# Biology and environmental factors affecting population dynamics and management of California red scale (*Aonidiella aurantii*)

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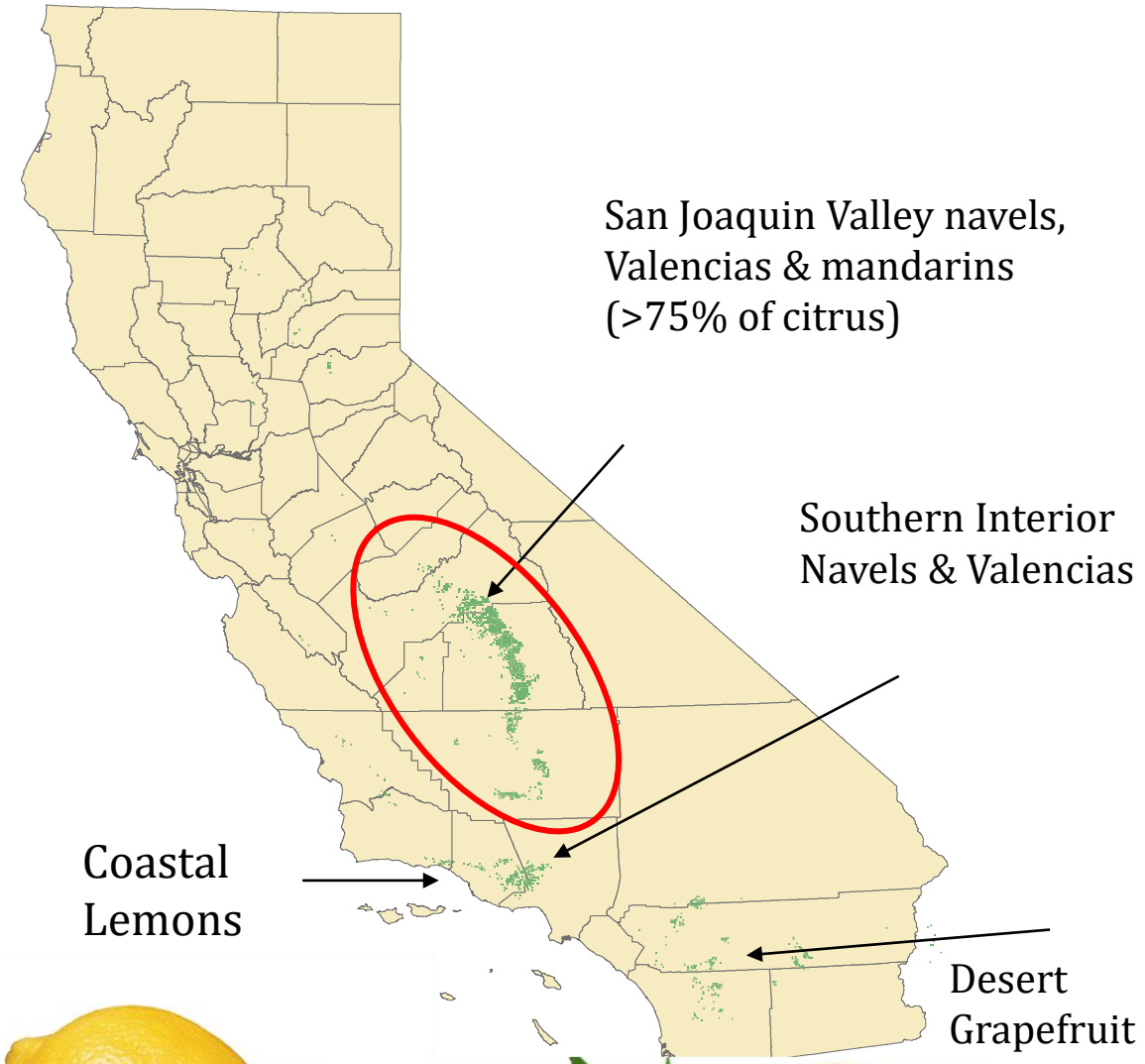
UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

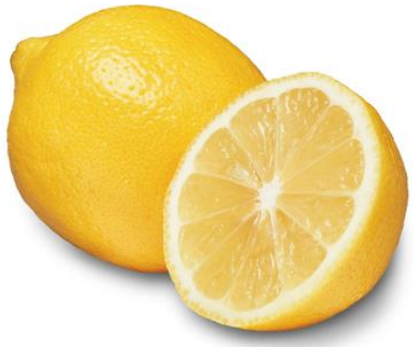
# Outline

- Background
- California red scale
  - Biology
  - Environmental factors affecting seasonal phenology
  - Management
    - Monitoring
    - Current Management Practices

# California Citrus

- Four distinct citrus growing regions
- 268,376 acres citrus in CA (108,608 hectares)
- Orange (navel/Valencia), lemon, grapefruit, mandarin, lime
- $3.4 billion farm gate value; economic impact on California's economy: $7.1 billion



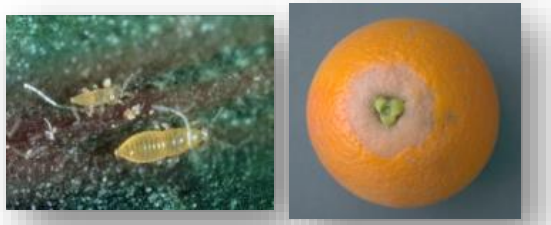
# Citrus Pest Management Navels & Mandarins

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|

Cosmetic damage

Citrus Red Mite, *Panonychus citri*

Citrus Thrips, *Scirtothrips citri*

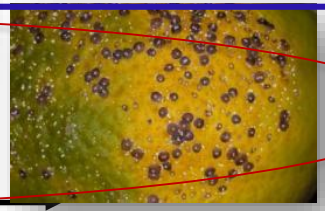


Forktailed Bush Katydid, *Scuddaria furcata*

Citrus cutworm, *Egira curialis*

Yield damage

California red scale, *Aonidiella aurantii*



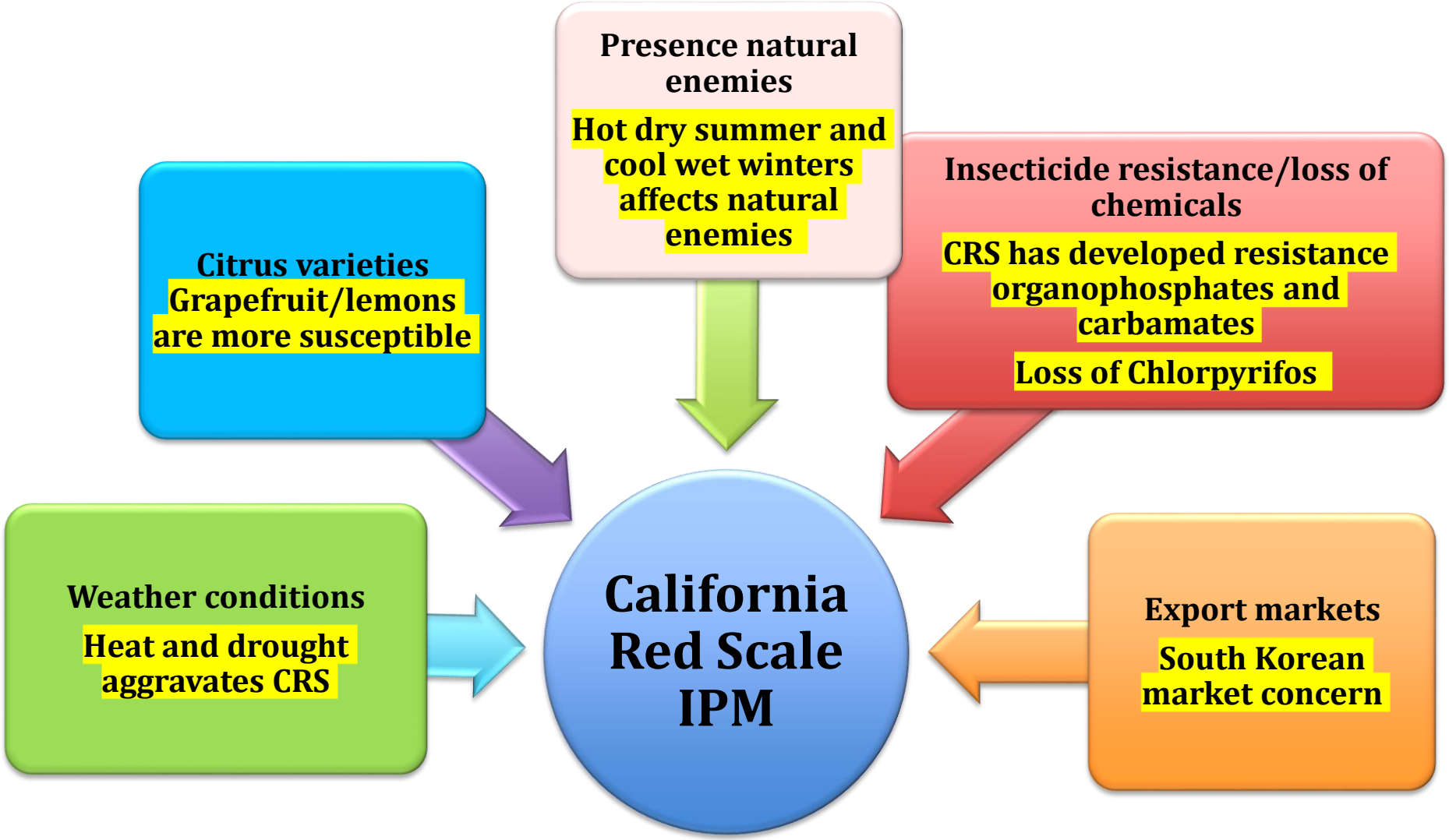
Citricola scale, *Coccus pseudomagnoliarum*

# California Red Scale

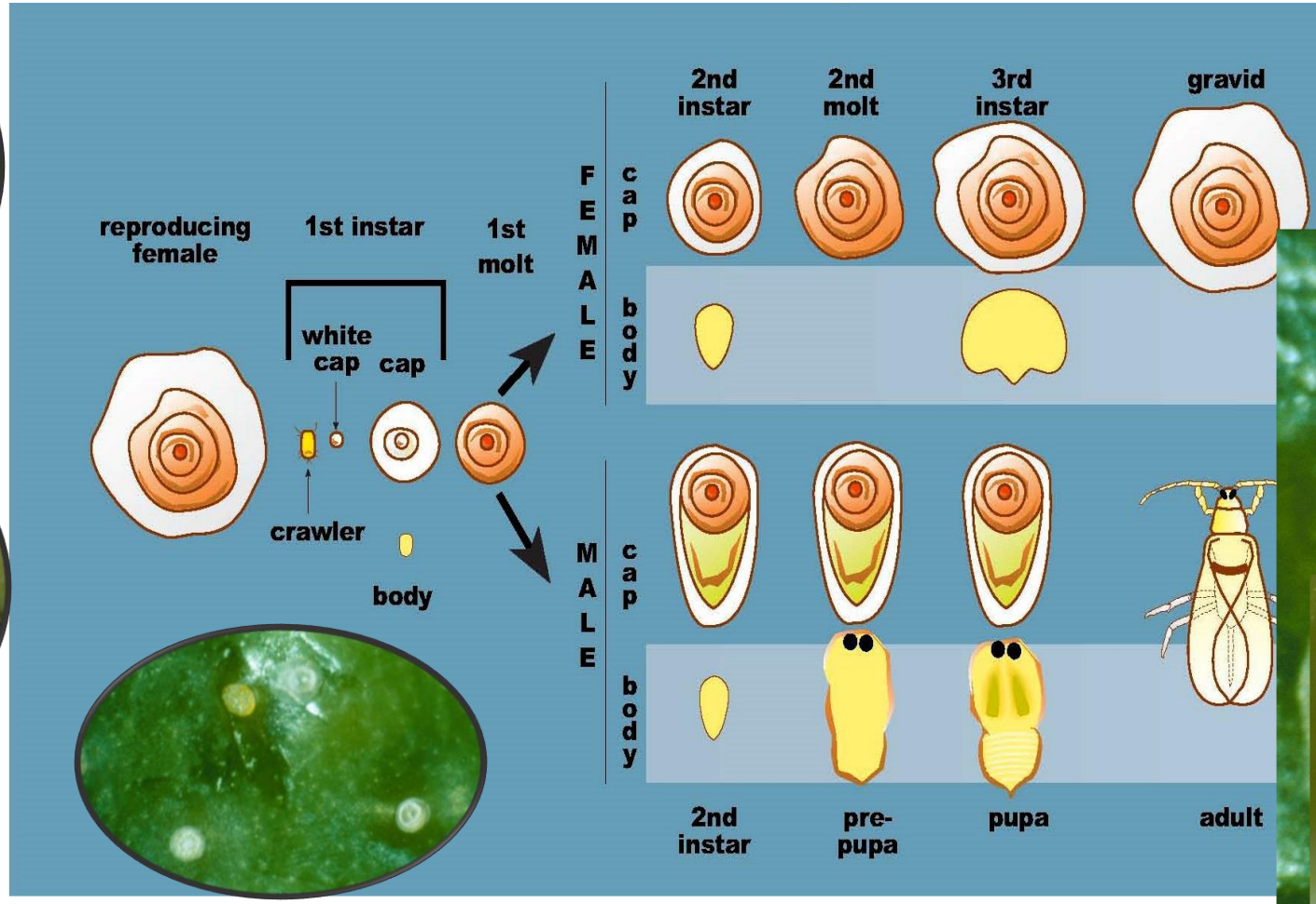
## *Aonidiella aurantii*

- **Sap-sucking insect**
- **Attacks all parts of trees including fruit**
- **Downgrading of fruit and yield loss**
- **Export issue in Korea**

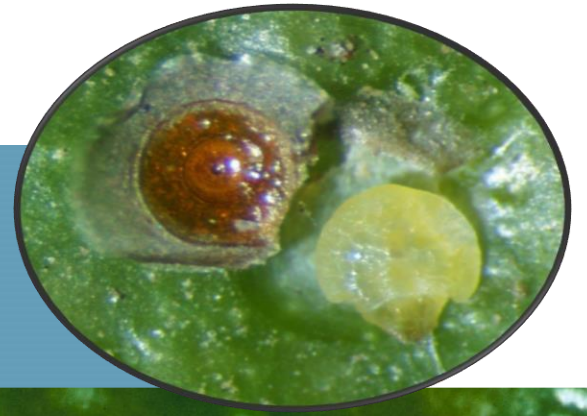
**Pest management program shifts/evolves along with the factors influencing it.**

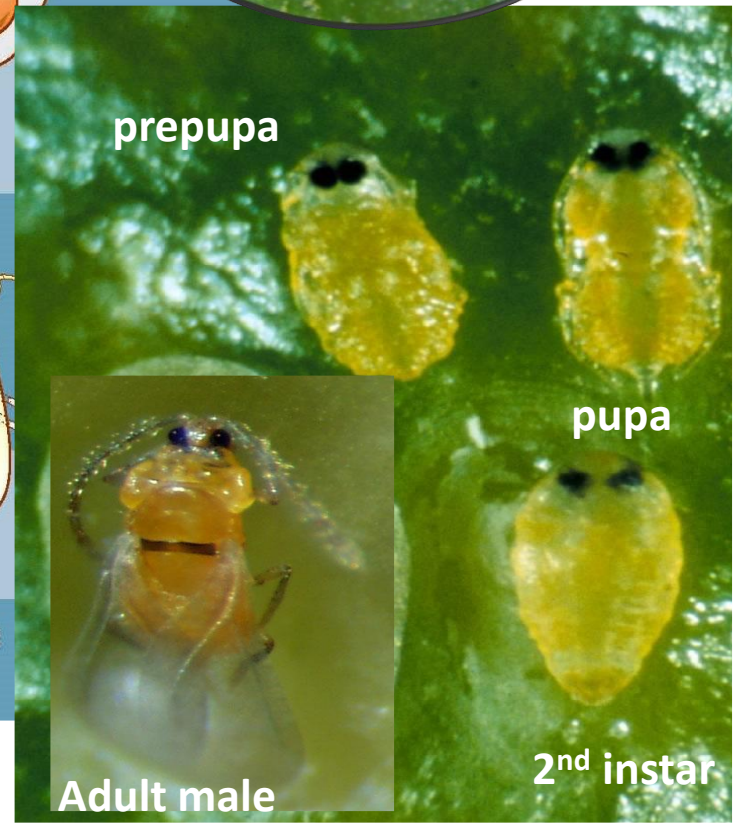


# California red scale biology and life cycle





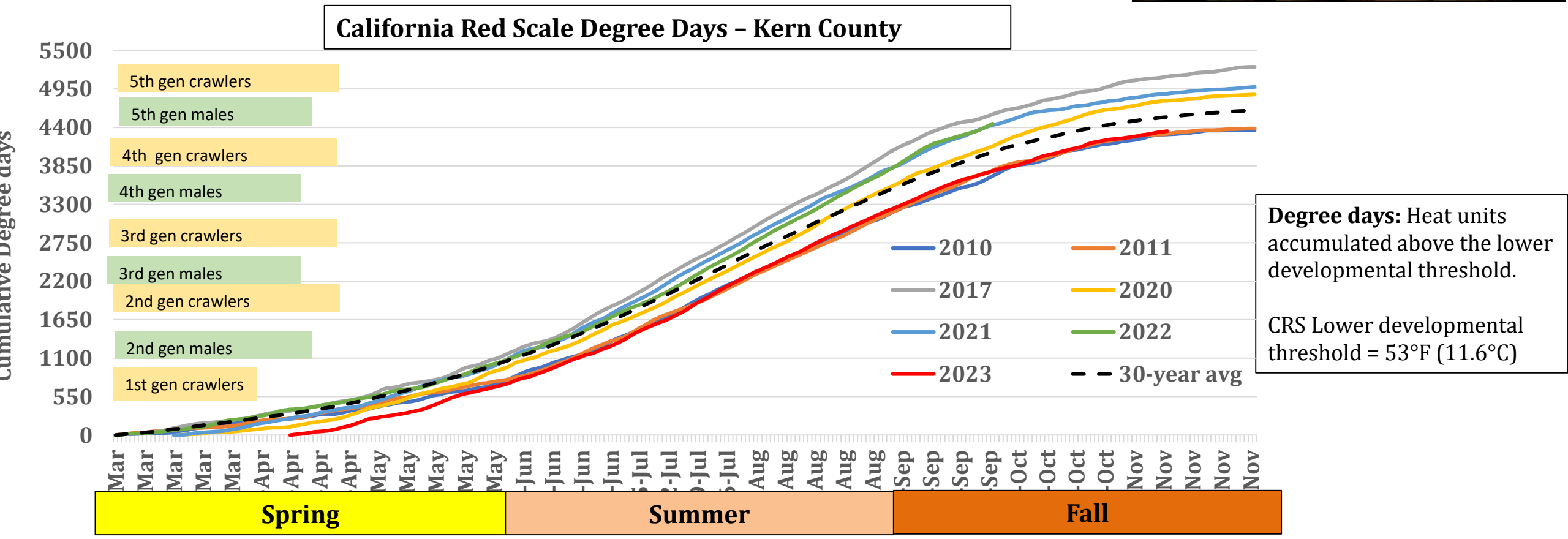


# California red scale biology/field ecology

- Under laboratory conditions, life cycle is completed within 6 weeks.
- In field, California red scale normally has 4 generations in a year
- Field season begins with overwintering females producing crawlers that develop with temperature
- CRS monitoring is based on male flights and degree days (heat units above the lower developmental threshold)
- Growers/pest control advisors monitor populations and treat when the population is most responsive

# Why are there so many scales from 2012-2022?

1. Warm winter = insects of all stages developing at all times, less overwintering mortality
2. Drought = dusty, stressed trees have more scale, parasites don't work as well
3. Heat = fast development of scale, the parasites don't keep up
4. Insecticide treatments only last about 1 generation –growers treat often=resistance
5. Some insecticides don't control scales on wood (imidacloprid, spirotetramat)

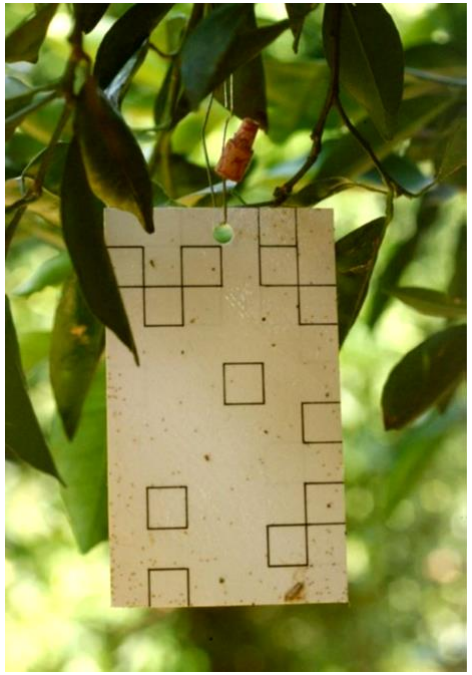



**Degree days:** Heat units accumulated above the lower developmental threshold.

CRS Lower developmental threshold = 53°F (11.6°C)

# Warmer weather in the last decade has affected seasonal phenology of CRS.

| CRS Male Flight 2001 to 2023 | | | | | | |
|---|---|---|---|---|---|---|
| Year | Biofix | F1 | F2 | F3 | F4 | Total degree days |
| 2001 | 3/20 | 6/5 | 7/31 | 8/30 | 10/22 | 4696 |
| 2002 | 3/21 | 6/12 | 7/24 | 9/6 | No Gen 4 | 4292 |
| 2003 | 3/12 | 6/14 | 7/25 | 9/2 | 10/26 | 4596 |
| 2004 | 3/15 | 6/3 | 7/18 | 8/28 | 11/23 | 4433 |
| 2005 | 3/22 | 6/12 | 7/21 | 8/26 | No Gen 4 | 4201 |
| 2006 | 4/11 | 6/17 | 7/23 | 9/2 | No Gen 4 | 4179 |
| 2007 | 3/14 | 6/10 | 7/22 | 8/31 | 12/5 | 4412 |
| 2008 | 3/17 | 6/17 | 7/26 | 9/5 | 11/19 | 4448 |
| 2009 | 3/23 | 6/10 | 7/23 | 9/1 | 11/27 | 4429 |
| 2010 | 3/30 | 6/28 | 8/7 | 9/26 | No Gen 4 | 4008 |
| 2011 | 4/1 | 6/27 | 8/8 | 9/20 | No Gen 4 | 4073 |
| 2012 | 4/6 | 6/16 | 7/30 | 9/7 | 11/21 | 4499 |
| 2013 | 3/15 | 6/4 | 7/15 | 8/25 | 10/29 | 4609 |
| 2014 | 3/10 | 6/4 | 7/12 | 8/23 | 10/9 | 4959 |
| 2015 | 3/2 | 6/2 | 7/8 | 8/21 | 10/9 | 4866 |
| 2016 | 2/24 | 5/31 | 7/11 | 8/21 | 10/15 | 4766 |
| 2017 | 3/15 | 6/4 | 7/15 | 8/16 | 9/26 | 5174 |
| 2018 | 3/13 | 6/4 | 7/19 | 8/19 | 10/4 | 4991 |
| 2019 | 3/19 | 6/6 | 7/13 | 8/24 | 9/30 | 4838 |
| 2020 | 2/28 | 5/30 | 7/11 | 8/18 | 9/25 | 5137 |
| 2021 | 3/19 | 6/3 | 7/16 | 8/14 | 9/25 | 5064 |
| 2022 | 3/4 | 6/3 | 7/26 | 8/19 | 9/27 | 5136 |
| 2023 | 4/11 | 6/15 | 8/22 | 9/2 | 11/8 | |



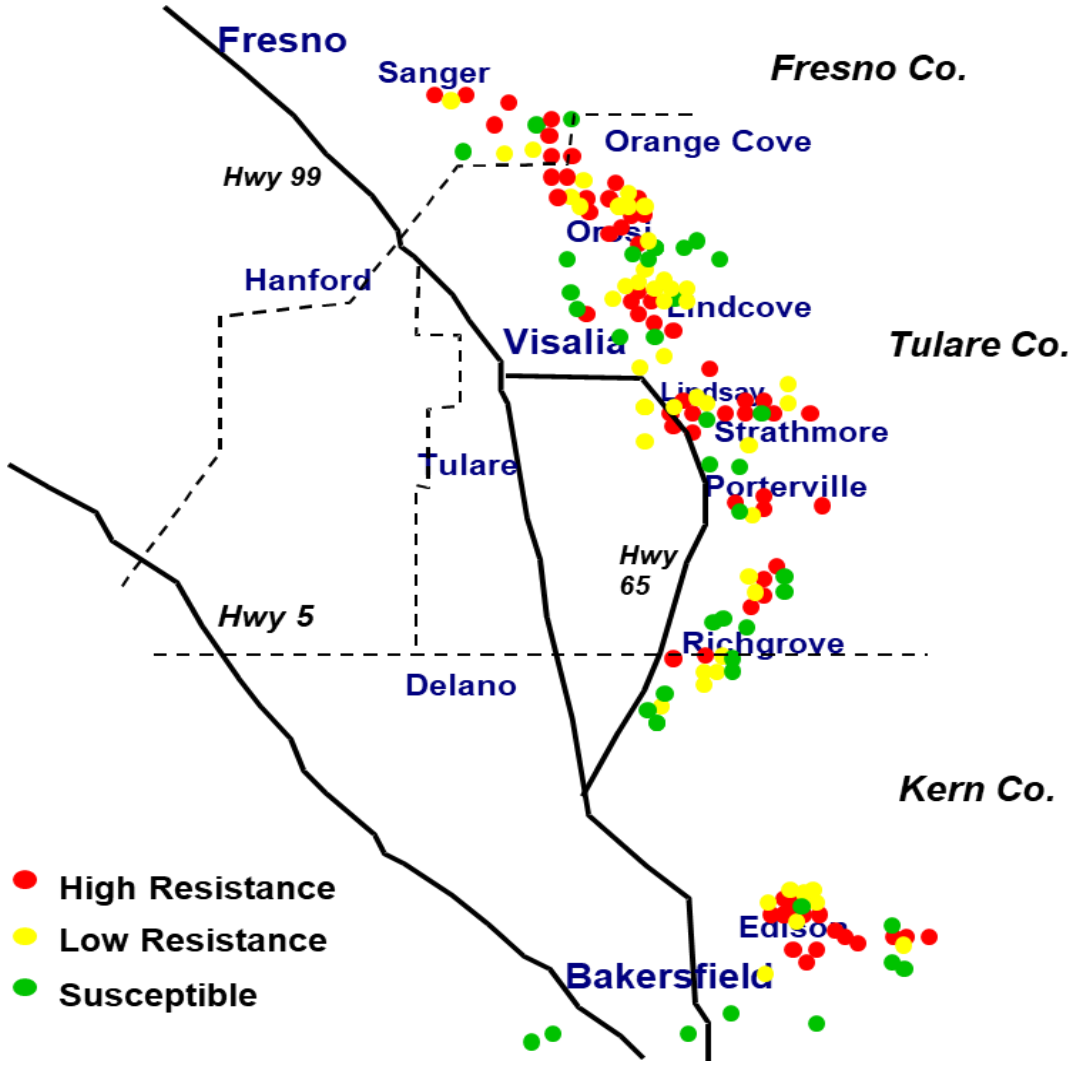
Coolest

Warmest

Year with 5th generation crawlers
4950 degree days after the biofix

# Six out of 10 years in the last decade had an extra generation (incomplete).

# CRS populations in California have developed resistance to organophosphates and carbamates.





**Populations of CRS resistant to OP insecticides have high esterase enzyme levels**

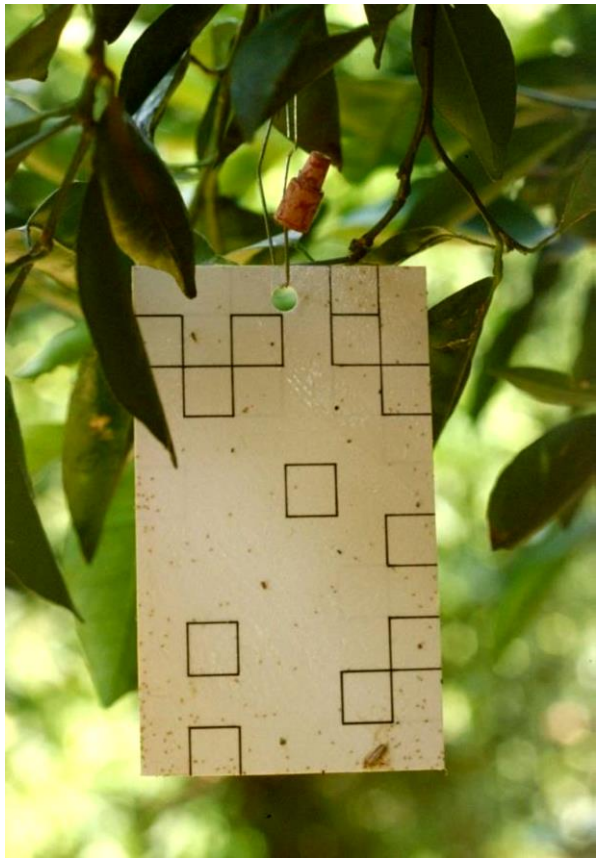
Grafton-Cardwell et al. 1998

# CRS IPM in California

- Pest Monitoring and treatment decisions
  - Monitoring using pheromone cards
  - Degree days to predict next life event
- Management
  - Mating disruption - Checkmate
  - Biological control – *Aphytis melinus, Comperiella*
  - Chemical control – IGRs, Spiroteramat, Pyriproxifen

# Monitoring CRS populations

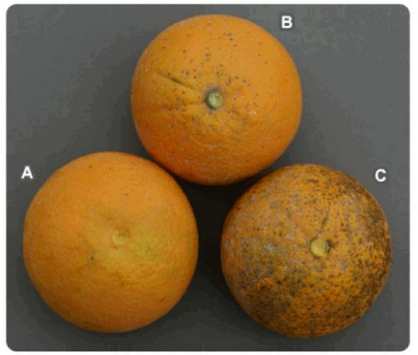
- Males: Pheromone traps - predict successive generations based on degree-day accumulation.
- Crawler tapes: target crawlers
- Leaf/twig: All life stages during the season
- Percent infested fruit at harvest/ 4th male flight – next season



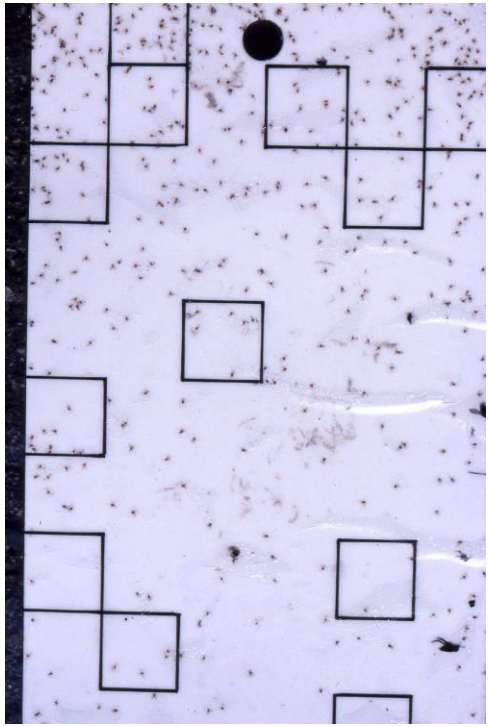
**The squares represent 20% of the**

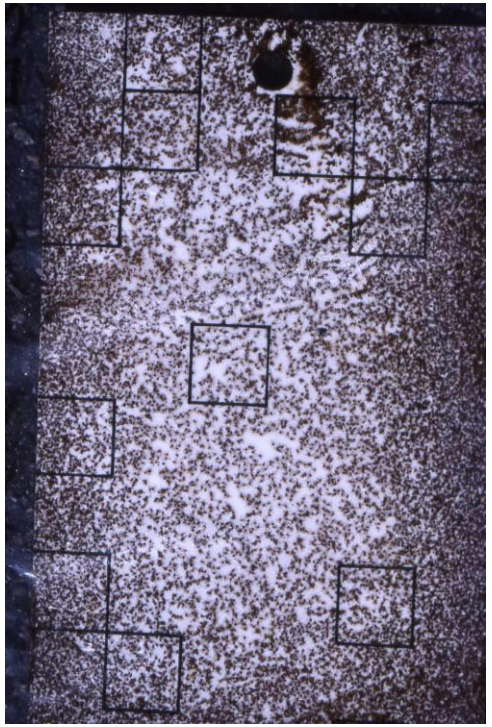
Crawler tape

During the season, check leaf/twig for live scales




At harvest, estimate % fruit with >10 scales

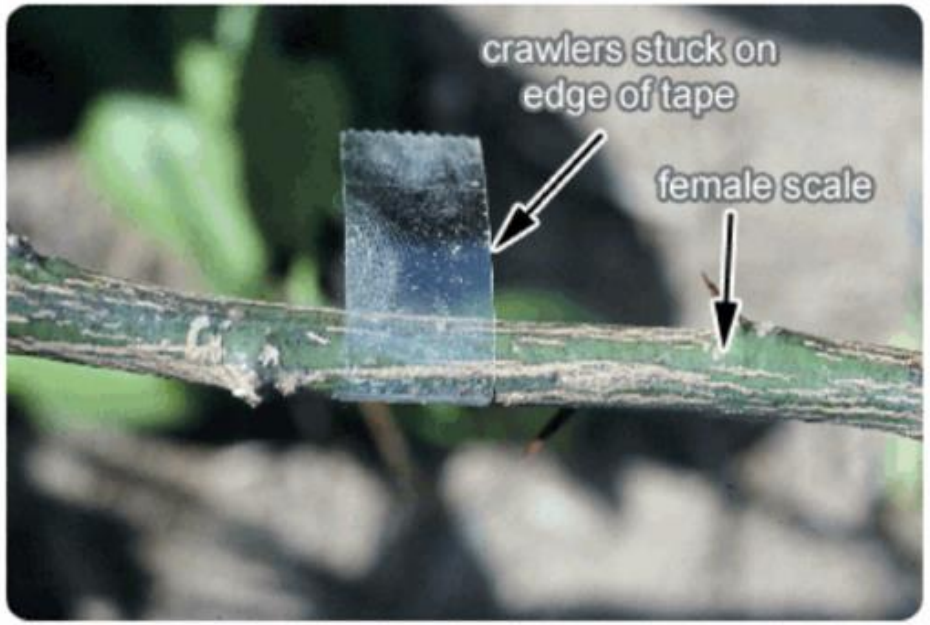


**The squares represent 20% of the card - you count what is inside the squares on both sides and multiply x 5 to estimate the total number**

Threshold varies as season progresses and with management program.

- Conventional program/4$^{th}$ flight: 1000 scales/card
- Mating disruption/4$^{th}$ flight: 50 scales/card

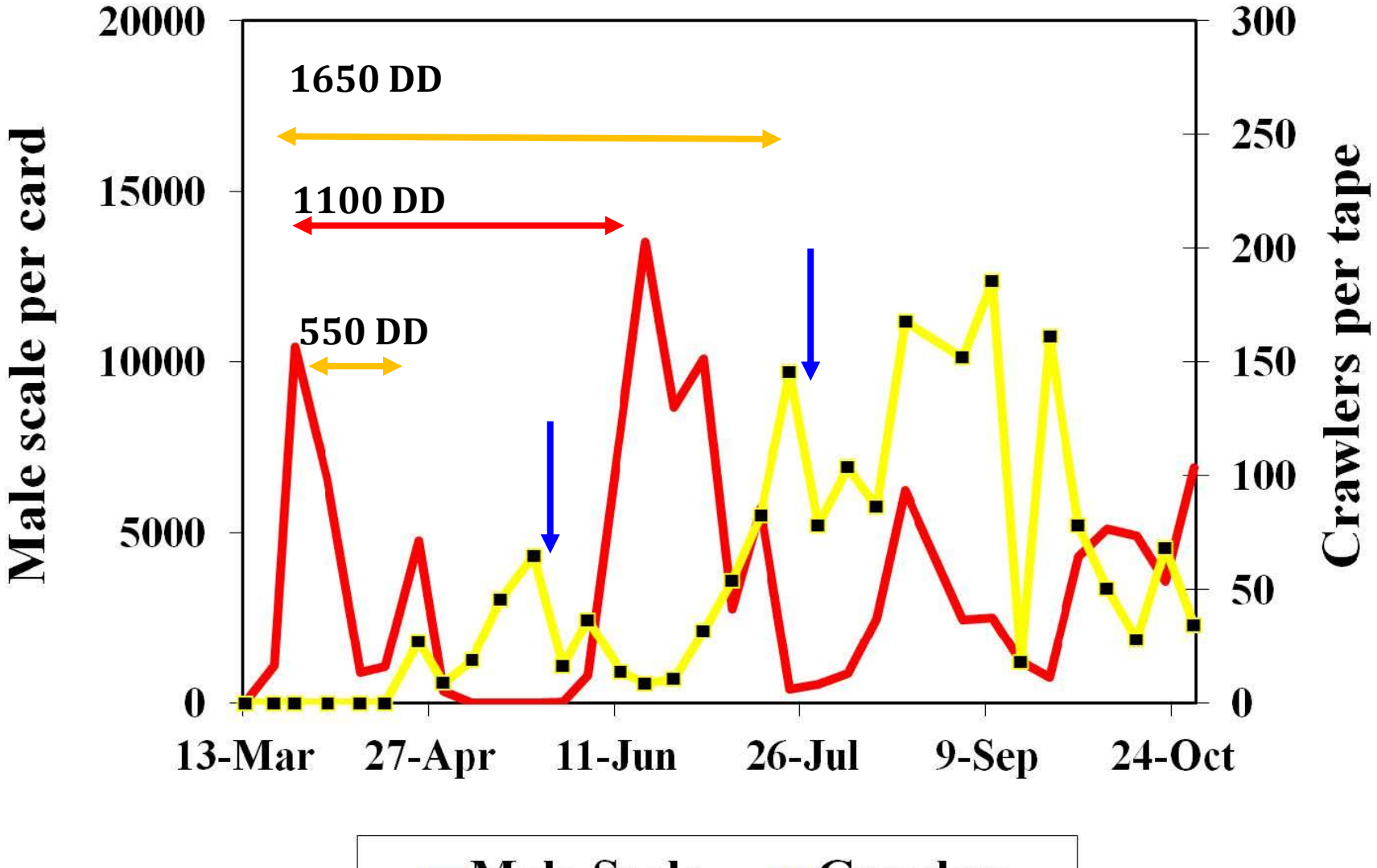
# Catching crawlers

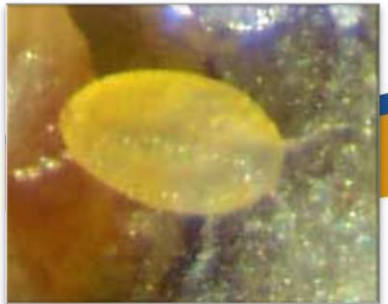



The crawler stage can be trapped using double sticky tape wrapped around a branch that has one or more live females on it. The tapes can be replaced weekly to find out when crawler emergence is occurring.

**The tapes can be replaced once a week and examined for crawlers with a hand lens or microscope.**

**Degree days** = accumulation of the average daily temperature above the lower developmental threshold (53°F)



# Calculating degree days (DD)

- Lower developmental threshold for CRS is 11.6°C (50°F)
- Any temperature accumulation above the LDT counts towards DD.

| | Spring temp (°F) | Summer temp (°F) |
|---|---|---|
| **High** | **77** | **105** |
| **Low** | **45** | **83** |
| **Average daily temp** | **61 = (77 + 45)/2** | **94 = (105 + 83 )/2** |
| **Degree days** | **8 = 61- 53** | **41 = 94-53** |
| **No. days from males to crawlers (i.e., 550 DD)** | **69 days (9.8 weeks)** | **14 days (2 weeks)** |

In summer things are happening very fast. Quick action is needed.

# During the season: check leaves and twigs and the wood for live scale

- Is the scale just on the dusty roads or throughout the orchard? (edge effect)
- Look at the interior and tops of the tree to see if scale is building there (improve coverage)
- Rub your thumb lightly over the scales and see if they easily rub off (get to know live vs dead scale)
- One month after treatment, take samples back to the office and look closely at 2nds and 3rds to see if they are healthy or parasitized (is biocontrol helping?)

# Prepare in advance for  the next season


**Walk the block and check fruit for live scale**
**At harvest check bins of fruit**

**Estimate the % of fruit with >10 scales**

**If you find more than 5% of fruit infested, the block likely needs a treatment next year**

# When to treat – making decisions?

- **Pheromone cards** & Degree Days to watch populations
  - Weekly basis, or before 4th flight
    - **IGRs and pheromones –** few male scales on the card, > CRS populations.
    - ***Aphytis* and Spirotetramat –** More male scales on card, but less CRS population.
- **Leaf/twig sampling**
  - Where is the scale? – sample edge (edge effect), interior and top
  - Are the scales live? – rub your thumb lightly over the scales
  - Evaluate after the treatment - dead, healthy, or parasitized
- **Planning for the next season**
  - 4th flight ≥1000 males/trap = treatment needed (**where mating disruption is a part of IPM, 50 males/trap)**
  - Estimate the % fruit with >10 scales (≥ 5%infested = treatment in next season)

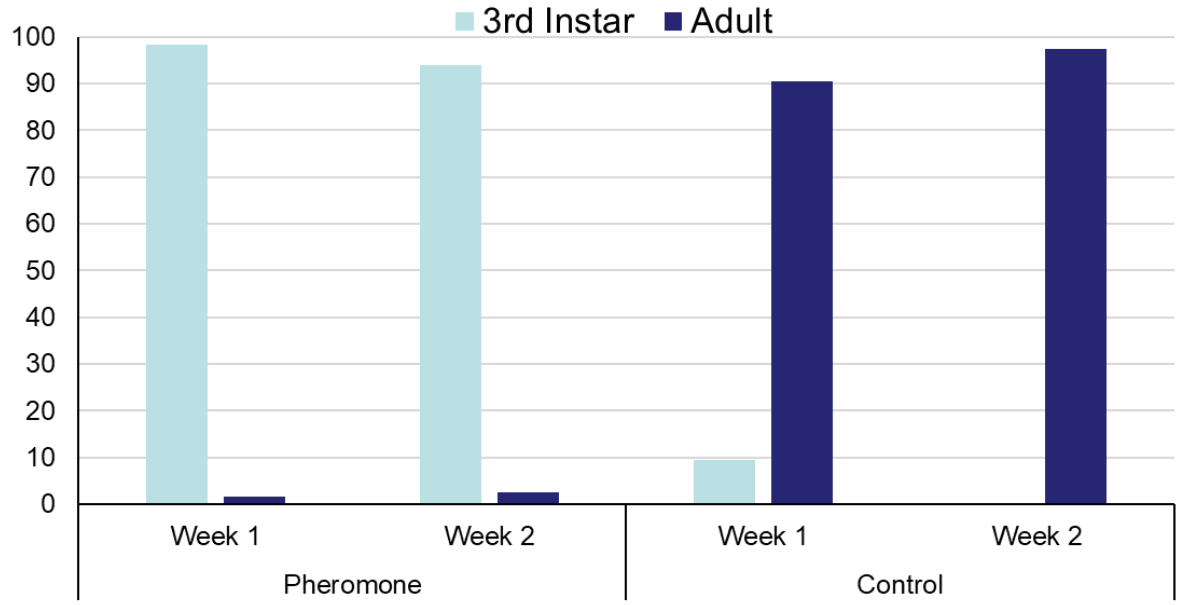
# California red scale management choices – UCIPM Guidelines

| Management choices | Efficacy | Selectivity | Spectrum |
|---|---|---|---|
| Mating disruption (Checkmate CRS) | Moderate: Effectiveness varies | Nontoxic | Narrow: CRS |
| *Aphytis melinus* | Moderate: effectiveness varies | Nontoxic | Narrow: CRS |
| Oils (415, omni) | Moderate: short residual | Short term effect on all arthropods | Broad: most pests |
| Esteem (Pyriproxyfen) | Moderate: Emerging resistance issues | Toxic to beetles | Narrow: CRS |
| Centaur (Buprofezin) | Moderate | Toxic to beetles | Interm: CRS, Citricola |
| Movento (Spirotetramat) | Moderate: Doesn't control scale on wood | Toxic to predatory mites | Interm: CRS, ACP |
| Sevin (Carbaryl) | Moderate: Resistance issues | Toxic to most natural enemies | Broad; CRS, Citricola scale, FRB |

# Mating disruption for CRS

**Female scales in the presence of pheromone disruption:**

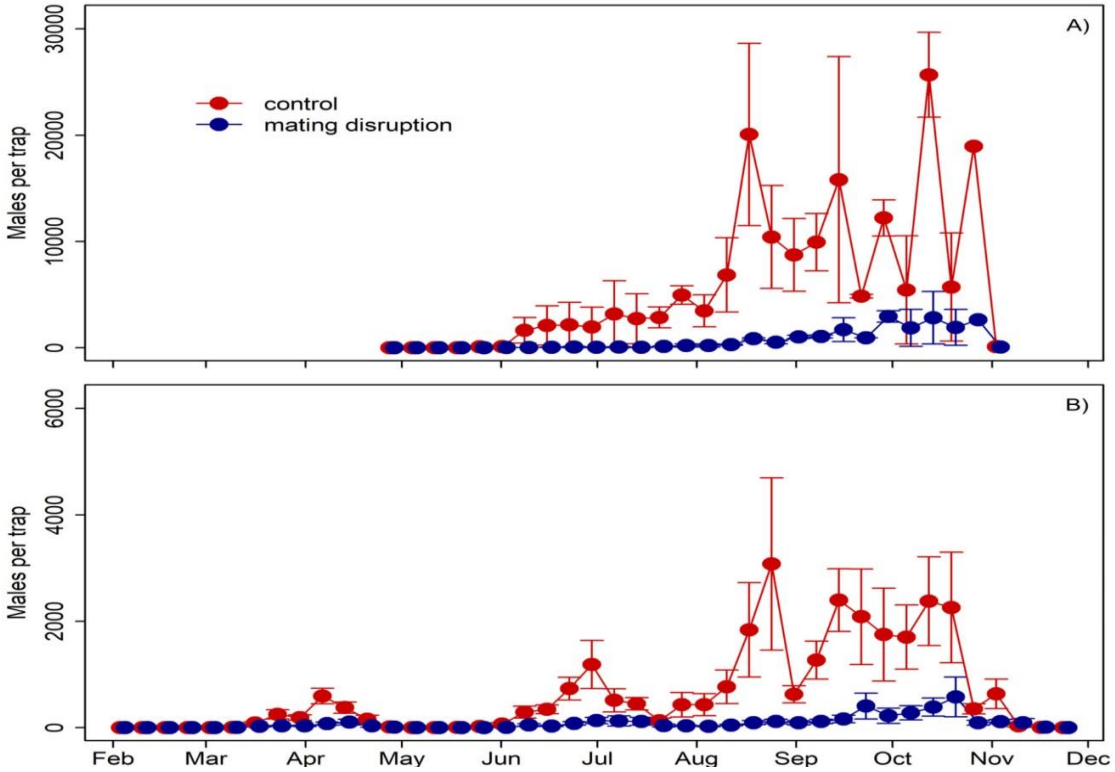
- If they never mate, they don't produce crawlers
- If they mate late in life, they produce fewer scales
- If they mate late in life, they produce mostly males
- If they remain 3rd instars, they are more vulnerable to *Aphytis*

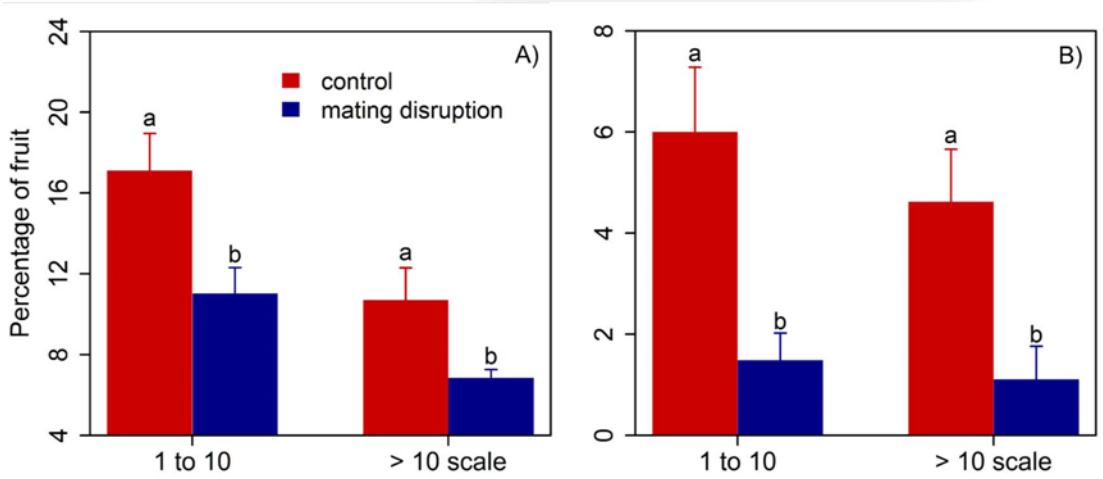



Grafton-Cardwell et al. 2021

# Product: Suterra CheckMate CRS®

- Mating disruption (180 dispenser/acre)
- 2 orchards in 2016-17, 10 in 2018-19
- After 1st male flight (2016) after 1st male flight (2018)



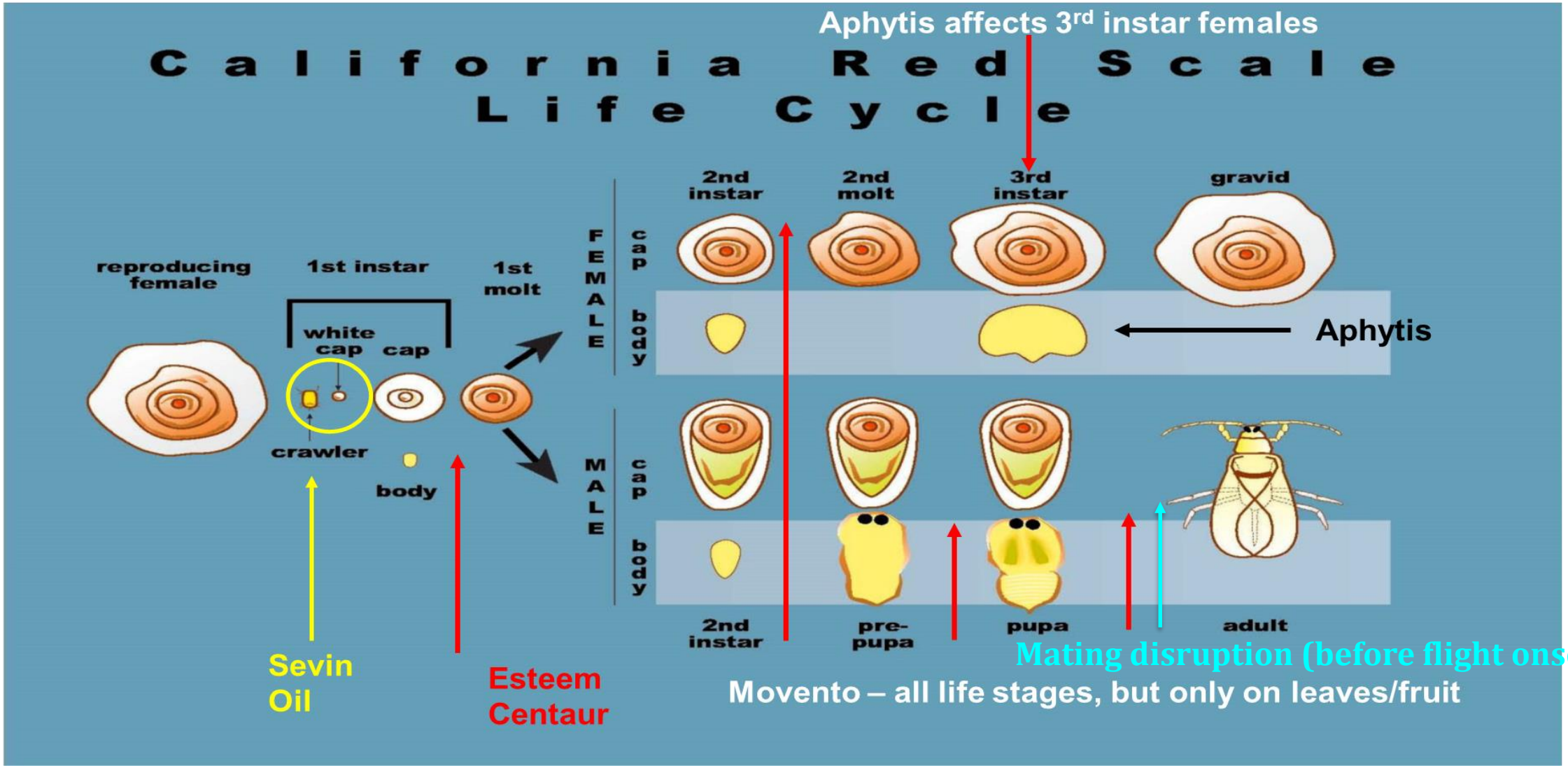




Percent fruit infestation

# *Aphytis* Pesticide Selectivity

| | MOA | Parasites | Predatory mites | Predatory beetles |
|---|---|---|---|---|
| OPS and Carb | 1a,b | Rate dependent | Resistant | resistant |
| Pyrethroids | 3 | Toxic | Toxic | Toxic |
| Admire Pro, Assail, Actara (Neonicotinoids) | 4a | Toxic | Toxic | Toxic |
| Sivanto (flupyradifurone) | 4d | Toxic | Soft | Egg production |
| Esteem (Pyriproxifen) | 7c | Soft | Soft | Toxic |
| Entrust/Success (Spinosad) | 5 | Soft | Soft | Soft |
| Delegate (Spinetoram) | 5 | Toxic | Soft | Egg production |
| Agri-Mek (Avermectin) | 6 | Soft | Toxic | Soft |
| Micromite (Diflubenzuron) | 15 | Soft | Soft | ? |
| Centaur/Applaud (Buprofezin) | 16 | Soft | Soft | Toxic |
| Fujimite, Nexter (Fenpyroximate) | 21a | Toxic | Toxic | Egg production |
| Movento (Spirotetramat) | 23 | Soft | Toxic | Soft |
| Exirel (Cyantraniprole) | 28 | Soft | Soft | Egg production |

## How to use life cycle for making pest management choices?




**All management choices should target first or second generation.**

# Best Management Practices: California Red Scale

- Weather affects populations, monitor and predict next life event
- Treatment Timing: Target early generations (1st and 2nd)
  - Mating disruption: Prior to the beginning first or second-generation male flight
  - *Aphytis*: Biweekly in spring and early fall
  - Insecticides: Treat generations 1 or 2 when the scale population is uniform in stage (exception is spirotetramat, which seems to work in fall)
  - Use the selective insecticides that allow natural enemies to survive when you can
- Rotate products to avoid resistance
- Good coverage: 750-1500 gpa/acre (7000-15000 l/ha) (spirotetramat 250 gpa/acre)
- Drive slowly! < 1.5 mph (2.4 kph)
- Postharvest options include: Phosphine fumigation ~48 hours; pressure wash @300 psi; ethyl formate

# Acknowledgements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- Ping Gu
- Sanjeev Dhungana