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

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

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

Extremely Low Tolerance for Damage (<2%)
**Navel Orangeworm**

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

- 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

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**Navel Orangeworm**

**Biology, Behavior and Ecology**

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**Basic Biological Parameters**

**Life Stages**

- Egg → Larva → Pupa → Adult
**Basic Biological Parameters**

**Eggs Deposited Directly onto the Nuts**

- Deposited directly onto nuts
- Crescent-shaped marked
- Pass through 5-6 stages (instars)
- Frass and webbing as they feed

**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 cocoon
- **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)

Increasing host availability as hull integrity declines

Mummy vs. New Crop Nuts

Seasonal Phenology

Overview

Overwintering Larvae

First Flight

Second Flight

Third Flight

Fourth Flight

First Generation

Second Generation

Third Generation

Fourth Generation

Overwintering Larvae

Increasing Populations Over Time

Increasing:
- temperatures
- host quality
- host availability

Results in faster development and larger populations

IPM for Almonds, UC ANR Publication 3308
**Seasonal Phenology**

Increasing Populations Over Time

- First Flight
- Second Flight
- Third Flight
- Fourth Flight

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**Navel Orangeworm**

Integrated Pest Management

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**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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Integrated Pest Management

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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 \rightarrow Don't leave it up to Weather + Microbes!
Go into your orchard, aggregate and destroy the mummies!!

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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

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

Predators
- Lacewings
- Phytocoris spp.

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

Phytocoris relativus + Phytocoris californicus

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

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

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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 plume

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

2017 Efficacy Trail - David Haviland

% NOW Damage

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
Control Aerosol Aerosol Aerosol Polymeric

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

**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

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**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

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**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**

**How to Run a Degree-Day Model**

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

- **Biofix**
- **Select Nearest Weather Station**
Monitoring
How to Run a Degree-Day Model

Accumulated Degree-Days Here

1050 DDF = Initiate 2nd egg-laying period
• Now compare this to what you see in your egg traps
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Integrated Pest Management

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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-larvicide
  - 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

<table>
<thead>
<tr>
<th>Timing</th>
<th>Priority</th>
<th>Goal</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st flight (late Apr-May)</td>
<td>Prevent</td>
<td>Prevent oviposition into mummies</td>
<td>No ideal application date (long flight), efficacy undocumented, disruption of Phytocoris</td>
</tr>
<tr>
<td>2nd flight (early July)</td>
<td>Prevent</td>
<td>Prevent oviposition into mummies</td>
<td>Typical timing in almonds, used in high-pressure pistachios</td>
</tr>
<tr>
<td>Early splits (late July)</td>
<td>Tie 2nd</td>
<td>Prevent late 2nd flight eggs from getting on early splits</td>
<td>Treatment based on flight data, precedence of early splits, split date</td>
</tr>
<tr>
<td>3rd flight (early mid Aug)</td>
<td>Prevent</td>
<td>Prevent eggs on new crop on 'hull split/10'</td>
<td>All orchards need a treatment usually '4 weeks to harvest'</td>
</tr>
<tr>
<td>3rd flight (late Aug-early Sept)</td>
<td>Protective</td>
<td>Prevent 2nd flight from getting on early splits on 'hull split/10'</td>
<td>Based on flights, pressure and harvest date</td>
</tr>
<tr>
<td>4th flight (mid Sept)</td>
<td>Protect</td>
<td>Protect nuts for second shake or late first shake</td>
<td>Based on flights, pressure, data from first shake, anticipated harvest date</td>
</tr>
</tbody>
</table>

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

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/

Slide/Figure: D. Haviland, 2013, Almond, UC West Side Research and Extension Center, unpruned, individual tree plots, sprayed with hand gun, 500 with 6 blocks, evaluations of 500 nuts per tree, sprayed 2nd flight, harvested 3 weeks later.
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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

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?"

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

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

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
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Thank you!!
Good luck out there!

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