprayed with hand gun, RCBD with 6 blocks, evaluations of ~350 nuts per tree, sprayed 2nd flight, harvested 2 weeks later

NOW Pyrethroid Resistance

- New pyrethroids were initially very effective
- Efficacy has been reduced over time
- Current efficacy similar to that of other products like Belt, Altacor and Intrepid
- Repeated applications to pistachios, as well as exposure in almonds, continue to place selective pressure on NOW

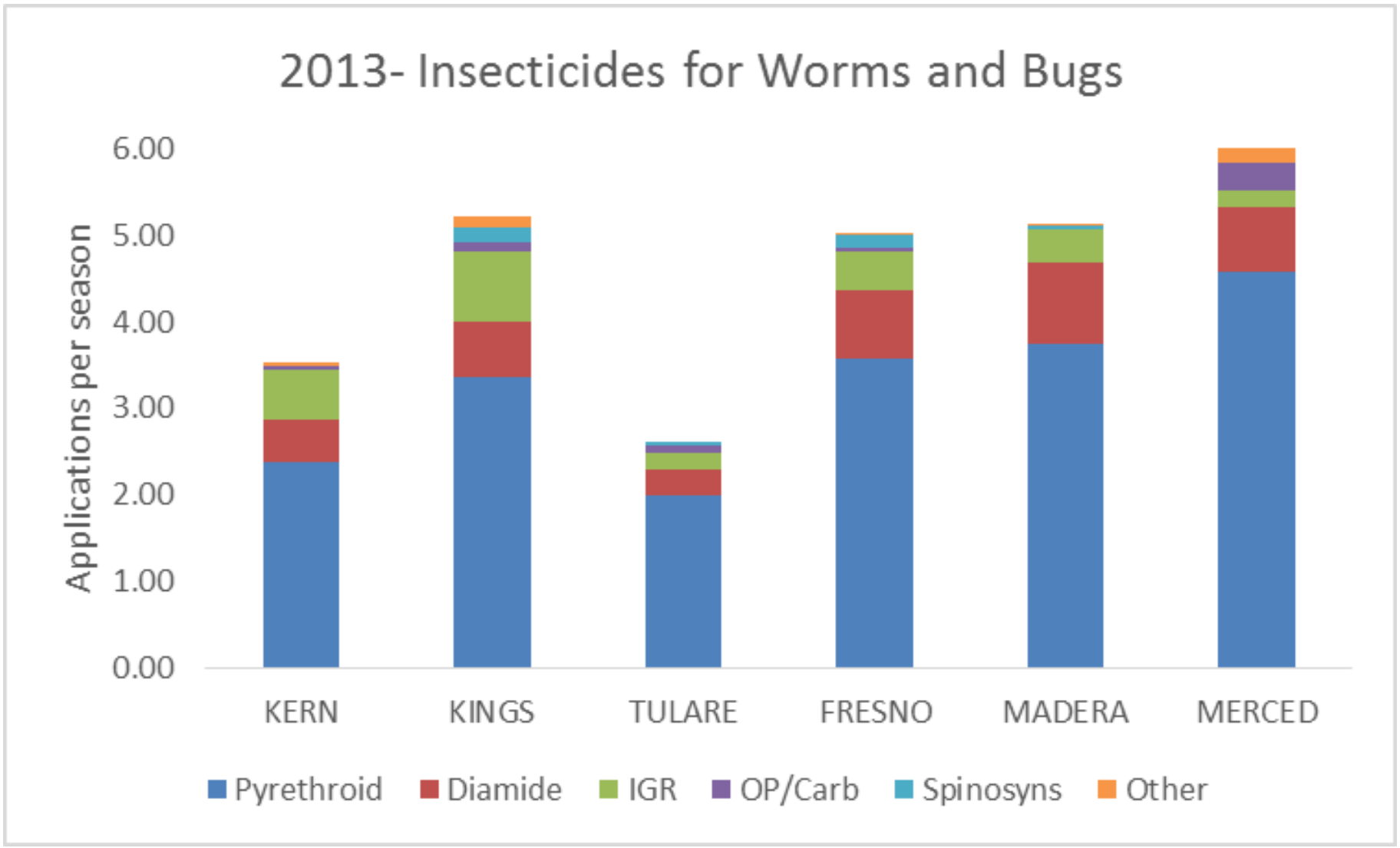
RF=Resistance factor = LC_{50} of field strain/LC_{50} of USDA strain

Bifenthrin is evaluated as a surrogate for all pyrethroids



Resistance development in populations with a history of low vs high bifenthrin use.

Source: B. Higbee, Wonderful Farming Co.


2013- Insecticides for Worms and Bugs
Applications per season
6.00
5.00
4.00
3.00
2.00
1.00
0.00
KERN
KINGS
TULARE
FRESNO
MADERA
MERCED
Pyrethroid
Diamide
IGR
OP/Carb
Spinosyns
Other

TOOL #6
MATING DISRUPTION

Mating Disruption

- Use synthetically-produced pheromone to disrupt mating
- Pheromone is placed in aerosol cans inside cabinets
- Dispensers emit female pheromone when mating occurs
- Males can’t find the females
- Mating is delayed or reduced
- Egg deposition reduced
- No PPE, MRLs, Tolerances, PHIs, REIs
- Work is done before/after the main season

NOW Mating Disruption History

1980's
- Trap suppression documented by Landolt, Curtis et al.

1990's
- Shorey showed trap shut-down with dispensers in 40 ac perimeters

2002-2007
- Higbee and Burks demonstrated impact on damage reduction in 20 and 40 ac almond plots using grids

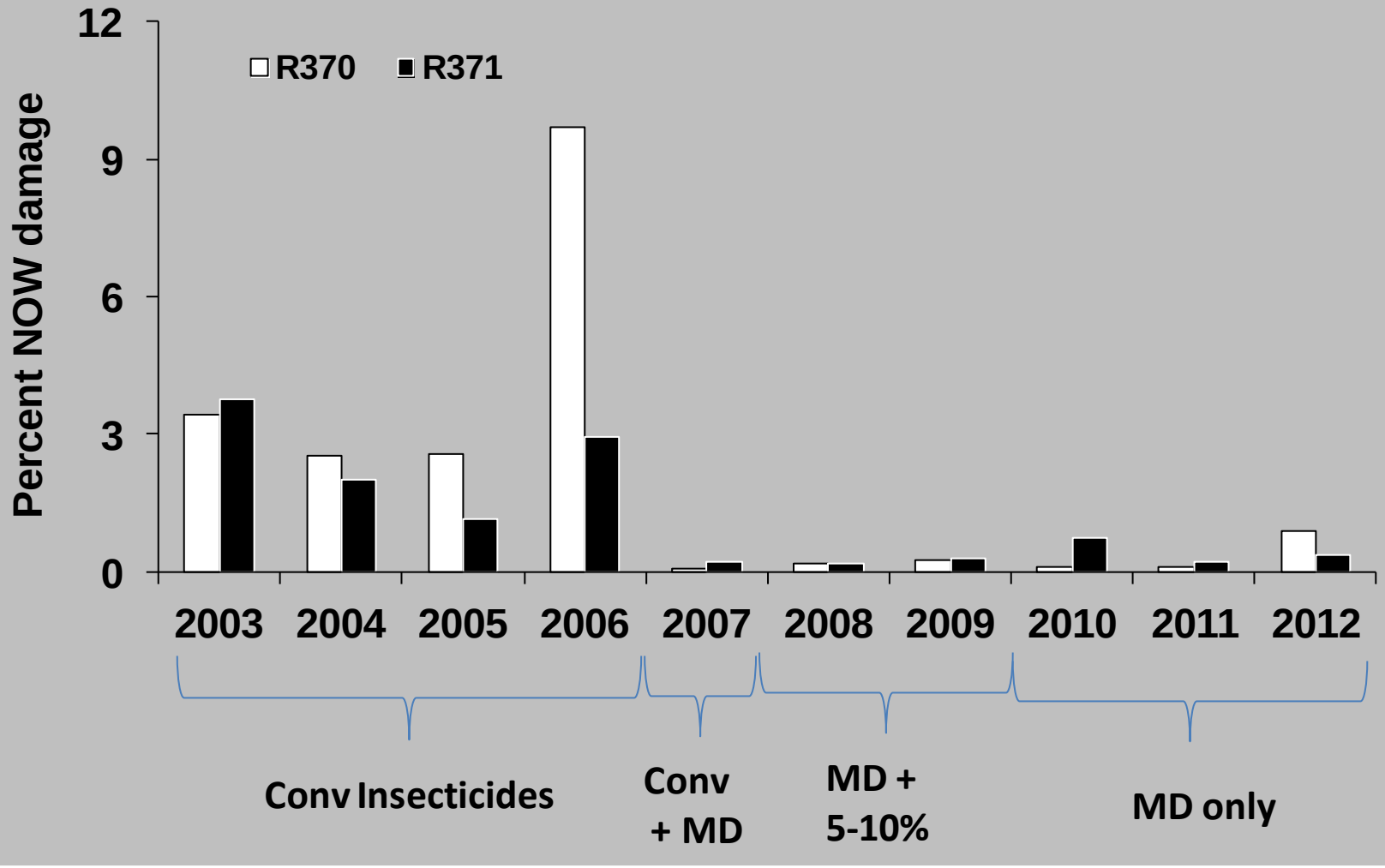
2005- Commercial product available

2008-2012- USDA NOW Areawide Project

2017- Three commercial products available

Santa Fe NOW Areawide Project

Historical NOW Damage - All varieties



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

Puffer NOW- Suterra

- Registered since 2005
- Set up a contract
- Send plot map
- Suterra installs batteries, sets clock, sets delayed start, sends through distributor with map
- Grower installs 2 Puffers per acre in top 1/3 of tree
- Puffers puff every 15 min. from 5 PM to 5 AM for 200 days
- Grower returns units to Suterra at the end of the year

Semios NOW- Semios

- Variable rate dispensers- 2016 label
- Dispensers are remotely controlled
  - On/off capabilities in real time
  - Based on wind, temp., flights, seasonal goals, etc., and customizable
- Network includes
  - 1 Dispenser per acre
  - Camera traps with daily counts
  - Weather station
  - Thermometers (deg.-day models)
  - Irrigation monitoring
- Semios does setup/cleanup

Isomate NOW- Pacific Biocontrol

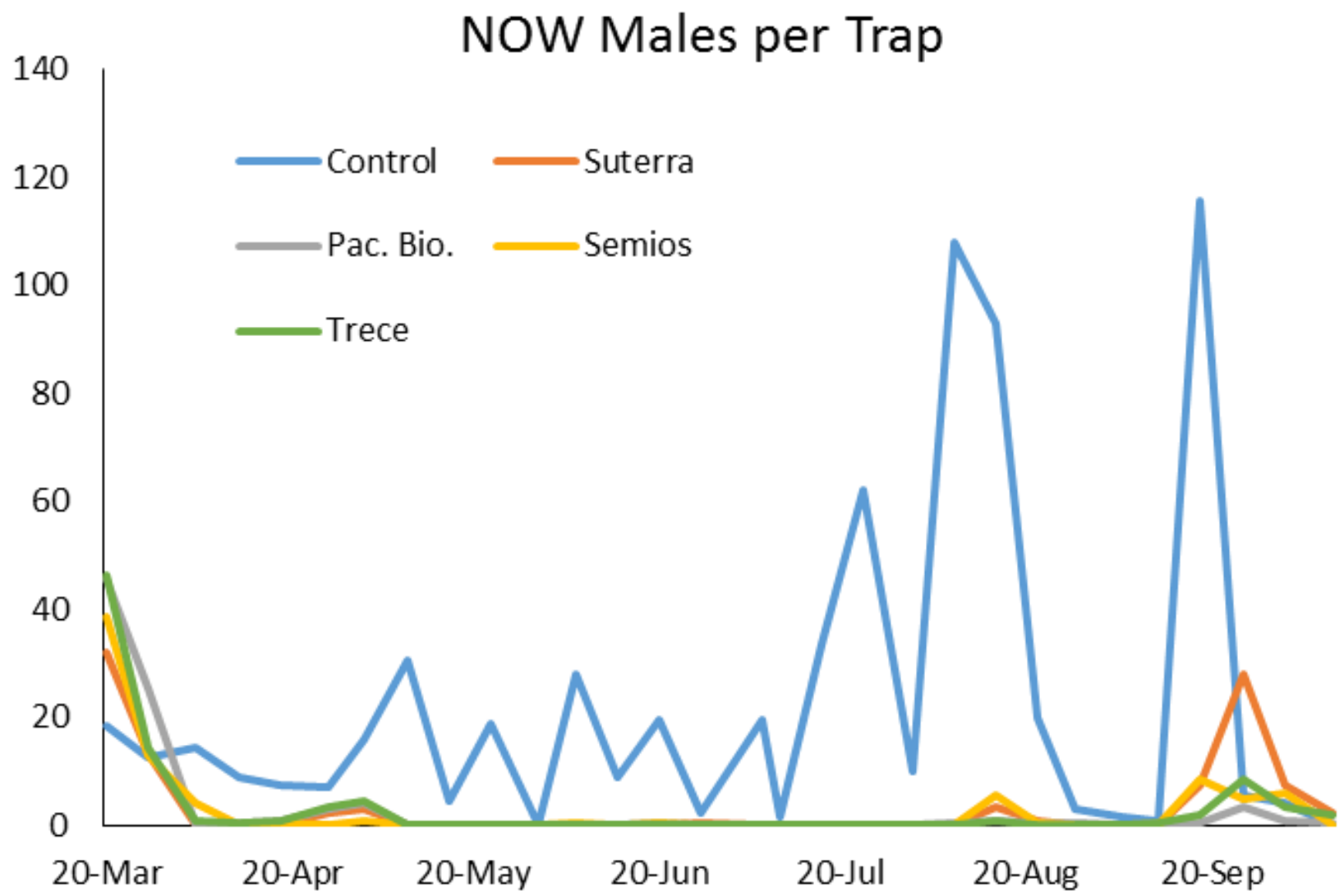
- Labeled in 2017
- Aerosol dispenser
- 1 dispenser per acre
- Submit ranch map to PacBio
- Set up contract
- Grower responsible for installation and removal
- Return units at the end of the season

MD products under development

Trécé

- Meso-emitters
- Passive dispenser system
- Hang on trees (~20/acre)
- Field evaluations started
- System is patterned after Trece's Meso products used for codling moth
- Federal label 2018 or later

CIDETRAK® CMDA COMBO™ MESO for Codling Moth

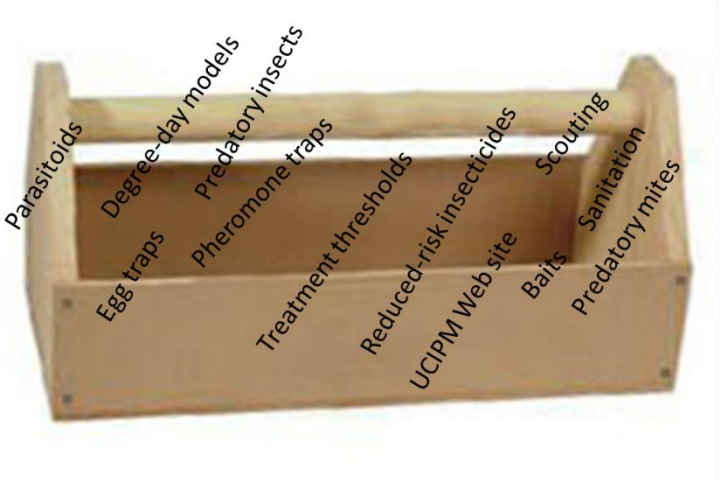


MD Trial, Maricopa, Kern Co. 2017

DEVELOPING A PROGRAM

Developing a program (death by a thousand cuts)

1. Sanitation, Sanitation, Sanitation
2. Maintain *Phytocoris* to the extent possible
3. Timely harvest
4. Monitoring program
    1. Eggs, adults, nuts
    2. Number of sprays needed
    3. Timing of sprays
5. Insecticides
6. Mating Disruption



Decision-making tools

Number of Treatments

- Mummy assessments
- Previous year's damage
- Neighbors/surroundings
- Pheromone trap compared to historic captures
- Crop size and value
- Anticipated harvest date
- 1 vs. 2 shakes
- Reliability of harvest date

Product choice

- Green vs. broad spectrum
- Resistance to pyrethroids
- Number of treatments
- Can mating disruption be used
- Costs

Treatment timing

- Egg count biofix to predict third flight
- Pheromone trap captures to determine overlap of 2nd flight with early splits
- Early split assessment
  - Presence/absence of early splits
  - Are eggs being found
- Hull slip/crop susceptibility
- How long since last spray?
  - Residues last about 2-3 weeks
- How long until harvest?
  - Are residues adequate?
- How long to get across all your acreage

Possible insecticide timings

Timing	Pri-ority	Goal	Comments
1st flight (late Apr-May)		Prevent oviposition into mummies	No ideal application date (long flight), efficacy undocumented Disruption of *Phytocoris*
2nd flight (early July)		Prevent oviposition into mummies	Typical timing in almonds Used in high-pressure pistachios
Early splits (late July)	Tie-2nd	Prevent late 2nd flight eggs from getting on pea splits	Treatment based on flight data, prevalence of early splits, split date
3rd flight (early-mid Aug)	1st	Prevent eggs to new crop at 'hull split/slip'	All orchards need a treatment Usually ~ 4 weeks to harvest
Post 3rd flight (late Aug-early Sept)	Tie-2nd	Maintain insecticide residues on hulls	Based on flights/pressure and harvest date
4th flight (mid-Sept)		Protect nuts for second shake or late first shake	Based on flights, pressure, data from first shake, anticipated harvest date


Thank you
David Haviland, UC ANR Cooperative Extension IPM Advisor, Kern County