Navel Orangeworm Biology and Management



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Outline for Today

Origins and Distribution
- Arrival in California
- Current pest status

Basic Biological Parameters
- Life stages
- Mating and reproduction
- Seasonal phenology

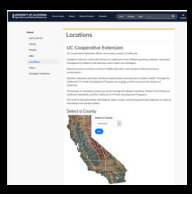
Modern Management
- Crop sanitation
- Biological control
- Mating disruption
- Monitoring, degree-days
- Insecticide sprays
- Early/timely harvest

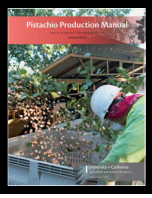
Key Additional Resources

Local Farm/IPM Advisor
- https://ucanr.edu/About/Locations/

UC Statewide IPM Program Website
- https://www2.ipm.ucanr.edu/agriculture/pistachio/Navel-Orangeworm/

Pistachio Production Manual (2016)
- UC ANR Publication #3545
- https://anrcatalog.ucanr.edu/Details.aspx?itemNo=3545

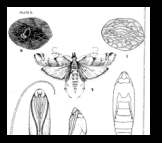




Navel Orangeworm
Origins, Arrival in CA, Current Pest Status

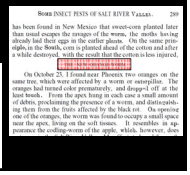
Navel Orangeworm
Origins + Arrival in CA

Species Name
Order: Lepidoptera
Family: Pyralidae
Species: *Amyelois transitella*



Arrival in California
1800s – Reported in Mexico, Caribbean, Central America, South America
1900s – Reported on citrus in AZ ("navel orangeworm")
1940s – Reported on walnuts and almonds in CA
1970s – Reported on pistachio in CA


Navel Orangeworm on Walnuts


SOME INSECT PESTS OF SALT RIVER VALLEY. 289

has been found in New Mexico that sweet-corn planted later than usual escapes the ravages of the worm, the moths having already laid their eggs in the earlier plants. On the same principle, in the South, corn is planted ahead of the cotton and after a while destroyed, with the result that the cotton is less injured.

On October 23, I found near Phoenix two oranges on the same tree, which were affected by a worm or caterpillar. The oranges had turned color prematurely, and dropped off at the least touch. From the apex lying in each case a small amount of debris, proclaiming the presence of a worm, and distinguishing them from the fruits affected by the black rot. On opening one of the oranges, the worm was found to occupy a small space near the apex, living on the soft tissues. It resembles in appearance the codling-worm of the apple, which, however, does

Navel Orangeworm
Current Pest Status
Extremely Low Tolerance for Damage (<2%)

High Crop Value
- Yield/quality x price – of course…
- Infestation leads to increased processing time/costs
- Carry over of infested remnant nuts to following year

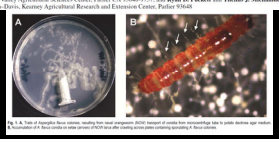
Navel Orangeworm
Current Pest Status
Extremely Low Tolerance for Damage (<2%)

Aflatoxin

- Known human carcinogen, regulated in domestic/foreign markets
- *Aspergillus flavus* fungi produce aflatoxin
- NOW adults move *Aspergillus* around
- Larval feeding create opportunities for fungal growth on nuts

Spread of *Aspergillus flavus* by Navel Orangeworm (*Amyelois transitella*) on Almond

Jeffrey D. Palumbo, Noreen E. Mahoney, and **Douglas M. Light,** Plant Mycotoxin Research Unit, Western Regional Research Center, United States Department of Agriculture–Agricultural Research Service (USDA-ARS) Albany, CA 94710; **Joel Siegel,** USDA-ARS, San Joaquin Valley Agricultural Sciences Center, Parlier CA 93648-9757; and **Ryan D. Puckett** and **Themis J. Michailides,** University of California–Davis, Kearney Agricultural Research and Extension Center, Parlier 93648

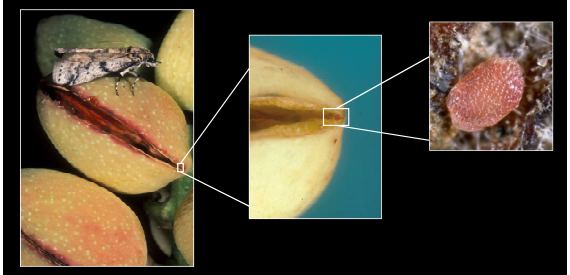


Navel Orangeworm
Biology, Behavior and Ecology

Basic Biological Parameters
Life Stages

Egg → Larva → Pupa → Adult

Basic Biological Parameters
Eggs Deposited Directly onto the Nuts



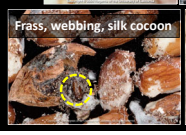
Basic Biological Parameters
Life Stages

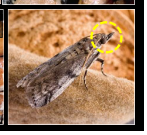
Eggs
- Deposited directly onto nuts

Larvae
- Crescent-shaped marked
- Pass through 5-6 stages (instars)
- Frass and webbing as they feed

Pupae
- Spins a silk coccoon

Adults
- Has a pronounced "snout"



Mating and Reproduction
Summary, Timing and Role of Pheromones

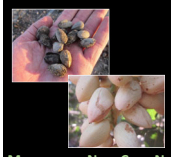
- NOW is active at night (nocturnal)
- Adults emerge (eclose) from pupae at dusk
- Females emit pheromone that males use to locate them
- Mate during the last few hours of the night / early morning
- Mated females will start to deposit eggs the following night

Female NOW with abdomen in the air ~3am emitting pheromone ('calling')

NOW mating ('in copula')

Seasonal Phenology

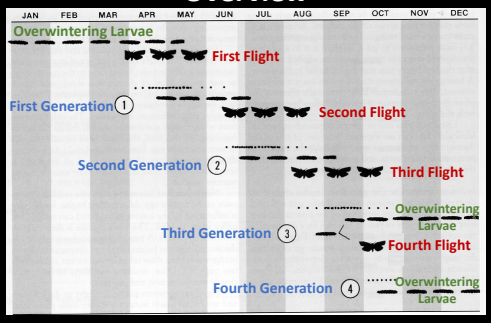
- Overview
  - Overwinter as larvae/pupae in remnant "mummy" nuts
  - Adults emerge in the spring
  - 3-4 generations per year, depending on weather and host quality
- Populations develop more rapidly as the season progresses
  - Warmer weather
  - Develop more rapidly on new crop vs. mummy nuts
  - Increased host availability (hull split / hull slip)



Mummy vs. New Crop Nuts

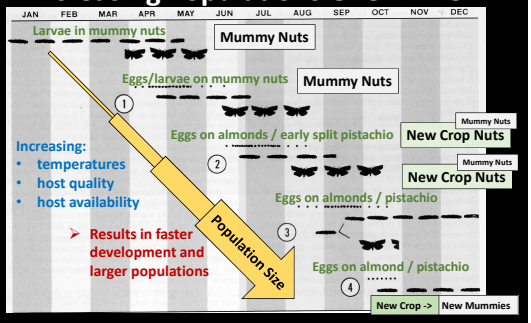
Increasing host availability as hull integrity declines

Seasonal Phenology
Overview



IPM for Almonds. UC ANR Publication #3308

Seasonal Phenology
Increasing Populations Over Time



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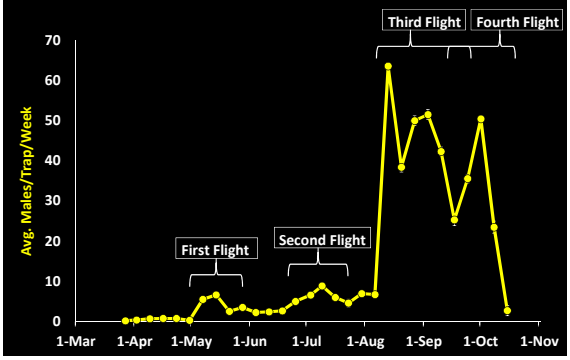

Navel Orangeworm
Integrated Pest Management

Modern NOW Management in Pistachio
Integrated Pest Management

Key Tools

1. **Sanitation** – Destroy mummy nuts
2. **Biological Control** – Natural enemies predate/parasitize
3. **Mating Disruption** – Reduce mating/reproduction
4. **Monitoring** – Egg traps, flight traps, biofix, degree days
5. **Spray Timing** – Maximize impacts
6. **Early/Timely Harvest** – Logistics

The Key to Success is Using Multiple Points of Attack!

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Winter Sanitation / Crop Sanitation

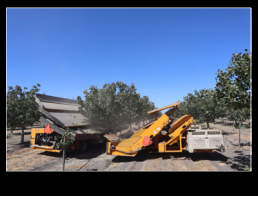
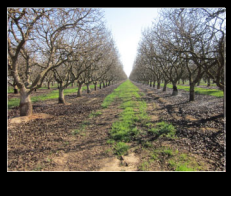
Key Points

- NOW overwinter as larvae in remnant "mummy" nuts
- These larvae are the base population for the coming year
- Mummies are ALSO reproductive substrate for moths in the spring!


Winter Sanitation / Crop Sanitation

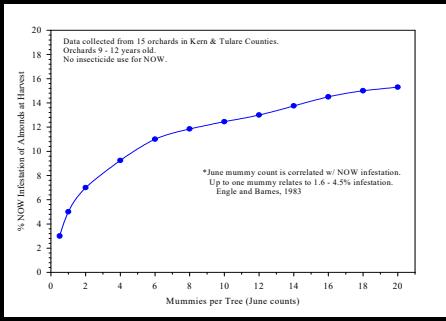
Procedures

- Harvest in a timely manner!
  - The longer nuts are exposed, the higher infestation rate of mummies
- After harvest – get all mummies onto the orchard floor
  - Shake or pole trees to remove mummies from canopy, tree crotches etc.
- Blow/sweep burms to aggregate mummies in the row middles
- Mow/disc the mummies to destroy them

Winter Sanitation / Crop Sanitation

Fewer Mummies = Lower Damage



Data: Engle and Barnes 1983 | Figure: D. Haviland

Winter Sanitation / Crop Sanitation

Take Note

- Sanitize ASAP before orchard access becomes difficult
- Weather (cold, moisture) can cause some NOW mortality
- For instance, mummies…
  - on the ground – fair worse than those in the tree canopy
  - in ground covers – fair worse than those on bare soil
  - on moist bare soil – fair worse than those on dry bare soil

REGARDLESS → Don't leave it up to Weather + Microbes!

Go into your orchard, aggregate and destroy the mummies!!

Modern NOW Management in Pistachio

Integrated Pest Management

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Biological Control
Natural Enemies of NOW

Parasitoids
- *Goniozus legneri* – attack larvae
- *Copidosoma plethorica* – attack eggs
- Not very effective at low NOW densities


Goniozus legneri

Vertebrates
- Some birds/mice eat mummy nuts or knock them to the ground
- Impacts are unclear

Predators
- Lacewings
- *Phytocoris* spp.


Phytocoris sp.

Biological Control
Phytocoris relativus + *Phytocoris californicus*

These small bugs attack…
- NOW eggs
- Soft scales
- Young pistachios


NOW Eggs


Young Pistachio

So are they good or bad?
- Can be a benefit…
- Tradeoffs with small/large bug control
- Monitoring is critical
- Newer pyrethroids (Brigade, Warrior) are more detrimental


Phytocoris sp.

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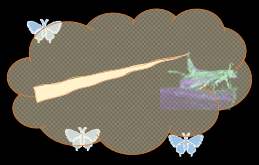
Mating Disruption
Basic Concept

- Synthetic pheromone 'disrupts' male ability to locate females
- Emitters go out in the spring and run all season

Males follow pheromone plume to locate females



Mating disruption interferes with male ability to locate and track the real pheromone lume

Mating Disruption
Commercial Products Available
Multiple Types of Emitters

Aerosol Emitter "Puffer"

Polymeric Emitter

Flowable Microencapsulated Spray

- Four companies
- Same pheromone
- Different systems

Mating Disruption
Active and Passive Emissions

Active Emitters

- Aerosol "Puffers"
  - Pressurize aerosol cannister
  - 1-2 cannisters/acre, spray frequently over the night

- Microencapsulated "Flowable"
  - Liquid that you apply like a pesticide
  - Applied multiple times, 30-day activity period

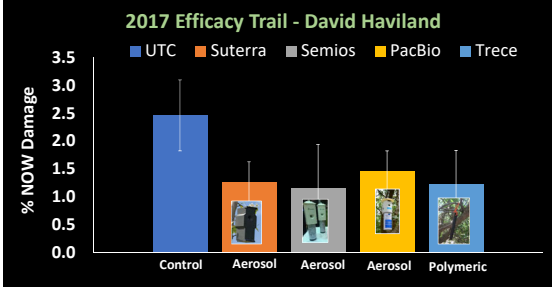
Passive Emitters

- Polymeric Strips
  - Plastic material impregnated with pheromone
  - 15-20 emitters/acre, passively emit all the time

Mating Disruption

Aerosol and Polymeric Products Work Well

Data on Flowable Formulations Still TBD



Mating Disruption

Key Considerations

- Mated female NOW can still migrate into your blocks
  - Best used in large contiguous areas
  - Square blocks >40 acres, ideally >100 acres
- It will shut down your pheromone traps
  - Phenyl-proprionate (PPO) lures will remain attractive
  - Egg traps will remain attractive
- Background NOW population is important
  - Works best with lower populations of NOW
  - Get them down, and then keep them down

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Monitoring
Key Points

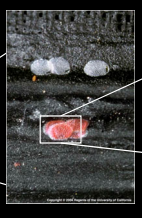
- With 2% damage tolerance, economic thresholds don't exist
- Monitoring is to track insect phenology to determine spray timing
- No singular method is perfect, use multiple trap types
- Populations are highly variable, so more traps is better than fewer




Monitoring
Overwintering Larvae

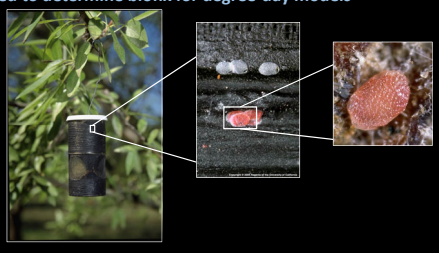
- Examine nuts around 20 trees/block
- Count total mummies and crack out to inspect for NOW larvae
- Provides info on relative mummy abundance and infestation rate
- Do you have a lot of mummies and/or NOW larvae in your blocks?

Monitoring
Egg Traps


Monitoring
Egg Traps

- Start in March or early April, 1 trap/5 acres (8 traps/40 acres)
- Count eggs 1-2x/week, replace bait every 4-6 weeks
- Most effective during first flight in well-sanitized orchard
- Used to determine biofix for degree-day models



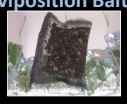
Monitoring
Flight Traps

Wing Traps

Delta Traps

Pheromone Lures

Oviposition Baits



Sticky Liners

PPO Lures

Monitoring
Flight Traps

Trap Types

- Pheromone trap
  - Attracts males – pheromone lure
- Peterson trap
  - Attracts females – oviposition bait
  - Remains attractive under mating disruption
  - Also marketed for mass-trapping females
- PPO trap
  - Attracts males + females – PPO lure
  - Remains attractive under mating disruption

Monitoring
Flight Traps

Timing and Use
- Set out traps in March / early April
- 1 trap/10 acres (2 per block min.)
- Hang where unobstructed by foliage
- Check 1x/week
- Replace liners every 1-2 weeks
- Replace baits every 4-6 weeks

Monitoring
Early Splits

- Early splits provide opportunity for NOW to get an early start
- Monitor in mid/late July
- Consider treatment is >2 early split per 100 nuts

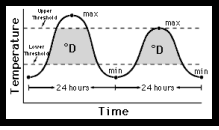
Monitoring
Biofix and Degree-Days

Biofix
- Start-date for development of the insect, determined by trap catch

Lower and Upper Developmental Thresholds
- Range of temperature within which an insect will develop

Degree-Days (DD)
- Unit of measure to track rate of development
- Calculated based on lower/upper thresholds

1 Degree-Day = 24 hours at 1 degree above the Lower Threshold



Monitoring
Biofix and Degree-Days

NOW Developmental Thresholds
- Lower Threshold = 55°F
- Upper Threshold = 94°F

NOW Degree-Day Requirements
- 1050 DDF between egg-deposition periods
- 2100 DDF to go from 1st to 3rd egg-deposition period

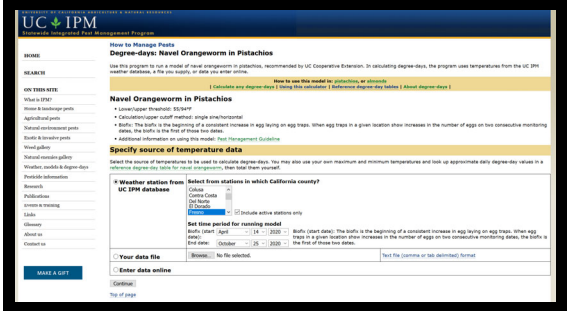
NOW Biofix
- Determined by egg trap data
- ID the 1st peak egg-deposition period

Monitoring
Biofix and Degree-Days

Monitoring
Biofix and Degree-Days

Monitoring

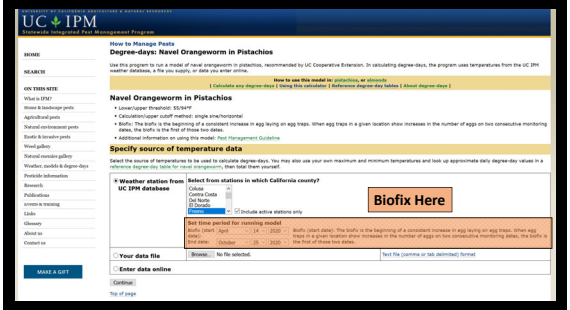
How to Run a Degree-Day Model



http://ipm.ucanr.edu/calludt.cgi/DDMODEL?MODEL=NOW&CROP=pistachios

Monitoring

How to Run a Degree-Day Model



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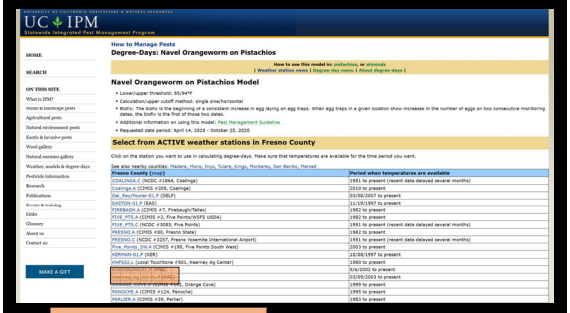
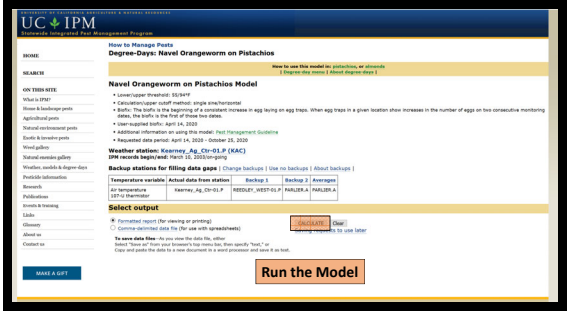


Select Nearest Weather Station

Monitoring
How to Run a Degree-Day Model



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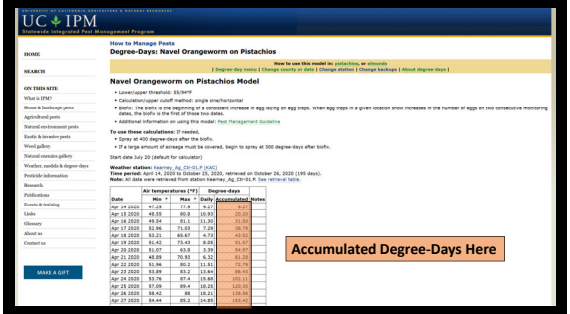
How to Run a Degree-Day Model



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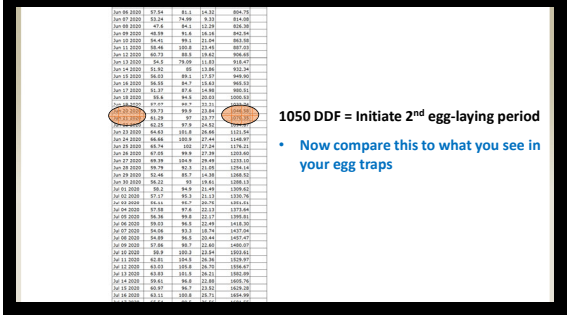

1050 DDF = Initiate 2nd egg-laying period

- **Now compare this to what you see in your egg traps**

Modern NOW Management in Pistachio
Integrated Pest Management

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The Key to Success is Using Multiple Points of Attack!

Chemical Control / Insecticides
Timing = Insect x Crop Phenology

- Degradation of hull integrity = crop vulnerability
- Spray timing should be based on…
  - Insect phenology – monitoring data
  - Crop phenology – hull integrity
  - Current pest pressure

Chemical Control / Insecticides
Current Products

- 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 into waterways
- Potential for regulation
- NOW becoming resistant to bifenthrin

Delegate (spinetoram)

- Fungal fermentation product
- Contact and ingestion toxin
- Primarily a larvicide, can kill adults
- Intrepid Edge = Intrepid + Delegate

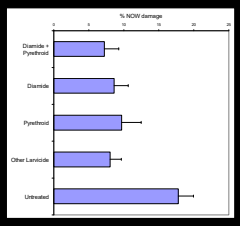
Chemical Control / Insecticides
Possible Timings and Priorities

Timing	Priority	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 early splits	Treatment based on flight data, prevalence of early splits, split date
3rd flight (early-mid Aug)	1st	Prevent eggs on 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

Slide/Table: D. Haviland

Chemical Control / Insecticides
Marginal Returns to Additional Sprays

Insecticide Efficacy
- 1 application - typically ~50% reduction in damage
- 2 applications - typically ~65% reduction in damage
- 3+ applications - ~70-75% reduction



Slide/Figure: D. Haviland, 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

Chemical Control / Insecticides
Make Your Sprays Count

For ANY spray…
- Spray calibration, drive speed (go slow) and weather conditions are critical

Consult With…
- Local Farm/IPM Advisor
  - https://ucanr.edu/About/Locations/
- UC Statewide IPM Program Website
  - https://www2.ipm.ucanr.edu/agriculture/pistachio/Navel-Orangeworm/

Spray Training Opportunities Available
- http://ipm.ucanr.edu/training/

Modern NOW Management in Pistachio
Integrated Pest Management

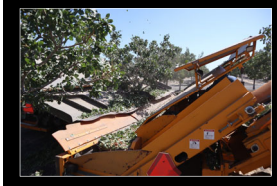
Key Tools

1. **Sanitation** – Destroy mummy nuts
2. **Biological Control** – Natural enemies predate/parasitize
3. **Mating Disruption** – Reduce mating/reproduction
4. **Monitoring** – Egg traps, flight traps, biofix, degree days
5. **Spray Timing** – Maximize impacts
6. **Early/Timely Harvest** – Logistics

The Key to Success is Using Multiple Points of Attack!

Early/Timely Harvest
Logistics and Management

- NOW populations build exponentially over time
- Longer crop hangs on the tree = higher probability of infest
- Higher infest a problem this year + mummies the following year
- Late 1st shake begets a late 2nd shake



Early/Timely Harvest
Logistics and Management
Damage Doubles +/- Every 10 Days ~Sept 15

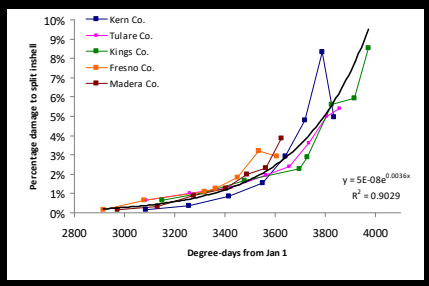


Figure: D. Haviland

Early/Timely Harvest

Logistics and Management

Damage Doubles +/- Every 10 Days ~Sept 15

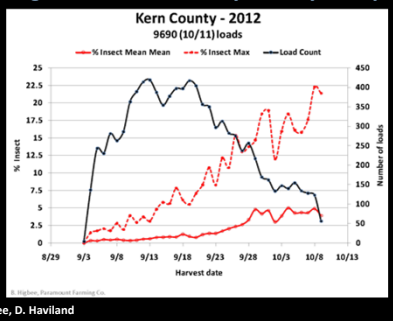


Figure: B. Higbee, D. Haviland

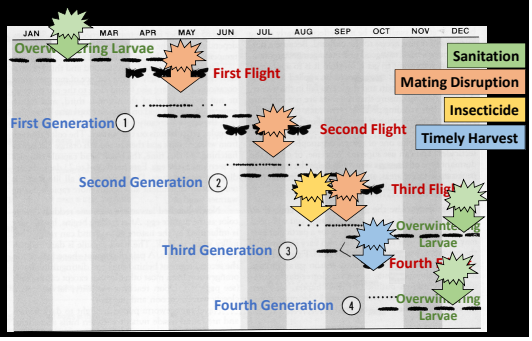
Navel Orangeworm

Bringing It All Together

"Where do I begin?"

Bringing It All Together

KEEP THEM ON THE RUN!



Bringing It All Together
Ideal NOW Management Program

October – February
- Crop sanitation – get mummies on the ground, blow/sweep, mow/till them

March-April
- Set out your flight traps and egg traps – monitor 1-2x/week
- Setup mating disruption

April-May
- Monitor traps and determine biofix

June
- Monitor traps, run degree-day models, see 2nd flight, adjust biofix if needed

July
- Monitor traps, degree-day models, monitor for early splits, prepare for 3rd flight

August
- Monitor traps, see 3rd flight, spray for 3rd flight moths

September-October
- Harvest ASAP, start thinking about sanitation

Bringing It All Together
Ideal NOW Management Program

Closing Thoughts…
- **Crop sanitation is fundamental – do it!**
  - In a bad year, no amount of spraying can replace this
- **Logistics, planning and management are fundamental**
  - Develop a monitoring plan – and then follow it!
  - Coordinate equipment/crews with weather/phenology

Bringing It All Together
Ideal NOW Management Program

Closing Thoughts…

Number of Treatments
- Mummy assessments, trap catch compared to last year
- Damage last year
- Neighbors and surrounding crops
- Crop size and value, 1 vs 2 shakes, reliability of harvest date

Treatment Timing
- Egg-trap biofix to predict 3rd flight
- Pheromone trap data
- Early splits, hull integrity
- How long until harvest?
- How long to cover your acreage?

Product Choice
- Costs
- Green vs broad spectrum
- Resistance to pyrethroids
- Total number of treatments needed

Bringing It All Together

Ideal NOW Management Program

Closing Thoughts…

Remember you have resources

- Local Farm/IPM Advisor
  - https://ucanr.edu/About/Locations/
- UC Statewide IPM Program Website
  - https://www2.ipm.ucanr.edu/agriculture/pistachio/Navel-Orangeworm/
- Pistachio Production Manual (2016)
  - UC ANR Publication #3545
  - https://anrcatalog.ucanr.edu/Details.aspx?itemNo=3545

Thank you!!
Good luck out there!

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