# Presentations Day 2

## Course Schedule

| Time | Activity Type | Title |
|---|---|---|
| **Morning Session** | | |
| 8:00 | Introduction | Welcome and Review of Day 1 |
| 8:30 | Presentation | Effects of Pesticides in the Field |
| 9:00 | Presentation | Use of Bait Sprays in IPM Programs:advantages and limitations |
| 9:25 | Presentation | Microbial Control in Orchard Systems |
| 10:00 | Presentation | Synthesis of Pesticide Effects |
| 10:30 | | **Break** |
| 10:55 | Presentation | Using commercially available natural enemies for biological control |
| 11:15 | Presentation | Conservation biological control through habitat modifications |
| 11:45 | Review | Review of morning session with Q&As |
| 12:05 | | **Lunch** |
| **Afternoon Session** | | |
| 1:05 | Exercise | ***Case Study #2:*** Designing BC Friendly IPM Programs |
| 2:05p | Introduction | Economics of BC – premises behind the model |
| 2:20p | Presentation | Economics of BC – results of economic model |
| 2:55p | | **Break** |
| 3:15p | Exercise | ***Case Study #3:*** Restoring BC after a major disruptive event; invasive insect: BMSB |
| 4:15p | Review | Overall Summary of Short Course |
| 4:40p | Evaluation | Evaluation of Short Course |
| 4:55p | Reception | **Social Hour and Poster Session of Day 2 Topics** |
| 6:00p | | End of Short Course |

# Effects of pesticides in the field

**Peter Shearer**, Oregon State University, Hood River OR
**Elizabeth Beers**, Washington State University, Wenatchee, WA

Washington State University
ars Agricultural Research Service
Oregon State OSU
Berkeley

## Presentation 1: Effects of Pesticides in the Field

Notes:

Effects of pesticides in the field

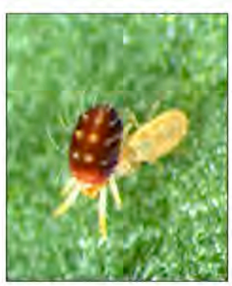
**Peter Shearer**, Oregon State University, Hood River OR
**Elizabeth Beers**, Washington State University, Wenatchee, WA

Washington State University
ars Agricultural Research Service
Oregon State OSU
Berkeley

Notes:

## Top 5 messages

- Effective orchard IPM involves more than just spraying pesticides.
- Nontarget pesticides effects have had a huge impact on pest control in past 100 years
- Nontarget effects on natural enemies are the main cause of secondary pest outbreaks
- Identifying, and mitigating, nontarget effects can restore biological control of secondary pests.
- Choosing the right products for IPM is complicated but worth it!



Notes:

Notes:

## Positive impacts of insecticide use in orchards

Pesticides, a component of IPM

- Protects against crop loss
  - Treatment thresholds
  - Reduce bottom line
  - Increase profits
- Can conserve natural enemies
  - Reduces insecticide use

Notes:

## Negative impacts of insecticide use in orchards

Insecticide use involves risks:

- Farmworkers, environment and consumers
- Impacts REIs, PHIs and MRLs
- Misuse increases insecticide resistance
- Can disrupt biological control

Notes:

## Non-target effects

- Pesticide causes mortality in target pest (e.g. codling moth), but has unwanted negative side effects on one or more beneficial insects.
  - Lethal: Kills one or more stages of the NE
  - Sublethal: reduces prey consumption, fecundity, egg sterility, longevity, increases development time, changes sex ratio, repellency, host masking, alters behavior so NE is less effective.
- Populations of minor pest can increase drastically in the absence of natural controls.

## Insecticide-induced disruption

- Insects and mites that become pests after their natural enemies are impacted by insecticides are called induced pests.
- Examples of insecticide induced pests:
  - San Jose scale

Notes:

## Insecticide-induced disruption

- Insects and mites that become pests after their natural enemies are impacted by insecticides are called induced pests.
- Examples of insecticide induced pests:
  - Wooly apple aphids

Notes:

## Insecticide-induced disruption

- Insects and mites that become pests after their natural enemies are impacted by insecticides are called induced pests.
- Examples of insecticide induced pests:
  - Walnut aphids


Notes:

Notes:

## Insecticide-induced disruption

- Insects and mites that become pests after their natural enemies are impacted by insecticides are called induced pests.
- Examples of insecticide induced pests:
  - Spider mites

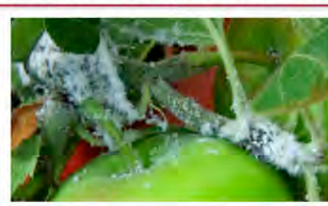
Notes:

## Insecticide-induced disruption

- Insects and mites that become pests after their natural enemies are impacted by insecticides are called induced pests.
- Examples of insecticide induced pests:
  - Pear psylla

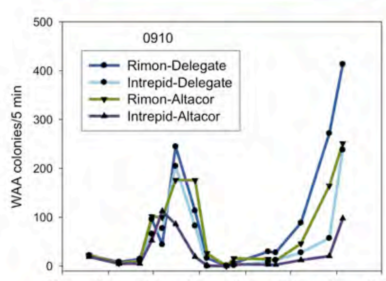
Notes:

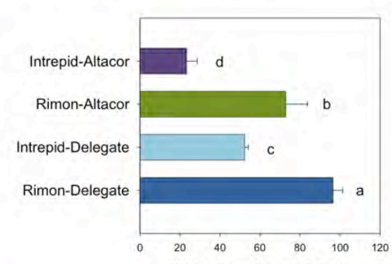
## Examples of insecticide-induced disruption: Apple



Beers, 2009.
4 trts x 4 one-acre reps - Bridgeport

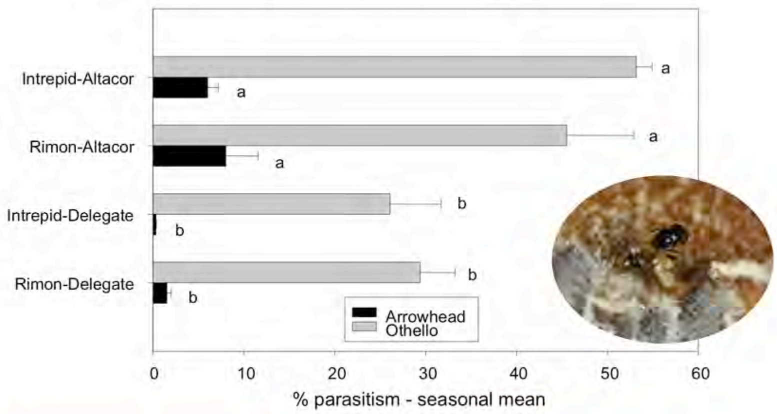
Woolly Apple Aphid Populations



## Examples of insecticide-induced disruption: Apple

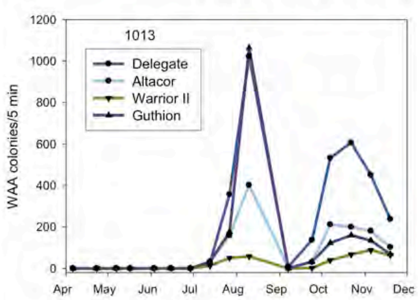
Reduction in WAA parasitism by *Aphelinus mali*

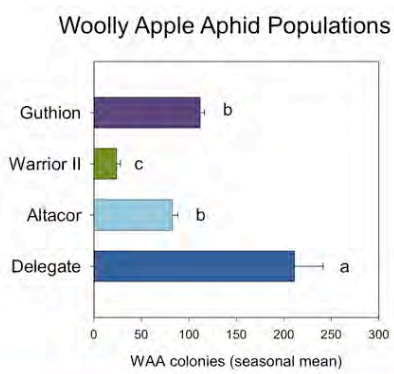



Notes:

## Examples of insecticide-induced disruption: Apple

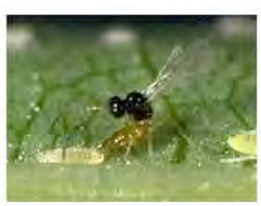
4 trts x 4 one-acre reps – Othello, 2010

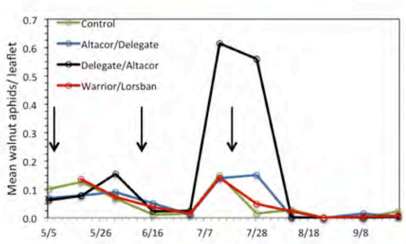


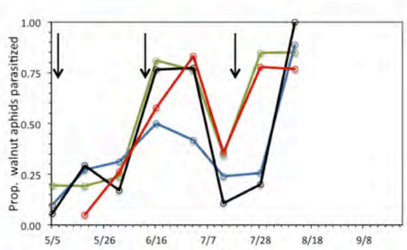




Notes:

## Examples of insecticide-induced disruption: Walnut






Mills, 2011 (CA)

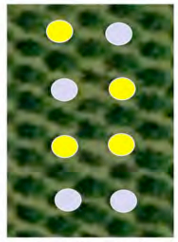
Notes:

Notes:

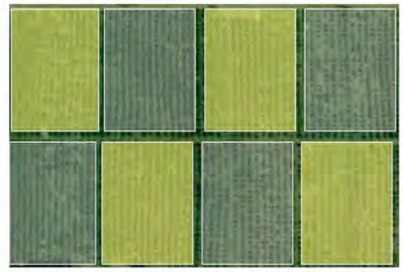
## Studying insecticide selectivity in the field

Conduct "large-scale" research in grower orchards

- Important to replicate on farm vs. between farms
- Can be considerably more expensive than lab assays
- More accurately simulates grower conditions



Replicated single tree plot



Replicated large plot

Notes:

## Replicated field trials: 2011 (WA)

4 replicates, 1 acre plots (apple)

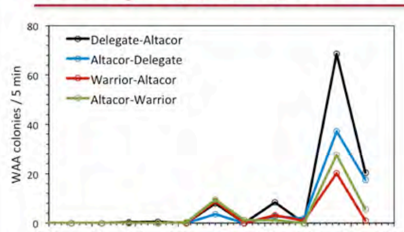
Treatments:

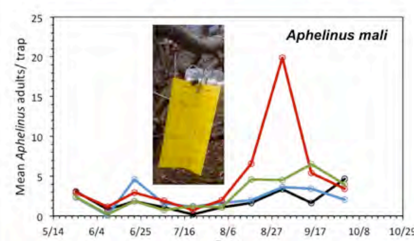
- 2 apps of Delegate 1st gen
- 2 apps of Altacor 2nd gen.
- All had Intrepid at PF

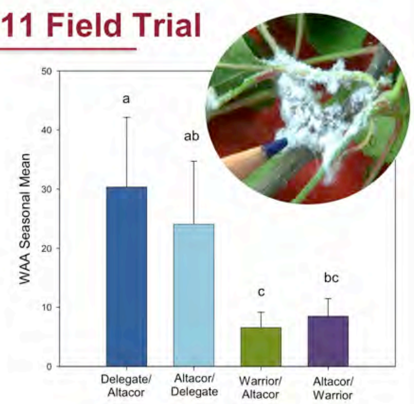
Sampled secondary pests and NEs sampled every 1-3 wks

Notes:

## Woolly Apple Aphid - 2011 Field Trial




## Replicated field trials: 2011 (OR)

0.6 acre plots, d'Anjou pear

- Hood River, OR
- 4 replicate blocks

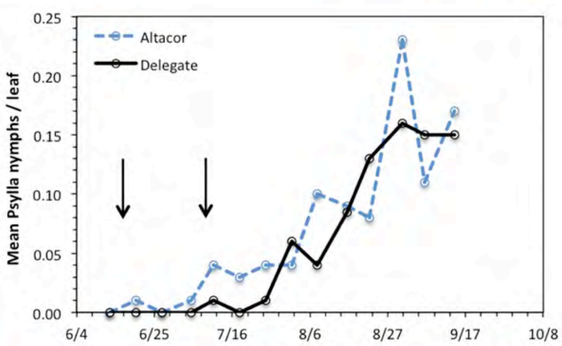
Two 1st generation applications

- 2 x Altacor
- 2 x Delegate
- 1st cover had Agri-mek + oil

Notes:

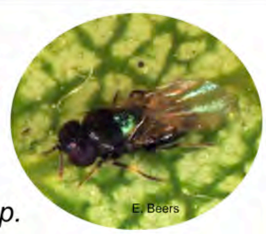
## Measuring natural enemy impact

**1. Measure pest density**



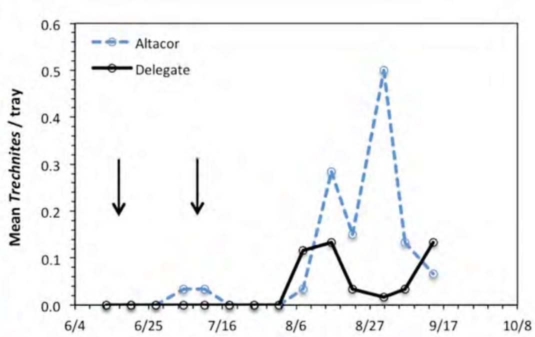

Notes:

## Measuring natural enemy impact



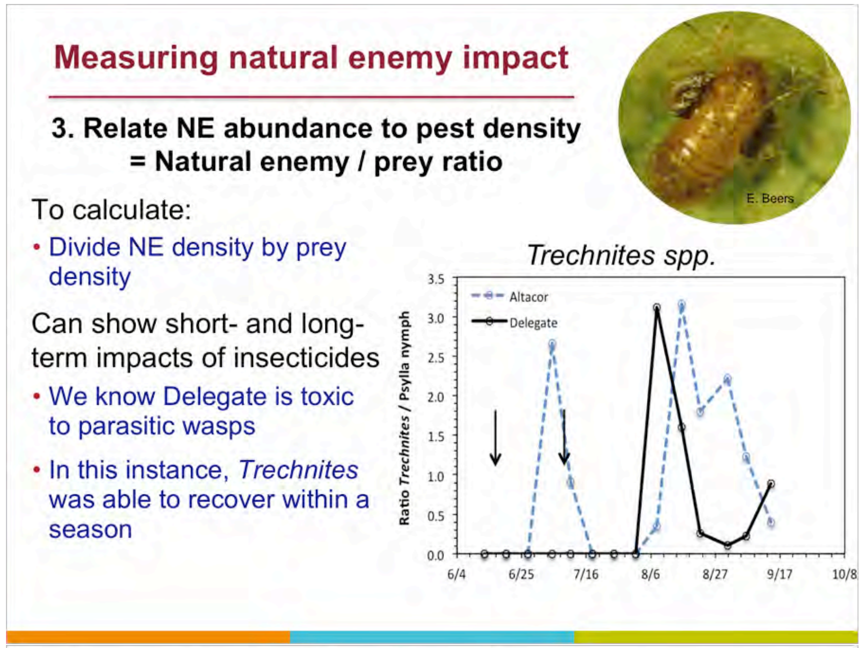

**2. Measure natural enemy density**

*Trechnites spp.*

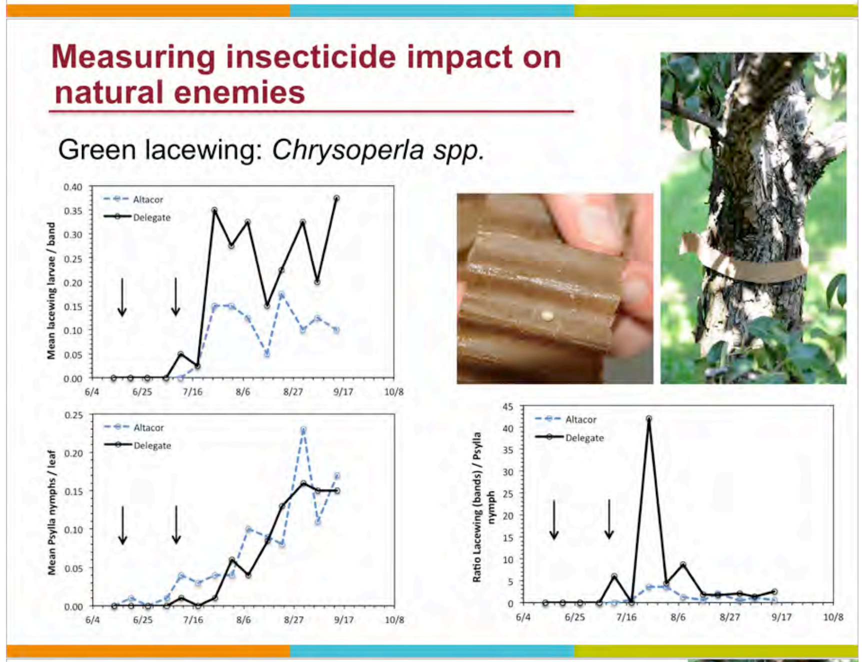



Notes:

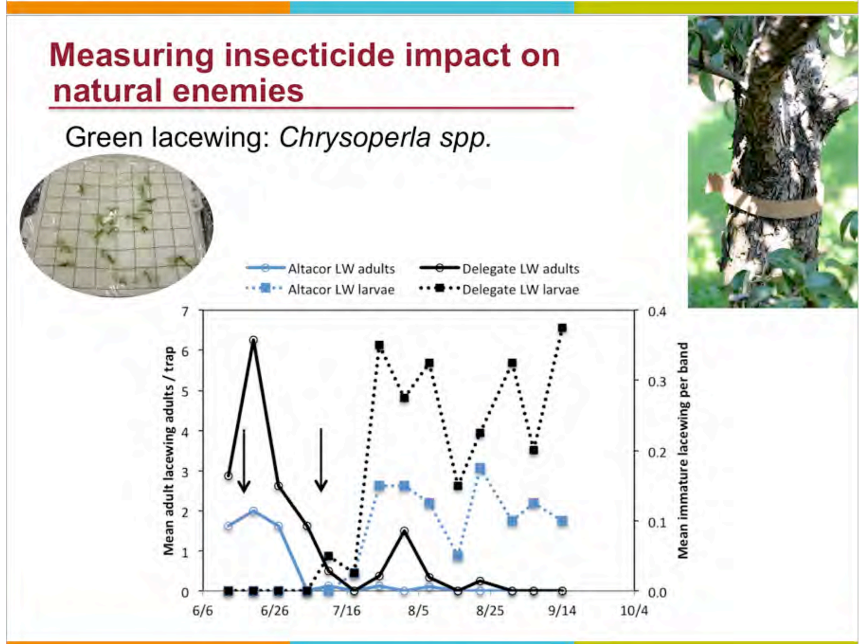
Notes:




Notes:



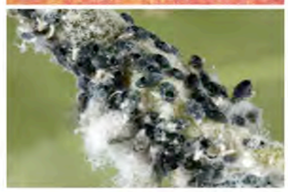

Notes:



## Tropic effects: enemies of natural enemies

Natural enemies have their own enemies

- Some are fairly specific
  - e.g. lacewings are attacked by several wasps that can reduce LW abundance
- Others are generalists
  - e.g. spiders, earwigs and ants
  - these can eat parasitized pests
  - consume pest + natural enemies
- The point here is that biological control is a complex system.

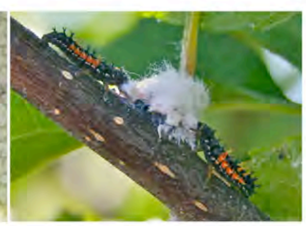


Notes:

## Mitigating risks to natural enemies

Conservation biological control

- A practice that promotes and protects natural enemies
  - Limit effects that are disruptive
    - Choose least toxic insecticides, or, time sprays to minimize impact

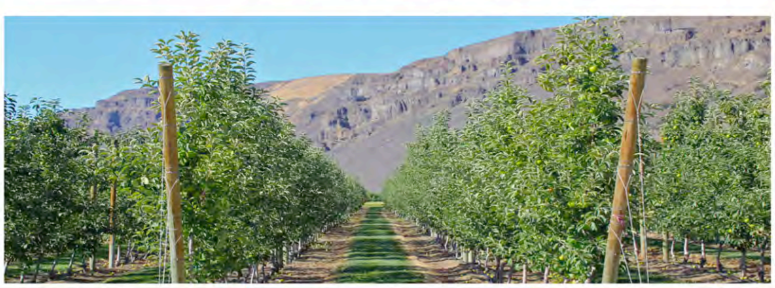


Notes:

## Mitigating risks to natural enemies

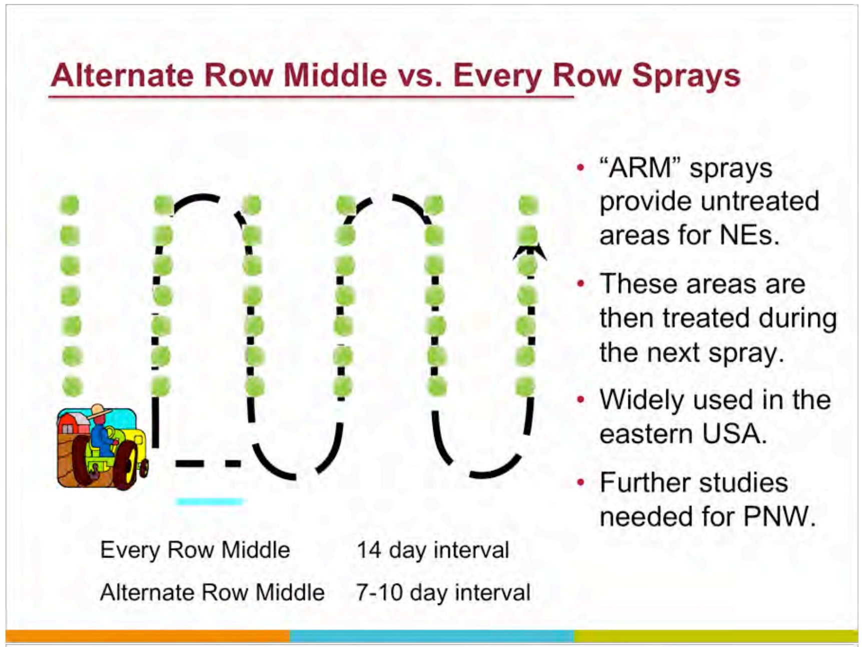
Promoting conservation biological control

- Provide refugia to enhance of protect natural enemies
  - Leave part of orchard unsprayed
    - Alternate Row Middle Spray technique

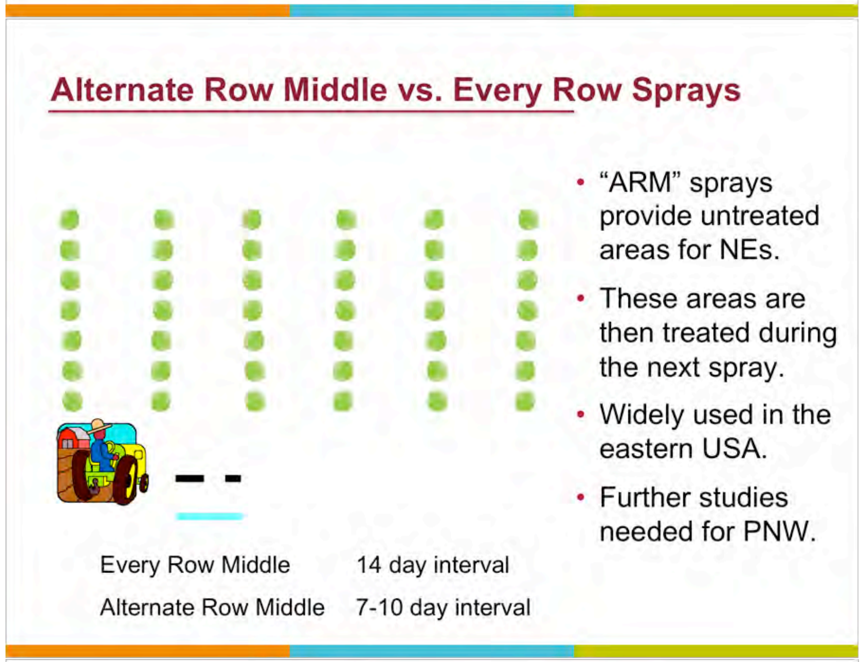


Notes:

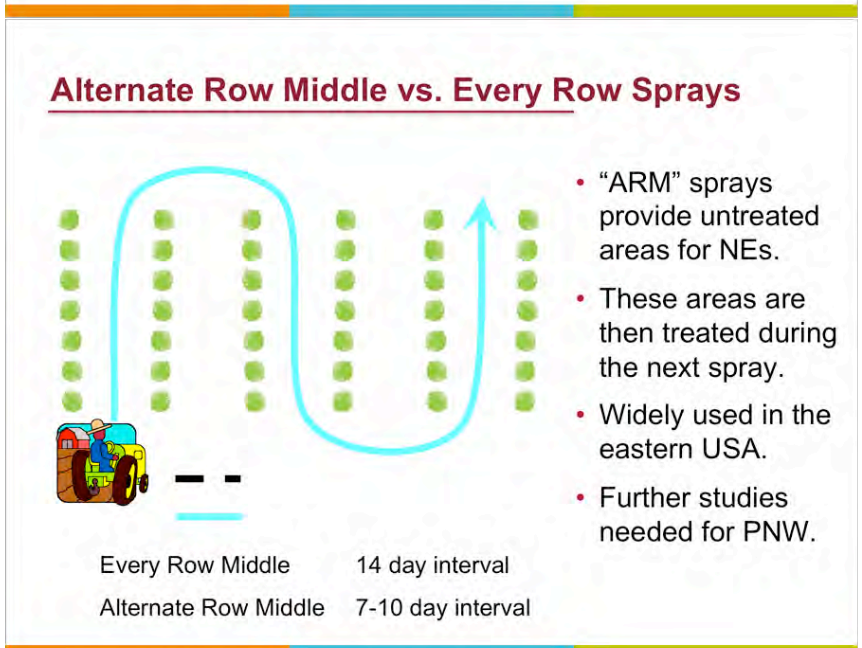
Notes:




Notes:

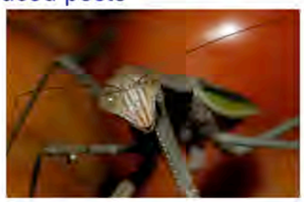



Notes:



## Summary

- Pesticides are important tools for orchard IPM
- Recognize the positive impacts that pesticides have on IPM and ramifications when they are misused
- Conserving natural enemies can lead to more stable orchard IPM systems
  - Choose products based upon efficacy and NE impact
  - Time sprays to minimize insecticide-induced pests
  - Provide refuge for natural enemies
- Help biological control work for you



Notes:

*Presentation 2: Use of Bait Sprays in IPM Programs*

Notes:

## Use of Bait Sprays in IPM Programs: Advantages and Limitations

**Marshall W. Johnson**

Department of Entomology, University of California, Riverside

UC Kearney Agricultural Research & Extension Center

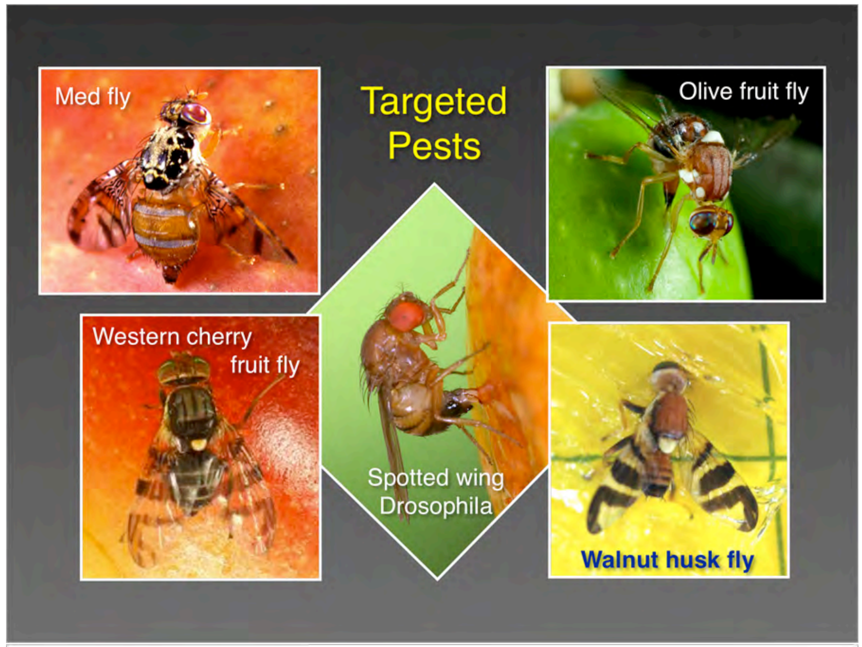
Parlier, California

Notes:

## What is a bait spray?

- A combination of a highly effective attractant and a small amount of insecticide that is applied within an environment where the target pest is likely to find and feed upon the bait-insecticide residues
- Contact residues may be ineffective because some pests do not feed within the crop, are very mobile, and do not remain long within the orchard
- A method is needed to attract the pest to the insecticide
- A bait spray is like the "Trojan Horse" in IPM systems
- Bait sprays allow the grower to use very low amounts of insecticide to achieve effective pest control

Notes:




Notes:

## Common baits

- Nu-Lure® protein bait
- Solbait (in GF-120)
- Molasses
- Sugar

Notes:

## Presentation topics

- Factors that influence the efficacy of a bait spray
- What is the impact of dilution rate and time after treatment on bait efficacy?
- Observed impacts of bait sprays on natural enemies
- Can species develop resistance to bait spray applications?

Notes:

## Factors that influence efficacy of bait sprays

- Placement within the canopy
- Behavior of pest species
- Presence of honeydew producing insects
- Ratio of insecticide bait to carrier (water)
- Weather conditions
- Impact on natural enemies
- Development of resistance to insecticide

Notes:


Notes:

Notes:

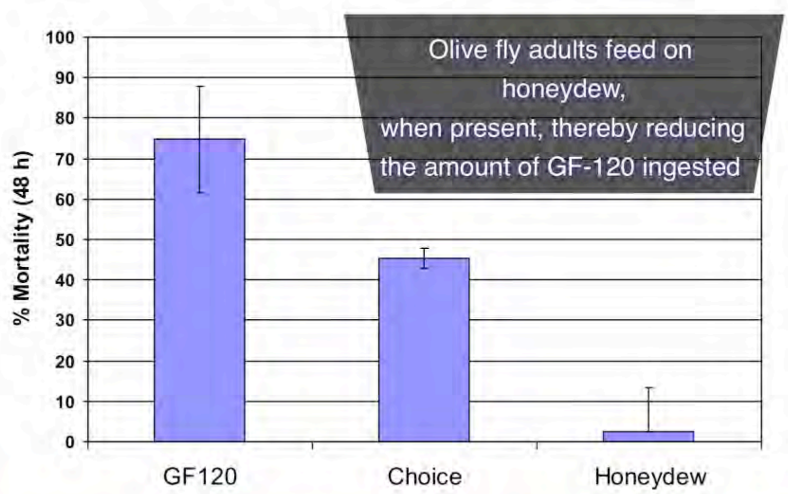

Notes:

## Blackscale honeydew vs. GF-120

- Adult OLF ingestion of “artificial” black scale honeydew was compared to GF-120 bait to determine the relative preference of the fly to each material.
- “Artificial” honeydew = 21.7% fructose, 18.9% sucrose, and 4.1% glucose based on analysis by Byrne et al. (2003)
- Sixty μl droplets of GF-120 bait and black scale honeydew on glass microscope slides were offered to adult OLF females in no choice preference tests. Each material was reduced to 30 μl in choice tests.
- Mortality resulting from ingestion was compared. Results indicate that the presence of honeydew may reduce the effectiveness of GF-120.

Notes:

Choice vs. No Choice Tests of GF120 vs. Honeydew



## Presentation topics

- Factors that influence the efficacy of a bait spray
- What is the impact of dilution rate and time after treatment on bait efficacy?
- Observed impacts of bait sprays on natural enemies
- Can species develop resistance to bait spray applications?

Notes:

## Dilution and post treatment time research

- Given the extremely high temperatures in California's Central Valley, studies were conducted at 3 different times during the growing season (August, September, October) using olive fruit fly as a model species
- Two dilutions of GF-120 NF Naturalyte fruit fly bait (1.5: 1 and 4:1 parts GF-120 to water, respectively) were tested and compared to a control treated with the attractant solbait alone

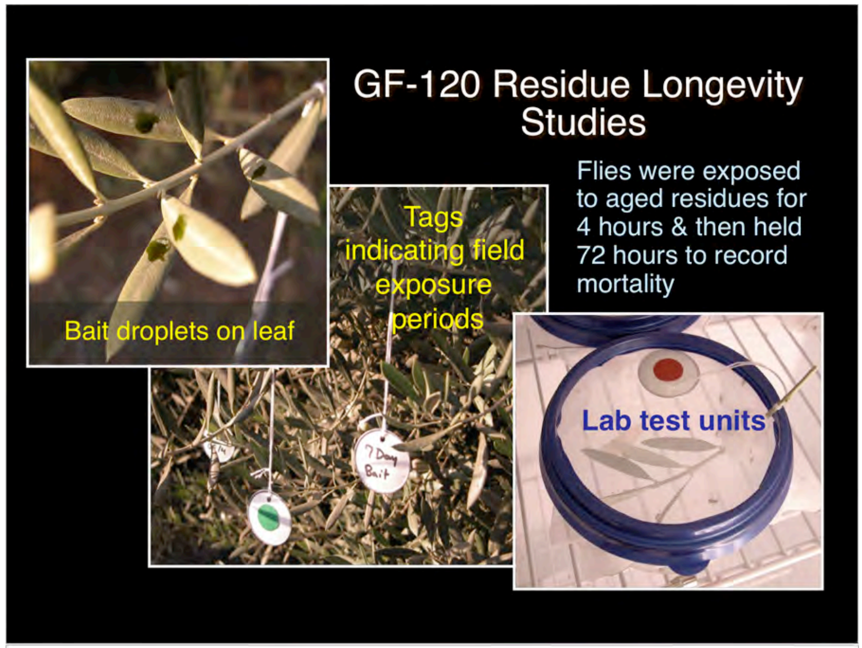
Notes:

## Dilution and post treatment time research

- Results indicated that:
  - high temperatures and low humidity did not reduce the effectiveness of GF-120 droplets
  - residues from the 1.5:1 dilution ratio resulted in higher mortality in the latter phases of the three trials than did the 4:1 ratio
  - mortality resulting from residues were greater during the months of August and September as compared to October

Notes:

Notes:

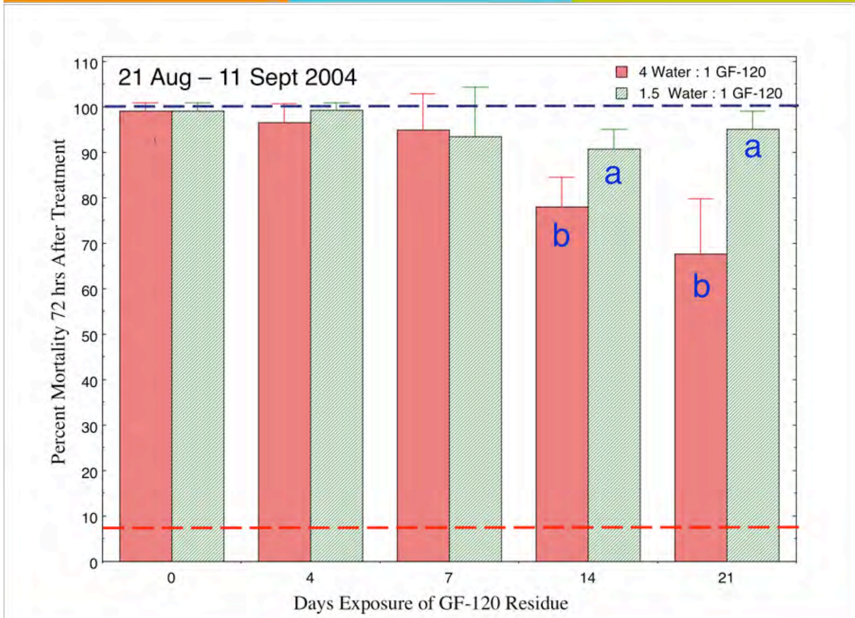



Notes:

## Dilution and post treatment time research results

- *All tests*: significant interaction between dilution ratios and DAT ($P$ < 005). Overall mortality (i.e., Days 0 to 21) resulting from the more concentrated solution was significantly higher than the 4:1 solution ($P < 0.05$; repeated measures ANOVA).
- *August 2004 test*: mean mortalities of flies exposed to the 1.5 :1 residues from 0 to 21 DAT ranged from 99.2 to 90.6%. Mortality in the 4:1 ratio residue was significantly less on Day 14 ($P = 0.012$) and 21 ($P = 0.0006$), but still higher than the control ($P < 0.0001$).

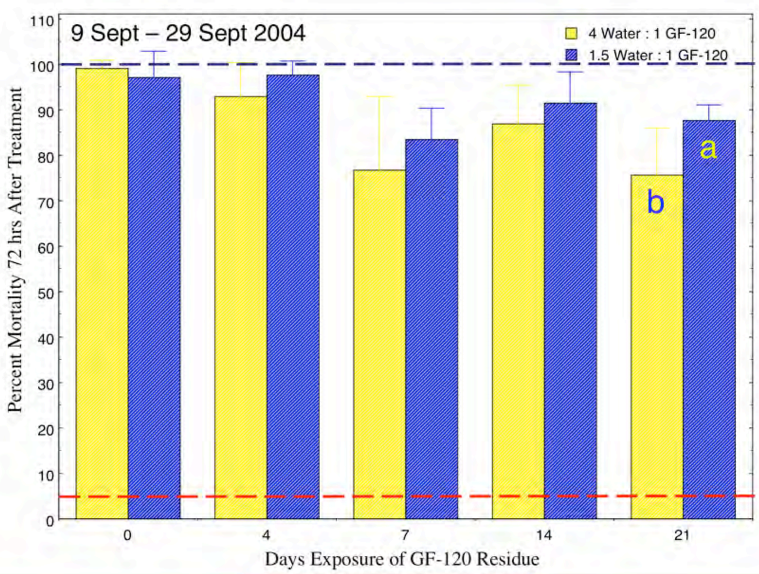
Notes:



## Dilution and post treatment time research results

- *All tests*: significant interaction between dilution ratios and DAT (*P* < 005). Overall mortality (i.e., Days 0 to 21) resulting from the more concentrated solution was significantly higher than the 4:1 solution (P < 0.05; repeated measures ANOVA).
- *September 2004 test*: mean mortalities recorded from the 1.5:1 ratio residues from 0 to 21 DAT ranged from 83.4 to 97.5%. Mortality in the 4:1 ratio residue was significantly less on Day 21 (*P* = 0.025), but higher than the control (*P* < 0.0001).

Notes:



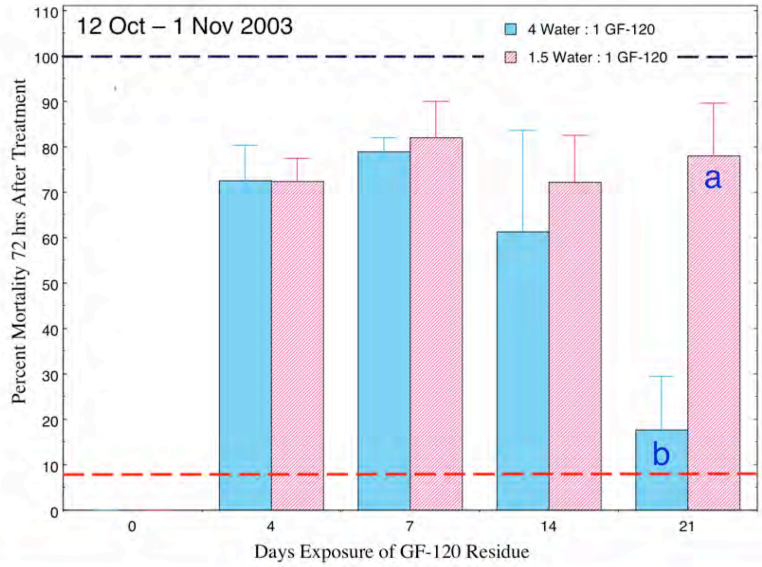

Notes:

## Dilution and post treatment time research results

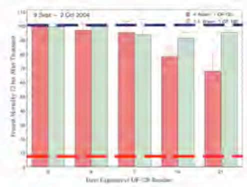
- *All tests*: significant interaction between dilution ratios and DAT (*P* < 005). Overall mortality (i.e., Days 0 to 21) resulting from the more concentrated solution was significantly higher than the 4:1 solution (P < 0.05; repeated measures ANOVA).
- *October 2003 test*: 21 days after treatment (DAT), mortality in the 1.5:1 solution residue held at 77.9%, but flies exposed to the 4:1 solution exhibited a mortality of only 17.7% (*P* = 0.0022) not significantly different from the control (*P* = 0.18).

Notes:

Notes:



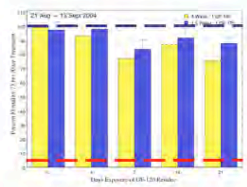

Notes:



Mean daily maximum temp = 94.4 ± 5.9°F

Mean maximum RH = 84.1 ± 3.7%

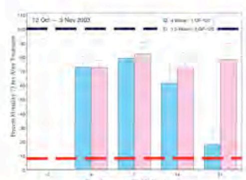
Days when dew formed = 0.0%



Mean daily maximum temp = 87.9 ± 8.8°F

Mean maximum RH = 84.9 ± 5.4%

Days when dew formed = 33.3%



Mean daily maximum temp = 82.0 ± 9.3°F

Mean maximum RH = 90.6 ± 1.9%

Days when dew formed = 95.2%

Notes:

## Presentation topics

- Factors that influence the efficacy of a bait spray
- What is the impact of dilution rate and time after treatment on bait efficacy?
- Observed impacts of bait sprays on natural enemies
- Can species develop resistance to bait spray applications?

## Observed impacts of bait sprays on natural enemies


### Predator Insect

- Green lacewing adults (*Chrysoperla carnea*) were tested as to their preference to feeding on GF-120 compared to a) the attractant (solbait) in GF-120, and b) 50% honey-water solution
- The predator preferred to feed on honey and was not attracted to GF-120 or the bait contained within
- However, lacewing adults did suffer low levels of mortality from feeding on GF-120, and female lacewings had a reduced lifetime fecundity when feeding on GF-120 as compared to feeding on solbait alone.

Notes:

## Observed impacts of bait sprays on NEs

### Parasitoids

- Studies on the parasitoid wasps *Psyttalia humilis* and *Scutellista caerulea* of olive fruit fly and black scale, respectively, show that these species were not attracted to feeding on the attractant (solbait) and did not suffer mortality as such.



Notes:

## Presentation topics

- Factors that influence the efficacy of a bait spray
- What is the impact of dilution rate and time after treatment on bait efficacy?
- Observed impacts of bait sprays on natural enemies
- Can species develop resistance to bait spray applications?

Notes:

Notes:

Research Article

SCI

Received: 15 September 2009 Revised: 5 December 2009 Accepted: 14 December 2009 Published online in Wiley Interscience: 9 February 2010

(www.interscience.wiley.com) DOI 10.1002/ps.1921

# Spinosad resistance development in wild olive fruit fly *Bactrocera oleae* (Diptera: Tephritidae) populations in California

Evdoxia G Kakani,[a†] Nikos E Zygouridis,[a†] Konstantina T Tsoumani,[a] Nicos Seraphides,[b] Frank G Zalom[c] and Kostas D Mathiopoulos[a*]

**Abstract**

**BACKGROUND:** Among target pests of the insecticide spinosad is the olive fruit fly, *Bactrocera oleae* (Rossi) (Diptera: Tephritidae). In Cyprus, spinosad has been sporadically used since its registration in 2002, whereas in Greece its use has been very limited since its registration in 2004, particularly in biological olive cultivars in Crete. By contrast, in California it has been the only insecticide used against the olive fruit fly since its registration in 2004. This study aimed at examining the resistance status of the olive fruit fly to spinosad.

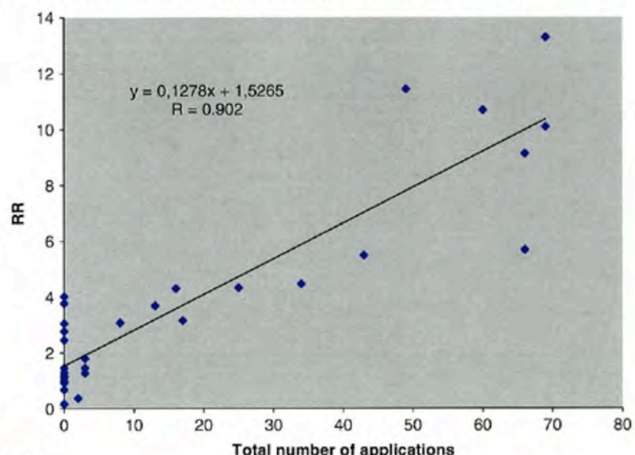
**RESULTS:** Populations from California, Greece and Cyprus, plus a laboratory population, were tested. Bioassays were performed by oral or topical application of different concentrations of the insecticide. Cypriot populations demonstrated no resistance as compared with that of the laboratory population. Among the Greek populations, only one from Crete demonstrated a fourfold increase in resistance, whereas five populations from California demonstrated a 9–13-fold increase.

**CONCLUSION:** The observed resistance increase was associated with spinosad applications in the respective areas. These values are relatively low and do not yet pose a serious control problem in the field. However, the observed variation documents that spinosad tolerance has increased in areas where the insecticide has been more extensively used.


**Keywords:** *Bactrocera oleae*; insecticide; tolerance

Notes:

Correlation between number of spinosad applications (total number of bait sprays performed in each sampling region) and resistance development (resistance ratio).




Kakani *et al*.

Notes:

## Summary

- Bait sprays can effectively deliver insecticides to pest insects using small amounts of insecticides.
- Longevity of bait residues are influenced by various factors such as dilution rates and temperature.
- Successful integration of bait sprays into an IPM program may vary depending on the natural enemy species present.
- Pest species may develop resistance to the insecticides used in bait sprays when treatments are applied frequently.

## Microbial Control in Orchard Systems: Prospects and Problems

Andrea Bixby-Brosi, Jay Brunner, & Ute Chambers
Washington State University
Tree Fruit Research and Extension

Notes:

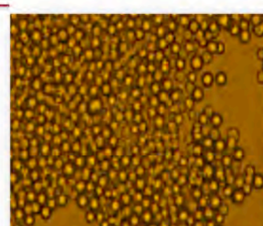
## Overview

- What is microbial control?
- Microbial control in orchards
  - Codling moth granulovirus
  - Entomopathogenic nematodes
  - *Bacillus thuringiensis* for leafroller
- How does microbial control fit into Western orchard systems?

Notes:

## What is microbial control?

- The use of virus, bacteria, fungi, and nematodes
- Safe for environment, applicators, food supply, conserve natural enemies
- Typically combined with mating disruption and reduced risk pesticides



Virus particles

Nematodes

Notes:

Notes:

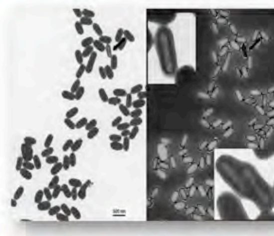
## How are microbial control products applied?

- Inundative biological control
  - Applications are not expected to persist for an extended period
  - No reproduction
  - Reapplication necessary
- Use of spray equipment
- Short pre-harvest interval
- Important to know the biology of pest insect and microbial organism!

Notes:

## Codling Moth Granulovirus (CMGnV)

- Virus particles
  - Infect and replicate in insect's gut.
  - Are slow acting but very toxic to codling moth.
- Benefits
  - Specific to CM larvae
  - Highly virulent
  - Naturally occurring



Virus Infected CM Larvae

Notes:

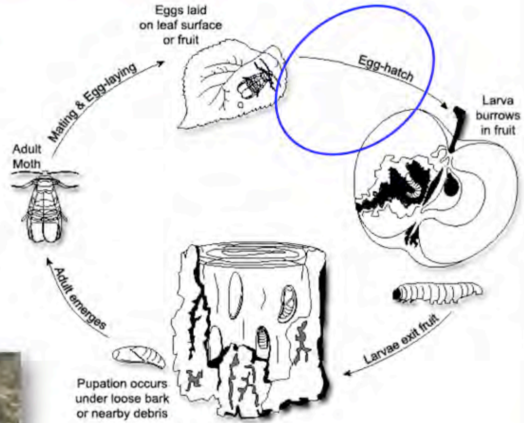
## Codling moth granulovirus

- Larvae must ingest virus from surface of contaminated, fruit, leaves, or eggs
- 1 to 2 virus particles is all that is required to cause a lethal infection
- A single ounce of CYD-X contains nearly 1 trillion virus particles

Notes:

## Efficient virus applications

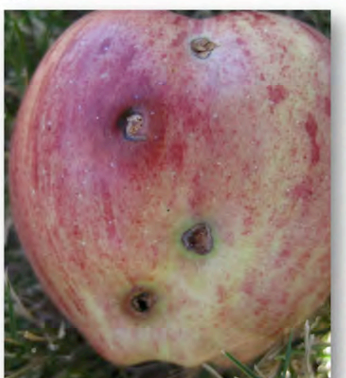
- Target newly hatched larvae before they enter apple.
- Typically used in combination with mating disruption
- Adding oil (1%) provides ovicidal activity




Notes:

## CM granulosis virus limitations

- Exposed larvae live long enough to damage fruit.



Washington State University World Class. Face to Face.   ars Agricultural Research Service   Oregon State University OSU   Berkeley

Notes:

## CM GnV Limitations

- Sensitivity to heat and solar degradation necessitates reapplication at short intervals
  - (residues last 7-10 d in spring, 3-7 d in summer)

- $ Cost
  - Cyd-x is about $10 per acre at 1 fl oz rate
  - Extra costs could be in labor if not incorporated into other management strategies (ie. other sprays)

Notes:

## 2010 Field Experiment

- CM virus applied in research orchard with initially high numbers of CM
- Cyd-X, Full rate
  - Full rate - 3 fl oz/acre
  - Low rate -1 fl oz/acre
  - Ultra low rate - 0.3 fl oz/acre
- Application interval
  - 7-10 days for entire season
    - 6 applications 1st gen
    - 5 applications 2nd gen

Notes:

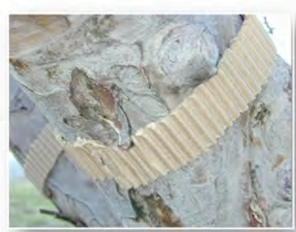
## Fruit Injury


Brunner 2010

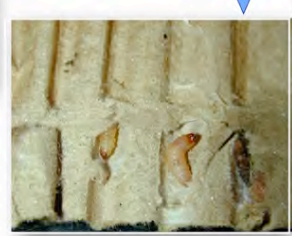
Notes:

## Collecting Emerging Larvae

Cardboard bands placed in the orchard at 600dd and 1800dd

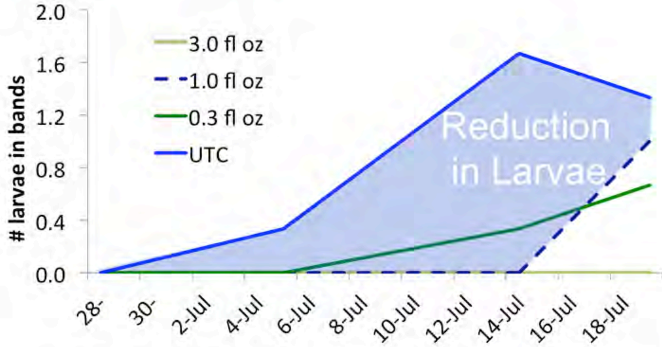


Mature larvae exit fruit and enter bands



Bands are collected and replaced for four weeks

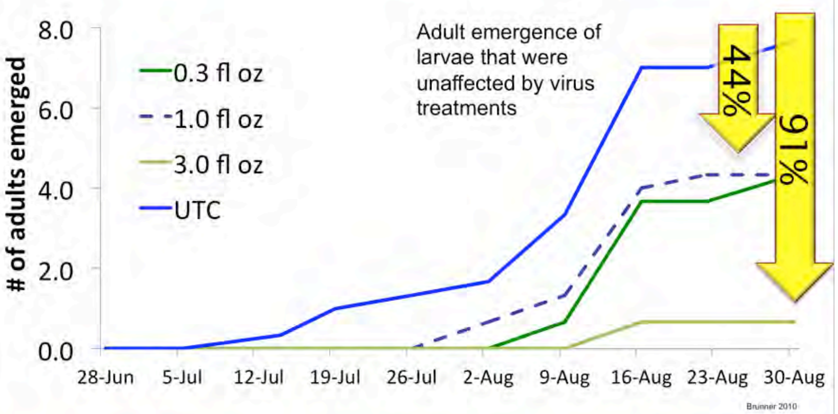
## CM reduction from virus in 1st generation




Brunner 2010

Notes:

## Cumulative Adult Emergence




Notes:

## CM virus summary

**Pros**

- Specific to CM larvae
  - Conservation of natural enemies
- Highly virulent
- Naturally occurring
- Short residual
  - Short pre-harvest interval

**Cons**

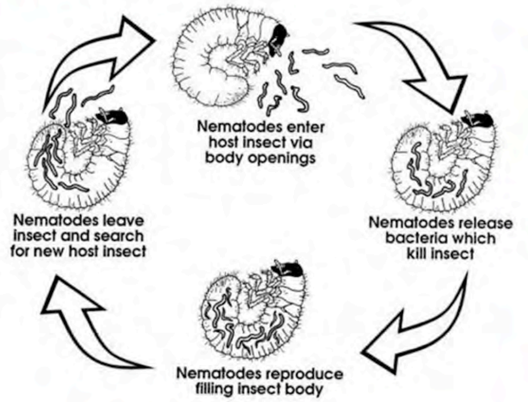
- Short residual
  - Re application necessary
- Could result in extra costs
- Some fruit damage

Notes:

Notes:

## Insect Parasitic Nematodes

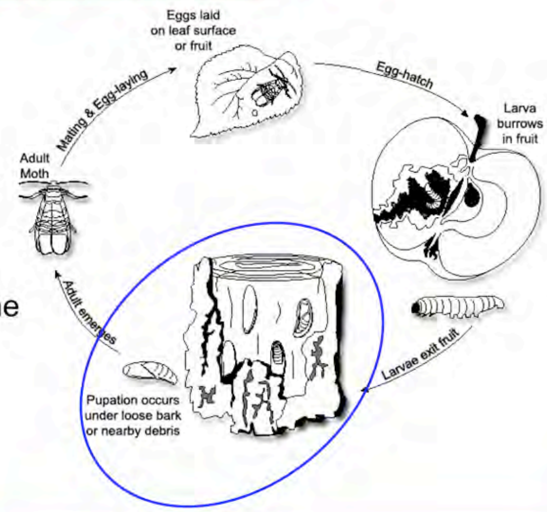
- Round worms




Notes:

## Control of codling moth in orchards

- Targets the overwintering pupae or diapausing cocooned larvae after harvest
- Reduce populations for the following spring




Notes:

## Apply to overwintering sites

- Under loose bark
- In leaf litter
- Nearby wood piles
- Fruit bins left in orchard

- Application
  - Spray equipment

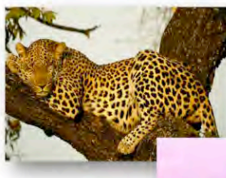
## Under the right conditions….

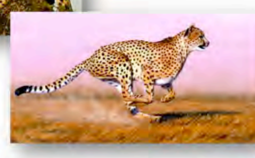
- Nematodes can control a high percentage of the overwintering population
  - Late Sept – late Oct
  - Adequate moisture
  - Temps between 60 - 75°F
  - Late afternoon or early morning

Notes:

## Nematode selection

- Host searching
  - Ambushers (sit and wait)
    - *Steinernema carpocapsae*
  - Cruisers (seek and search)
    - *Heterorabditis bacteriophora*
  - Combined tactics
    - *S. feltiae*





- Commercial products
  - Exempt from US EPA registration
  - Millenium® (Becker Underwood)
    - 600 million/acre at $115/acre
  - Rincon-Vitova
  - Rarely used by growers in WA


Notes:

## Why Nematodes Haven't Been "The Answer" (at least so far….)

- Moisture and temp. - requirements hard to maintain!
- Limited shelf life
- High Cost
- Inconsistent performance

Notes:

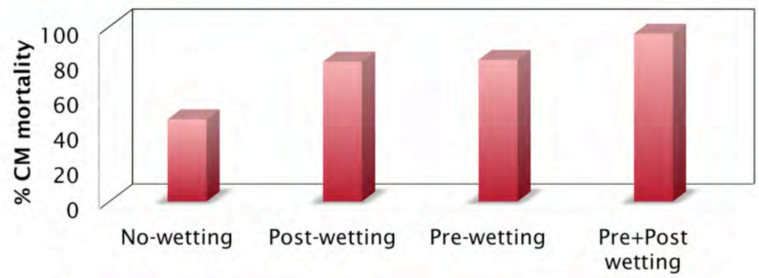
Notes:

## Ways to enhance or prolong nematode activity

- Habitat modification
  - Irrigation before and after application
  - Mulches around tree bases
- Ideal orchard – young with smooth trees
- Apply at certain times of the day
- Addition of adjuvents
  - Protect from solar degradation
  - Prolong moist conditions

Notes:

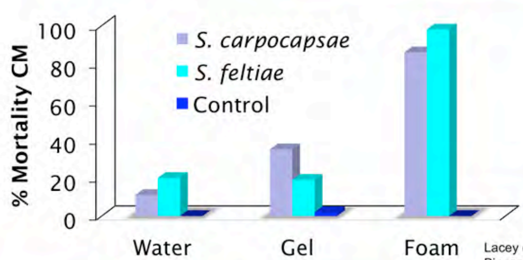
## Adding moisture to enhance nematode activity (*S. carpocapsae*)




Unruh & Lacey 2001 Biological Control

Notes:

## Enhanced activity with post application anti-desiccant agents


Lacey et al. 2010 Biocontrol Science and Technology

## Nematode summary

**Pros**

- Can reduce CM from overwintering population
- Non-toxic
  - No residue
  - Short lived
  - Conservation of natural enemies

**Cons**

- Moisture and temp. requirements hard to maintain!
- Limited shelf life
- High Cost
- Inconsistent performance

Washington State University | ars | Oregon State OSU | Berkeley

Notes:

## *Bacillus thuringiensis* kurstaki (Bt): Control of leafroller

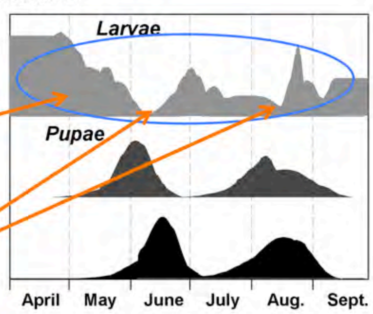
- Toxins produced by bacteria function as stomach poisons and kill larvae once digested


Notes:

## Effective control with Bt

- Target small larval form
- Windows for effective application

SPRING: Between pink and petal fall of bud development




SUMMER: Coincide with 90% egg hatch based on OBLR or PLR model

Notes:

Notes:

## Effective control with Bt

- Temps must remain at or above 65°F during and 3-4 days following Bt application
  - This is when active feeding occurs
- Residues break down slowly in spring (7-9 days), but faster in summer (3-7 days)
- Usually 2-3 applications are necessary at 7-10 day intervals


Notes:

## Limiting factors

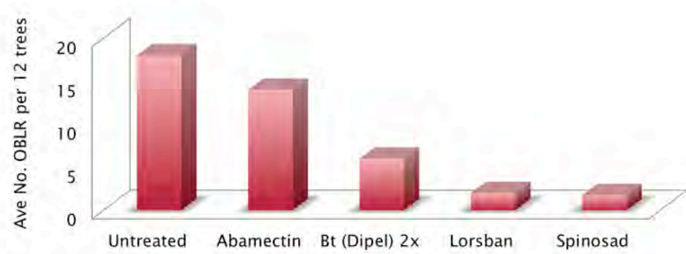
- Leafroller has to ingest Bt sprayed leaf material to obtain a lethal dose
- UV degradation
- Possible interactions with leafroller parasitoids


OBLR with tachinid fly eggs attached


Tachinid fly laying eggs

Notes:

## Comparison of control OBLR methods




Application timings: all treatments at pink , Bt (Dipel) 2x at pink and petal fall.

## Bt summary

**Pros**

- Short residual
  - Conservation of natural enemies
  - Short pre-harvest interval

**Cons**

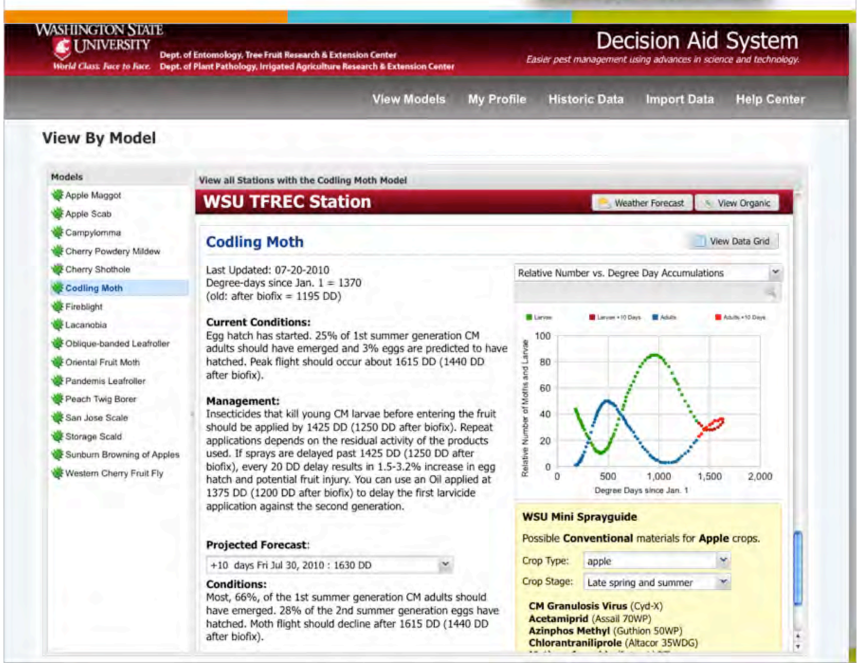
- Leafroller has to ingest Bt sprayed leaf material to obtain a lethal dose
- UV degradation
- Multiple applications

Notes:

## The reality of microbial use in Western orchards

- Unlikely to be considered a stand-alone tactic, and should be incorporated with IPM
- Limitations exist and should be considered
- Cost competitiveness with mainstream pest management practices
- Must be OK with some amount of damage
- It takes smart management to implement microbial tactics
  - Monitoring!
  - Use of decision aid system!

Notes:

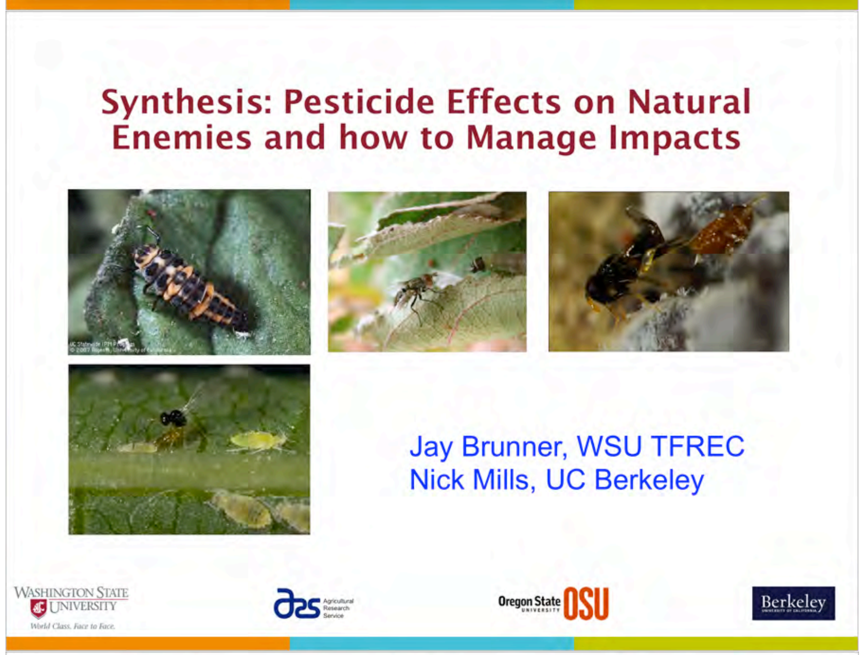



Notes:

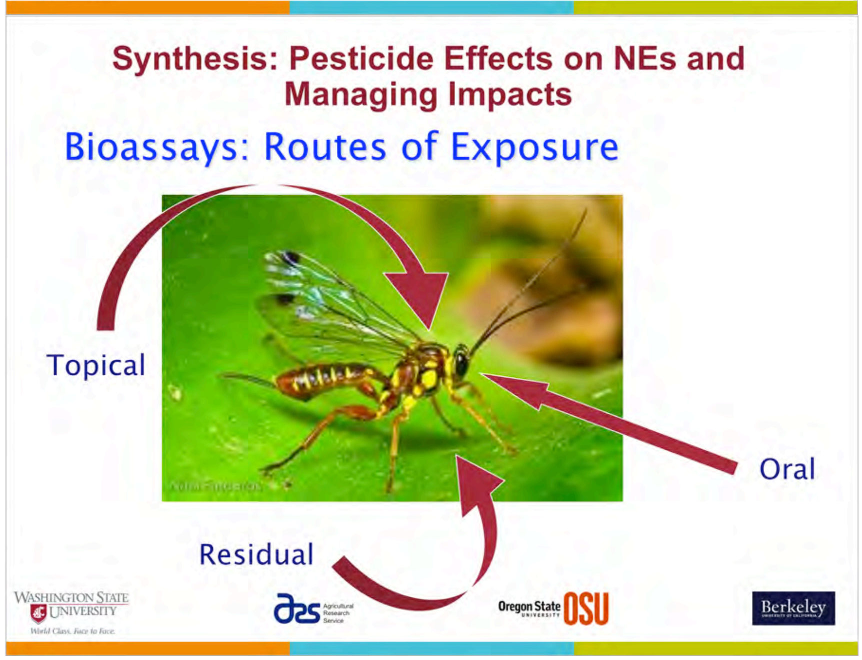
Notes:


*Presentation 4: Synthesis of Pesticide Effects*

Notes:




Notes:



## Extrapolation from Bioassays

Direct effects (acute toxicity)

- Conventional lab bioassays
- 48h mortality as endpoint measurement

Indirect effects (sub-lethal)

- Life table response experiments
- Life history parameters as endpoint measurements

Extrapolation

- Demographic matrix models
- Integrate endpoint measurements into a single index representing population growth rate (r)

Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

Pesticides tested

- Kumulus
- Kocide-Manzate
- Altacor
- Cyazypyr
- Delegate
- Rimon
- Warrior

Natural enemies tested

*Galendromus occidentalis*
*Chrysoperla carnea*
*Deraeocoris brevis*
*Hippodamia convergens*
*Aphelinus mali*
*Trioxys pallidus*
*Misumenops lepidus*
*Pelegrina aeneola*

Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

Natural enemies tested

| | |
|---|---|
| *Galendromus occidentalis* | **Predatory mite** |
| *Chrysoperla carnea*, *Deraeocoris brevis*, *Anthocoris nemoralis*, *Hippodamia convergens*, *Forficula auricularia* | **General predators** |
| *Aphelinus mali*, *Trioxys pallidus*, *Mastrus ridibundus*, *Colpoclypeus florus* | **Parasitic wasps** |
| *Misumenops lepidus*, *Pelegrina aeneola* | **Spiders** |

Notes:

Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

Replicated Field Trials

- GOAL
  - Validate results of laboratory bioassays
- Constraints
  - Requires large plots to see results
  - Limited number of treatments & scenarios
  - Unknown presence of NE
  - High degree of variability between replicates/sites
  - Variability between years at same site

Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

Summary of bioassay results on web site

### Pesticide Effects on Natural Enemies

Updated 1/15/2012

These data will be updated as data become available

| | |
|---|---|
| 0 (green) | < 25% acute mortaility or reduction in r |
| 1 (yellow) | 25 - 75% acute mortality or reduction in r |
| 2 (red) | > 75% acute mortality or reduction in r |

**This color key applied to all tables**

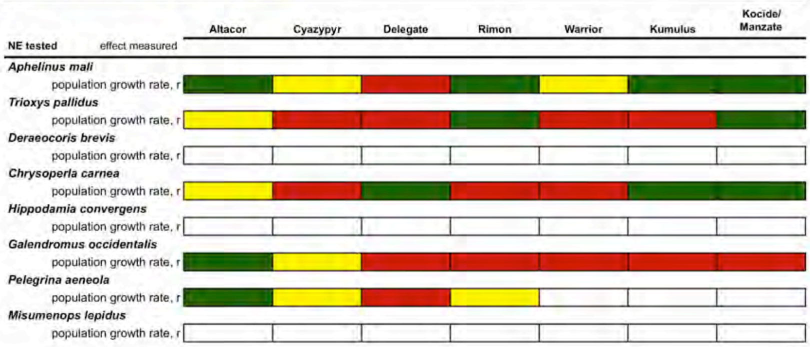
Notes:

Acute toxicity information

| NE tested / effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|
| ***Aphelinus mali*** | | | | | | | |
| acute mortality, adult parasitoid | yellow | yellow | red | yellow | yellow | green | green |
| ***Trioxys pallidus*** | | | | | | | |
| acute mortality, aphid host | yellow | red | red | green | red | red | green |
| acute mortality, adult parasitoid | green | red | red | green | red | yellow | green |
| ***Deraeocoris brevis*** | | | | | | | |
| acute mortality, nymph | green | green | green | red | red | green | green |
| acute mortality, adult | green | green | green | green | red | green | green |
| ***Chrysoperla carnea*** | | | | | | | |
| acute mortality, larva | green | green | green | green | yellow | green | green |
| acute mortality, adult | yellow | red | yellow | green | yellow | green | green |
| ***Hippodamia convergens*** | | | | | | | |
| acute mortality, larva | green | yellow | green | green | red | green | green |
| acute mortality, adult | green | green | green | green | red | green | green |
| ***Galendromus occidentalis*** | | | | | | | |
| acute mortality, immature | green | green | green | green | red | red | green |
| acute mortality, adult | green | green | red | yellow | red | green | yellow |
| ***Pelegrina aeneola*** | | | | | | | |
| acute mortality, immature | green | yellow | red | red | red | green | green |
| acute mortality, adult | green | yellow | red | yellow | | | |
| ***Misumenops lepidus*** | | | | | | | |
| acute mortality, immature | green | yellow | yellow | green | red | green | green |

## Synthesis: Pesticide Effects on NEs and Managing Impacts

### Population growth rate




WASHINGTON STATE UNIVERSITY

ARS Agricultural Research Service

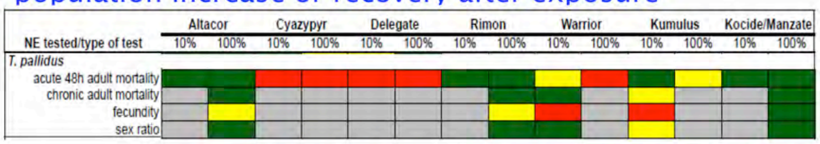
Oregon State OSU

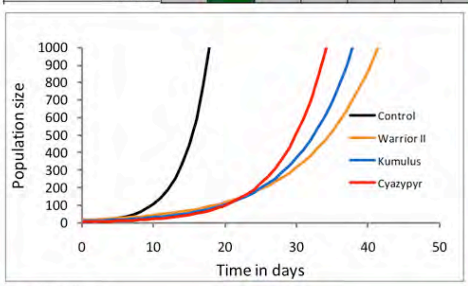
Berkeley

Notes:

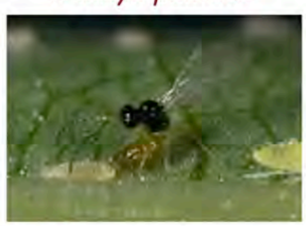
## Synthesis: Pesticide Effects on NEs and Managing Impacts

### Life table data provides a way to model the rate of population increase or recovery after exposure




*Trioxys pallidus*



WASHINGTON STATE UNIVERSITY

ARS Agricultural Research Service

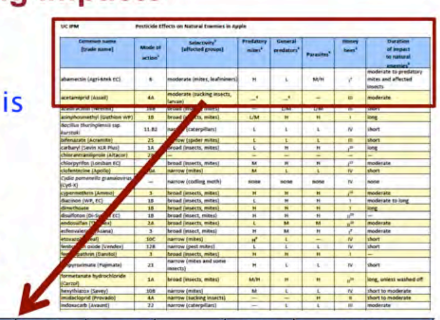
Oregon State OSU

Berkeley

Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

- Current method of presenting information is tabular or dynamically through DAS
- Synthesis of pesticide effects on shoulders of managers/consultants



| Common name (trade name) | Mode of action[1] | Selectivity[2] (affected groups) | Predatory mites[3] | General predators[4] | Parasites[4] | Honey bees[5] | Duration of impact to natural enemies[4] |
|---|---|---|---|---|---|---|---|
| abamectin (Agri-Mek EC) | 6 | moderate (mites, leafminers) | H | L | M/H | I[7] | moderate to predatory mites and affected insects |
| acetamiprid (Assail) | 4A | moderate (sucking insects, larvae) | —[8] | —[9] | — | III | moderate |
| azadirachtin (Neemix) | 18B | broad (insects, mites) | — | L/M | L/M | III | short |

WASHINGTON STATE UNIVERSITY

ARS Agricultural Research Service

Oregon State OSU

Berkeley

Notes:

Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

- Current method of presenting information is tabular or dynamically through DAS
- Synthesis of pesticide effects on shoulders of managers/consultants
- Current information has a lot of holes in it
- Is there a better way?

| Trade Name | Compound | WPM[2] | ARM[3] | *Colpoclypeus florus*[4] | *Pnigalio flavipes*[4] | *Aphelinus mali* | Coccinellids[4] | Lacewing |
|---|---|---|---|---|---|---|---|---|
| | | Relative impact rating[1] | | | | | | |
| Acramite 50WS | bifenazate | L | -- | -- | -- | -- | -- | -- |
| Actara 25WDG | thiamethoxam | L[8] | L[8] | -- | -- | -- | -- | -- |
| Agri-Mek 0.15EC | abamectin | H[6] | H[6] | M[6] | L | -- | M[6] | -- |
| Altacor 35WDG | chlorantraniliprole | L | -- | -- | -- | L[14] | -- | -- |
| Ambush 25WP | permethrin | H | L | M | -- | -- | -- | -- |
| Apollo 4SC | clofentezine | L | L | -- | -- | -- | -- | -- |
| Asana 0.66EC | esfenvalerate | H | L | M | M-H | -- | -- | L |
| Assail | acetamiprid | M-H[10] | L | H | -- | M-H[14] | -- | M |
| Avaunt 30DG | indoxacarb | L[9] | L[9] | -- | -- | -- | -- | -- |
| Aza-Direct 1.2%L | azadirachtin | -- | -- | L | -- | -- | L | -- |
| *Bacillus thuringiensis subsp. kurstaki* | | L | L | L | L | -- | L | -- |
| Calypso 4F | thiacloprid | 10 | L | -- | -- | M-H[14] | -- | -- |
| Carzol 92SP | formetanate hydrochloride | M-H | M-H | H | -- | -- | L | -- |
| Danitol 2.4EC | fenpropathrin | H | -- | -- | -- | -- | -- | -- |
| Delegate 25WG | spinetoram | M-H[13] | -- | -- | -- | H[14] | -- | -- |
| Diazinon | diazinon | L | L | H | -- | -- | H | -- |
| Dimethoate | dimethoate | L-M | L | H | -- | -- | H | -- |
| Dimilin 2L | diflubenzuron | -- | -- | H | -- | -- | L | -- |
| Esteem 35WP | pyriproxyfen | -- | -- | M | -- | -- | -- | L |
| FujiMite 5%EC | fenpyroximate | -- | M | -- | -- | -- | -- | -- |
| Guthion 50WP | azinphos methyl | L | L | H | L | H[14] | H | -- |
| Imidan 70W | phosmet | L | L | H | L | -- | H | L |
| Intrepid 2F | methoxyfenozide | L | L | L | L | -- | -- | L |
| Lannate | methomyl | H | L | -- | -- | -- | -- | -- |
| Lorsban | chlorpyrifos | L-M | L | H | H | H[14] | H | L |
| M-Pede | potassium salts of fatty acids | M[6] | M[6] | -- | -- | -- | L | L |
| Nexter 75WSB | pyridaben | M | H | M-H | -- | -- | -- | -- |
| petroleum oil-summer | | M[6,7] | L[6] | L | L | -- | -- | -- |
| Pounce 3.2EC | permethrin | H | L | M | -- | -- | -- | -- |
| Proganic Micronized Sulfur 92% | sulfur, wettable | M | -- | -- | -- | L[14] | -- | -- |
| Provado | imidacloprid | L[8] | L[8] | M-H[6] | -- | -- | M | M-H |
| Rex Lime Sulfur | lime sulfur/calcium polysulfide | M-H | H | -- | -- | -- | -- | -- |
| Rimon 0.83EC | novaluron | M-H[10] | -- | 11 | -- | M[14] | -- | 12 |
| Savey 50DF | hexythiazox | L | L | -- | -- | -- | -- | -- |
| Sevin | carbaryl | M-H | L-M | H | L | H[14] | H | L |
| Success 2F | spinosad | M | -- | M-H | H | -- | L | L |
| Surround WP | kaolin clay | M-H | -- | -- | M | -- | M-H[5] | -- |
| Thionex | endosulfan | L | M-H | M | M | -- | M-H | L |
| Ultor 1.25L | spirotetramat | L | -- | -- | -- | L[14] | -- | -- |
| Vendex 50WP | fenbutatin oxide | M | H | L | -- | -- | L | -- |
| Vydate 2L | oxamyl | M-H | -- | H | L-M | -- | M | L |

Washington State University World Class. Face to Face.

ARS Agricultural Research Service

Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

Can we develop an index to ***predict the RISK of*** disruption of natural enemies?

It might be possible, for example

Develop a *disruption risk value* (DRV) for products

DRV could be an index between 0.0 and 1.0

e.g. ***Product A*** has a DRV of 0.8 while ***Product B*** DRV is 0.2.

Accumulate DRV values over the season

As the accumulated *DVR value increases* the risk (likelihood) of disruption increases

The likelihood increases for additional pesticide applications for secondary pests

Washington State University World Class. Face to Face.

ARS Agricultural Research Service

Oregon State University OSU

Berkeley University of California

Notes:

| NE tested | effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|---|
| ***Aphelinus mali*** | | | | | | | | |
| | acute mortality, adult parasitoid | 1 | 1 | 2 | 1 | 1 | 0 | 0 |
| | population growth rate, r | 0 | 1 | 2 | 1 | 1 | 0 | 0 |
| ***Trioxys pallidus*** | | | | | | | | |
| | acute mortality, aphid host | 1 | 2 | 2 | 0 | 2 | 2 | 0 |
| | acute mortality, adult parasitoid | 0 | 2 | 2 | 0 | 2 | 1 | 0 |
| | population growth rate, r | 1 | 2 | 2 | 0 | 2 | 2 | 0 |
| ***Deraeocoris brevis*** | | | | | | | | |
| | acute mortality, nymph | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| | acute mortality, adult | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | population growth rate, r | | | | | | 0 | 0 |
| ***Chrysoperla carnea*** | | | | | | | | |
| | acute mortality, larva | 0 | 0 | 0 | 0 | 1 | | |
| | acute mortality, adult | 1 | 2 | 1 | 0 | 1 | | |
| | population growth rate, r | 1 | 2 | 0 | 1 | 1 | 0 | 0 |
| ***Hippodamia convergens*** | | | | | | | | |
| | acute mortality, larva | 0 | 1 | 0 | 0 | 2 | 0 | 0 |
| | acute mortality, adult | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | population growth rate, r | | | | | | | |
| ***Galendromus occidentalis*** | | | | | | | | |
| | acute mortality, immature | 0 | 0 | 0 | 0 | 2 | 2 | 0 |

Here I have assigned these values to an effect:

- '0' for effects <25% on NE (**GREEN**),
- '1' for effects between 25% and 75% (**YELLOW**)
- and '2' for effects >75% (**RED**).

| NE tested | effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|---|
| *Aphelinus mali* | | | | | | | | |
| | acute mortality, adult parasitoid | 1 | 1 | 2 | 1 | 1 | 0 | 0 |
| | population growth rate, r | 0 | 1 | 2 | 0 | 1 | 0 | 0 |
| *Trioxys pallidus* | | | | | | | | |
| | acute mortality, aphid host | 1 | 2 | 2 | 0 | 2 | 2 | 0 |
| | acute mortality, adult parasitoid | 0 | 2 | 2 | 0 | 2 | 1 | 0 |
| | population growth rate, r | 1 | 2 | 2 | 0 | 2 | 2 | 0 |
| *Deraeocoris brevis* | | | | | | | | |
| | acute mortality, nymph | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| | acute mortality, adult | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | population growth rate, r | | | | | | | |
| *Chrysoperla carnea* | | | | | | | | |
| | acute mortality, larva | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | acute mortality, adult | 1 | 2 | | | | | 0 |
| | population growth rate, r | 1 | 2 | | | | | 0 |
| *Hippodamia convergens* | | | | | | | | |
| | acute mortality, larva | 0 | | | | | | 0 |
| | acute mortality, adult | 0 | 0 | | | | | 0 |
| | population growth rate, r | | | | | | | |
| *Galendromus occidentalis* | | | | | | | | |
| | acute mortality, immature | 0 | 0 | | | | | 0 |
| | acute mortality, adult | 0 | 0 | | | | | 1 |
| | population growth rate, r | 0 | 0 | | | | | 2 |
| *Pelegrina aeneola* | | | | | | | | |
| | acute mortality, immature | 0 | 1 | 2 | 2 | 2 | 0 | 0 |
| | acute mortality, adult | 0 | 1 | 2 | 1 | | | |
| | population growth rate, r | 0 | 1 | 2 | 1 | | | |
| *Misumenops lepidus* | | | | | | | | |
| | acute mortality, immature | 0 | 1 | 1 | 0 | 2 | 0 | 0 |

We can then take an average across all categories for a single chemical, or

For an average across a group of NEs, like parasitoids

Notes:

Since the highest average value assigned would be '2' we can divide the average value for a category by 2 and get an index between 0 and 1.

For example,

Delegate average for predatory mites = 1.33

1.33 / 2 = *0.67* as a DRV index value

Below are examples using our data to calculate an index value for each pesticide effect on NEs.

| NE tested | effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|---|
| | Total accum effect | 0.13 | 0.45 | 0.58 | 0.32 | 0.88 | 0.26 | 0.09 |
| | Total effect on pop. growth rate | 0.20 | 0.60 | 0.80 | 0.50 | 0.70 | 0.40 | 0.20 |
| | Acute effects | 0.11 | 0.39 | 0.50 | 0.25 | 0.82 | 0.18 | 0.04 |

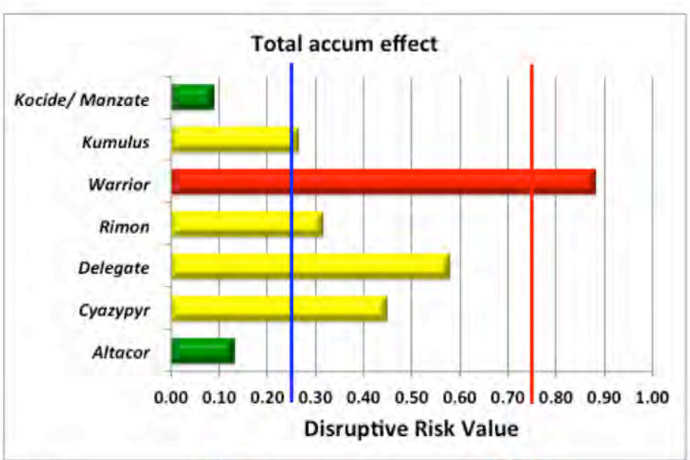
| NE tested | effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|---|
| | effect on parasitoids | 0.30 | 0.80 | 1.00 | 0.10 | 0.80 | 0.50 | 0.00 |
| | effect on predators | 0.11 | 0.28 | 0.06 | 0.22 | 0.67 | 0.00 | 0.00 |
| | predatory mites | 0.00 | 0.00 | 0.67 | 0.50 | 1.00 | 0.67 | 0.50 |
| | spiders | 0.00 | 0.50 | 0.88 | 0.50 | 0.50 | 0.00 | 0.00 |

If we examine these data graphically it is easier to see the relationships between pesticides and effects on NEs.

Washington State University | ARS Agricultural Research Service | Oregon State University OSU | Berkeley

Notes:

| NE tested | effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|---|
| | Total accum effect | 0.13 | 0.45 | 0.58 | 0.32 | 0.88 | 0.26 | 0.09 |

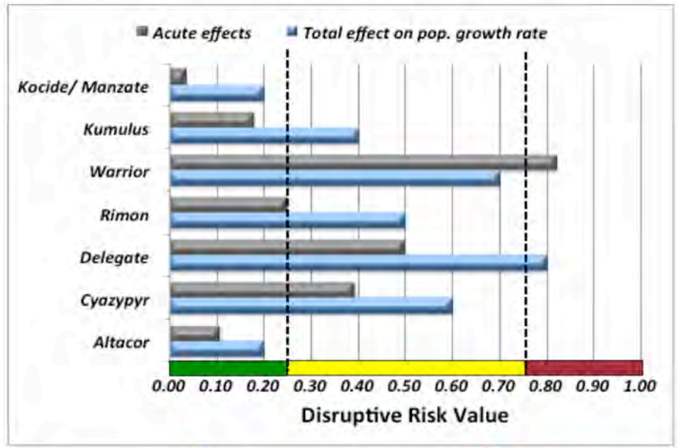



Washington State University | ARS Agricultural Research Service | Oregon State University OSU | Berkeley

Notes:

Notes:

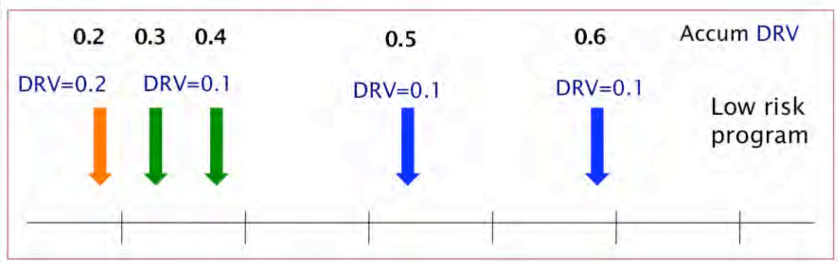
| NE tested effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|
| Total accum effect | 0.13 | 0.45 | 0.58 | 0.32 | 0.88 | 0.26 | 0.09 |
| Total effect on pop. growth rate | 0.20 | 0.60 | 0.80 | 0.50 | 0.70 | 0.40 | 0.20 |
| Acute effects | 0.11 | 0.39 | 0.50 | 0.25 | 0.82 | 0.18 | 0.04 |




Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

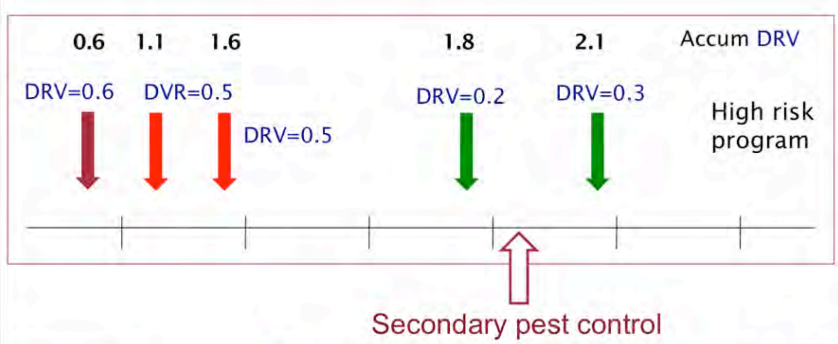
A hypothetical example of how the DRV concept could work for growers/consultants.




Notes:

## Synthesis: Pesticide Effects on NEs and Managing Impacts

A hypothetical example of how the DRV concept could work for growers/consultants.



## Synthesis: Pesticide Effects on NEs and Managing Impacts

### Factors impacting effects of pesticides on NE

1. Toxicity – products have different impact
2. Exposure – duration of residue
3. Rate – dose makes the poison
4. Timing – life history of NE (models)
5. Frequency – number of applications

Notes:

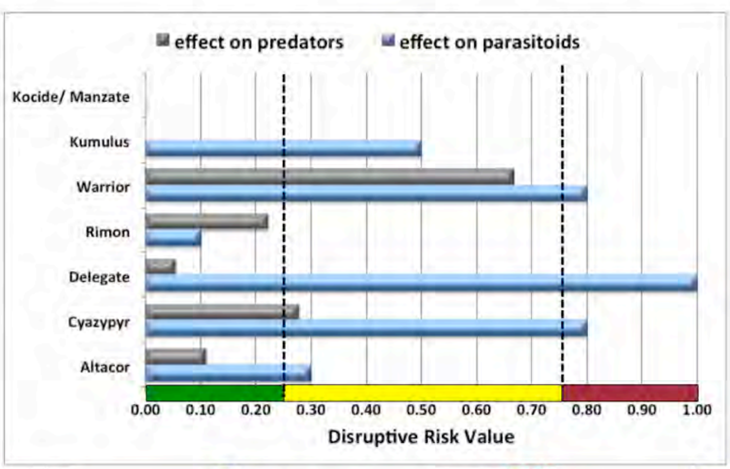
## Synthesis: Pesticide Effects on NEs and Managing Impacts

### Mitigating negative effects of pesticides on NE

1. Toxicity – choice of products - identify the *NE being protected*
2. Exposure – short duration better *(need more information in this area)*
3. Rate – reduce rates where possible
4. Timing – apply higher risk products at times when NE not present
5. Frequency – avoid using disruptive products multiple times

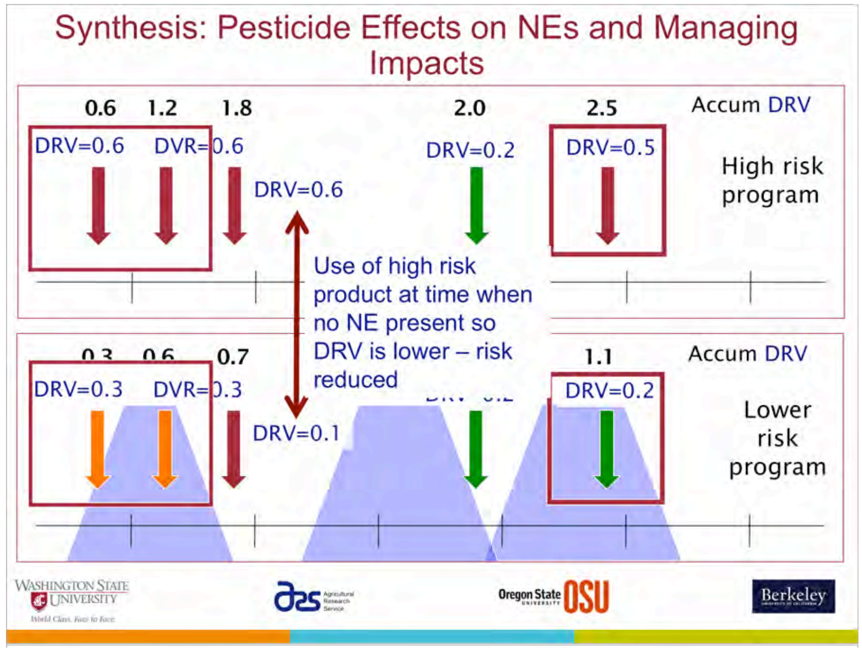
Notes:

| NE tested | effect measured | Altacor | Cyazypyr | Delegate | Rimon | Warrior | Kumulus | Kocide/ Manzate |
|---|---|---|---|---|---|---|---|---|
| | effect on parasitoids | 0.30 | 0.80 | 1.00 | 0.10 | 0.80 | 0.50 | 0.00 |
| | effect on predators | 0.11 | 0.28 | 0.06 | 0.22 | 0.67 | 0.00 | 0.00 |




Notes:

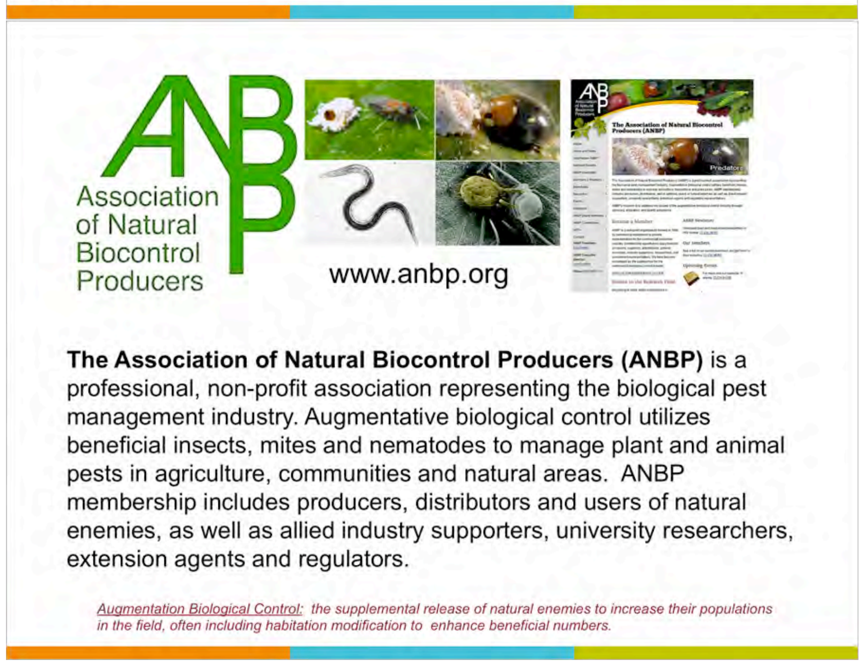
Notes:




*Presentation 5: Using Commercially Available Natural Enemies for Biological Control*

Notes:


Notes:



## Presentation Overview

- What questions to ask before getting started and where to find those answers
- What types of beneficial insects and mites are currently available for western orchard crop pests.
- Key points to locating, ordering, handling, evaluating, and releasing natural enemies to optimize biological control.

Notes:

## Getting Started
## Ask the right questions - Find the answers

- Evaluate your pest situation – is biological control an option? Know your pest and it's biology.
- Is an effective natural enemy *available* commercially that will work in your system?
- How do I find a supplier?
- Ordering online or via the phone is easy, but how many beneficials do I order? Should I order more than one species?
- How are they shipped?
- How do I handle and determine when to release products?
- Are they compatible with pesticides? If so, which ones?
- *Who* can help me successfully use these natural enemies and how can I determine if they are working?

Notes:

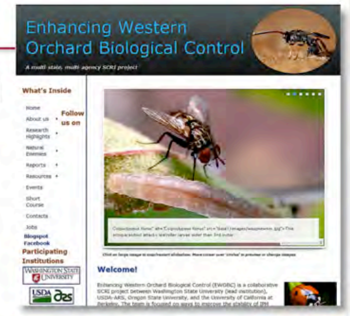
## *Ask the right questions - Find the answers*

- How does temperature, humidity, or sunlight affect these live products?
- Does foliage density or distribution dictate how I should apply natural enemies?
- Do I start with a low or high pest density for this natural enemy to work effectively? Must a pest be knocked down first?
  ✓Release timing is critical!
- Will irrigation affect their success?

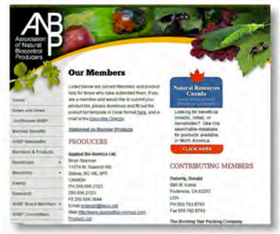
Notes:

Notes:

## Consult All Sources




- WSU, OSU, UC Biological Control Specialists and Researchers
- Farm Advisors
- USDA
- WSU, UC-IPM and many other reputable websites
- Professional crop consultants
- Commercial Insectaries




Notes:


## Consult All Sources

- WSU, OSU, UC Biological Control Specialists and Researchers
- Farm Advisors
- USDA
- WSU, UC-IPM and many other reputable websites
- Professional crop consultants
- Commercial Insectaries



- **Biology of the pest**
- **Biology of the natural enemy**
- **All environmental parameters**
- **Cost of production**

***More…***

Notes:

## Questions for a commercial insectary/supplier

★ *Know your supplier – communication is key!*

- Do they provide consulting services to set up a program prior to selling you beneficials? Some do!
- Are they cost effective for my system?
- Can they recommend a local consultant to help you if needed?

- Can they send written material in advance, or direct you to web-based information on how to prepare for beneficial use and release?
- Do they ship overnight in insulated containers?
- How are the natural enemies packaged?
- What is the company policy on product that arrives late? And, how will I evaluate quality (if applicable)?

## *First Questions…*

- Evaluate your pest situation – is biological control an option?
- Is an effective natural enemy *available* commercially that will work in your system?
- How do I find a supplier? Do they need to be nearby?


***Insect Producer Database***

*…listing of producers who sell live insects, mites or nematodes.*


Notes:


Notes:

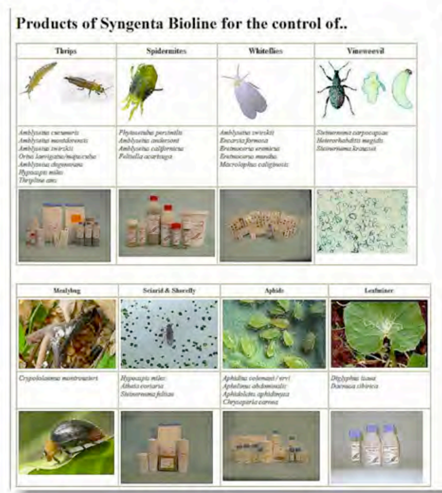

Notes:

Notes:


Notes:

Most insectary websites will have a complete description of their products including Factsheets.

- Pest species they target
- How they are shipped
- How long to hold them and under what conditions
- Pesticide avoidance issues
- How many per unit/cost
- How often to apply (multiple shipment programs)
- How to evaluate quality
- Encourage you strongly to contact them with any quality issues asap!




Notes:

## Shipments arrive via private air/ overnight services

- Tracking numbers via email have been a tremendous help to anticipating package delivery.
- Insectaries will have required permits – should not ship otherwise.
- Many companies these days are also distributors, so they may not be actually be *producing* – the Canadian database lists only producers

- Packages held up or delivered to the wrong address, especially during hot summer months, need special attention. Contact the insectary and delivery companies immediately.

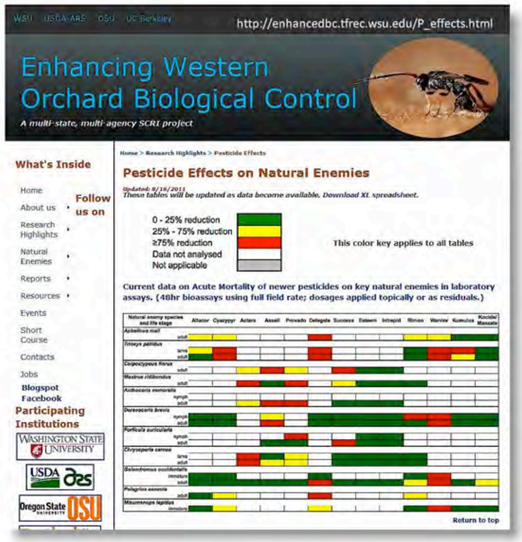
***Galendromus occidentalis*** **are sent direct from the Insectary Next Day Air. ALL ORDERS MUST BE RECEIVED BY NOON (MT. TIME) THURSDAY TO SHIP THE FOLLOWING WEEK**

**Spider mite Predators are very sensitive to heat in shipping**
**During High Temperature Months (May - August)**
**Next Day Air ONLY!!**

Pesticide effects on natural enemies can be found at the WSU site.

Acute mortality and sublethal effects are being documented in lab assays.

Natural enemies need a *clean tree* to optimize survival.

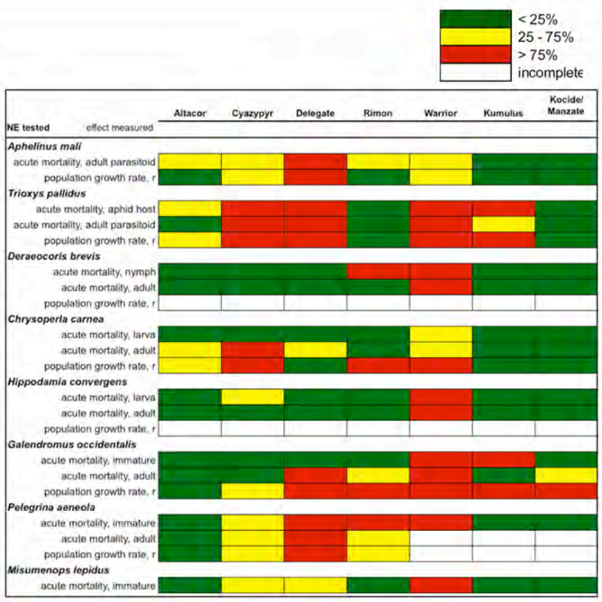



Notes:

Pesticide effects on natural enemies can be found at the WSU site.

Acute mortality and sublethal effects are being documented in lab assays.

Natural enemies need a *clean tree* to optimize survival.

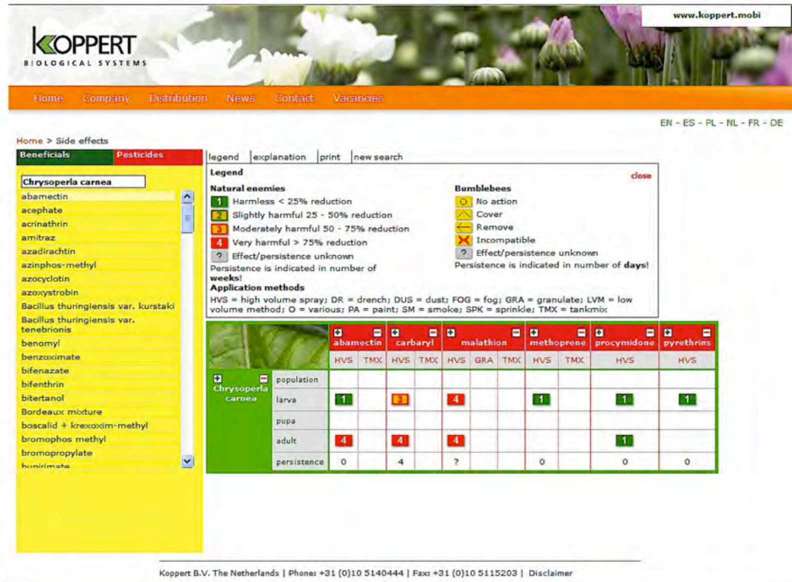



Notes:

Some insectaries will have pesticide compatibility information on their websites


Notes:

Notes:




Notes:

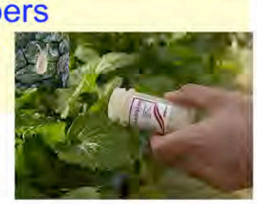
## What about Quality Control?

Producer wants to…

- Ensure that regular and effective Quality Control procedures are in place
- Develop dating system or at least a confidential batch date system
- Constantly evaluate culture for negative characteristics
- Regularly challenge culture for promised traits (e.g. Non-diapausing)
- Ensure packaging is effective
- Usually includes 10-25% more product in package to allow for deaths due to shipping/handling.

*The Producer wants to ensure:*

- Correct species
- Sex ratio
- Viability
- Fecundity
- Fitness
- Numbers
- Purity



Notes:

## What about Quality Control?

Producer wants to…

- Ensure that regular and effective Quality Control procedures are in place
- Develop dating system or at least a confidential batch date system
- Constantly evaluate culture for negative characteristics
- Regularly challenge culture for promised traits (e.g. Non-diapausing)
- Ensure packaging is effective
- Usually includes 10-25% more product in package to allow for deaths due to shipping/handling.

Grower

- Buy from a reputable distributor
- Immediately open the shipping package
- Inspect products immediately
- Apply products as soon as possible
- Immediately inform supplier of any concerns or problems
- Monitor the development in the crop


Notes:

## How to communicate with your supplier for optimizing shipment quality

- Keep good written records; date shipment received, dates or lot numbers on packages.
- Call the supplier immediately to report a problem!
- Low count numbers or high numbers of dead individuals are unacceptable.
- Complain about consistently low counts.
- Suppliers should give you information on how to sample your shipment.

Notes:

## What types of beneficial insects and mites are currently available for Northwestern orchard crop pests?

| | | |
|---|---|---|
| | *Adalia bipunctata* Coccinellid beetle | Aphids |
| | *Coccinella septempunctata* Coccinellid beetle | aphids |
| | *Cryptolaemus montrouzieri* Coccinellid beetle | Mealybugs |
| ✓ | *Hippodamia convergens* Coccinellid beetle | aphids |
| | *Aphidoletes aphidimyza* Cecidomyiid (midge) | Aphids |
| ✓ | *Chrysoperla carnea* Green lacewing | Aphids, mealybugs |
| ✓ | *Chrysoperla rufilabris* Green lacewing | Aphids, mealybugs |
| | *Macromus veriagatus* Brown lacewing | Aphids, mealybugs |
| ✓ | *Anthocoris nemoralis* Predatory bug | Pear psyllid |

Note: *Chrysopa nigricornis* and *C. plorabunda*, are not commercially available. Why not?

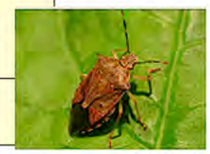
Notes:

Notes:

A number of other predators may be suggested for spider mites, caterpillars, and other pests, but again, they may not be appropriate for your field conditions.

| | |
|---|---|
| *Feltiella acarisuga*<br>Predatory midge | Spider mites |
| *Aphidoletes aphidimiza*<br>Predatory midge | Aphids, pysllids |
| *Stethorus punctillum*<br>Coccinellid beetle | Spider mites |
| *Orius insidiosus*<br>Minute pirate bug | Spider mites, aphids, thrips, scale crawlers, psyllids |
| *Podisus maculiventris*<br>Spined solider beetle | Caterpillars |

*Aphidoletes*



*Podisus*

Notes:

**Parasitoids available – that might *seem* applicable**

| | |
|---|---|
| *Aphelinus abdominalis* | Aphids |
| *Aphidius colemani* | Aphids |
| *Aphidius ervi* | Aphids |
| | |
| | |
| *Trichogramma minutum* | Caterpillars |
| *Trichogramma ostriniae* | Caterpillars |
| *Trichogramma platneri* | Caterpillars |
| *Trichogramma pretiosum* | Caterpillars |
| *Trichogramma minutum* | Caterpillars |

Notes:

Predatory mites represent the highest volume of sales in the commercial insectary industry today.

- Species are available for many different agricultural situations.
- Easily mass-produced, generalist predators of small, soft-bodied pests.

| | | |
|---|---|---|
| | *Amblyseius andersoni* | Spider mites, eriophyid mites |
| | *Amblyseius degenerans* | Spider mites, thrips |
| | *Amblyseius swirskii* | Whitefly, thrips |
| ✓ | *Galendromus (Metaseiulus) occidentalis* | Spider mites, eriophyid mites |
| | *Hypoaspis aculeifer* | Thrips, bulb mite, fungus gnats |
| | *Hyposapis miles* | Fungus gnat, thrips |
| | *Mesoseilus longipes* | Spider mites |
| | *Neoseiulus californicus* | Spider mites, Persea mite, eriophyid mites |
| | *Neoseiulus cucumeris* | Thrips |
| | *Neoseiulus fallacis* | Spider mites |
| | *Phytoseiulus persimilis* | Spider mites |

## Predatory Mites *Example*

**Western predatory mite**
*Galendromus occidentalis*
*(=Typhlodromus occidentalis)*

Suppliers: 4

Shipping

- Shipped as adults in vials with a carrier, or on cut bean leaves in bags with a very low level of two-spotted spider mites to prevent starvation for predatory females.

Shipment Quality

- Bring package to room temp. Adults should be active. Need to assess with a hand lens.

Notes:

## Predatory Mites *Example*

**Western predatory mite**
*Galendromus occidentalis*
*(=Typhlodromus occidentalis)*

Release methods/Issues

- Mites numbers can explode in the field. Many crops benefit from predatory mite releases when the conditions for mites occurs – getting predators out early can help. When the pest mite population has exploded, it may be too late.
- Release rates range from 2,000 – 5,000/acre in orchards (early release rates). Later release rates require much higher numbers.
- Apply immediately, but can be stored up to 5 days at 45-50 F.
- Likes warmer temperatures and tolerates low humidity.

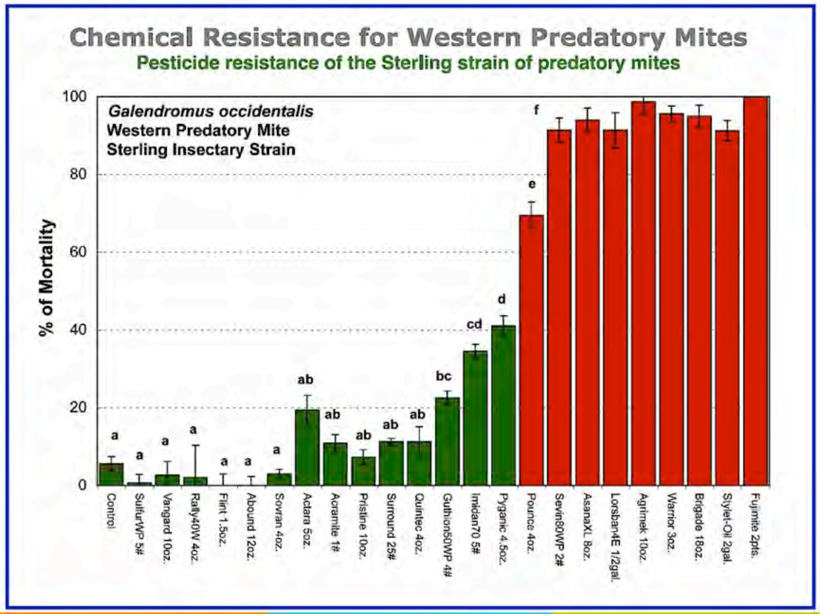
Notes:

## Release methods/Issues

- Bean leaf releases may be preferable in some crops where carriers (corn grit or vermiculite) might easily fall to the ground.
- Biobest (example): one flat or bouquet of cut bean plants = 10,000 predators on 250 plants. Spread bean plants throughout crop at desired rate. To release from bottles, gently rotate bottle evenly to mix contents and sprinkle on foliage (do not shake!).
- Avoid pesticides one week before application to one week afterwards!
- A pesticide resistant strain is available.

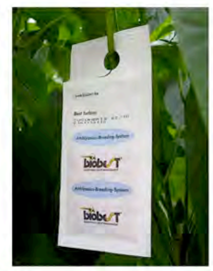

Notes:

Notes:




Notes:

Many novel methods for applying predatory mites are being constantly developed – most for protected crops.



Koppert Biological has an "airbug"- a hand-held blower that distributes predatory mites quickly and evenly.



Biobest's "breeding system: sachets release *A. cucumeris* and contain starter predators, host mites, and proprietary components.

Notes:

## Lady Beetles *Example*


***Hippodamia convergens***

*(a native beetle, found throughout N.A.)*

Suppliers: 4 "producers"
(many suppliers – issues)

Shipping
- Shipped as adults in containers with packing material.

Shipment Quality
- Adults should be active once they are brought to room temp.
- Purchasing from suppliers vs. buying at a big box retail store may insure a fresher product. Why?

## Lady Beetles *Example*

***Hippodamia convergens***

*(a native beetle, found throughout N.A.)*

### Release methods/Issues

- Release adults as soon as possible. Large quantities needed and release on infested plants. If they must be held, a light misting of water (not puddling) may help. Repeat weekly and cull dead beetles.
- *Hippodamia* are collected as adults at overwintering sites. They tend to disperse once they are released. But, ideally, they should be "pre-conditione" to lay eggs first to get a population going. Voracious, active feeders once established.
- Avoid pesticides on trees!

Notes:

## Green Lacewings *Example*

***Chrysoperla rufilabris***

### Suppliers: 5

### Shipping

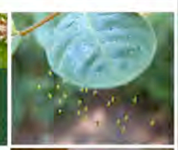
- All stages can be shipped (eggs, larvae, pupae, adults)
- Eggs: overnight in cold packs. Will be 48-72 h old upon arrival.
- Larvae: sold in bottles or rearing frames that keep them separated.
- Pupae: in rearing frames
- Adults: in card board tubes or containers.

### Shipment Quality

- Adults and larvae should be active.
- Eggs should be creamy in color – a few may be bright green (unviable), but eggs should start turning yellow – grey as they get closer to hatching.

Notes:

## Green Lacewings *Example*



***Chrysoperla rufilabris***

### Release methods/Issues

- Release adults as soon as possible (no later than 24 h).
  Never refrigerate them; eggs on cards can be hung on trees.
- Do not refrigerate pupae. Hold for 3-5 days for emergence.
- Larval frames have a limited food supply, so use as soon as possible. Bottles of larvae are for immediate release!
- Releases should be made when the pest is at a manageable level.

Notes:

Notes:

## Factsheets for each stage available.

- Eggs may also be applied via mechanized liquid applicators.

### Optimizing Applications of *Chrysoperla rufilabris* Eggs.

**Improving methods for Better Pest Management by providing practical and applicable information to our cu**

**Introduction**

Beneficial Insectary's modem insect rearing methods provide healthy egg, larval, and adult stages of *Chrysoperla rufilabris* (green lacewing) for n biological control programs. We provide large quantities of each stage that are packaged according to your needs. Our shipping procedures ens of viable insects.

To advance Better Pest Management, we strive to provide applicable and practical technical information to our customers. We encourage t information to improve efficacy in the use of our products.

The purchase of *Chrysoperla rufilabris* eggs and the delivery of the egg stage of this effective predator is inc with *Chrysoperla* egg releases on a variety of pest species, including the grape leafhopper in California, the groves.

Figure 1

As new release methods for *Chrysoperla rufilabris* are developed, we will provide assistance to our custome products that achieve Better Pest Management at least cost.

***Chrysoperla rufilabris*** A green lacewing.

The following recommendations, along with easily recognizable biological and physical clues, are designed to assist customers in the effectiv most optimally developed *Chrysoperla* eggs to the target pest.

Beneficial Insectary rears *Chrysoperla* in age cohorts of 0-24 hours old. There are peaks of oviposition in *Chrysoperla* culture; therefore, most produced within a 12-15 hour period. Consequently, hatching or larval eclosion also peaks within this more narrow time frame. *Chrysoperla* eggs a prepared for shipment in a process that requires 36 hours. Eggs shipped to customers are therefore 36-60 hours old. Eggs, shipped overnig containers, range from about 48-72 hours old upon arrival.

Very large orders may require that several days of egg harvest be combined. In these cases, harvested eggs are held at the insectary, unde temperatures, until sufficient quantities for shipment are processed. This careful cooling process allows for aggregated development of the combin thus nearly all eggs in a group shipped to a customer will hatch within 24 hours of each other. Final hatch of eggs depends upon temperature, hu of egg development at the time of receipt and/or release.

Beneficial Insectary, Redding, CA

Notes:

## Factsheets for each stage available.

- Eggs may also be applied via mechanized liquid applicators.

### Optimizing Applications of *Chrysoperla rufilabris* Eggs.

**Improving methods for Better Pest Management by providing practical and applicable information to our cu**

**Introduction**

Beneficial Insectary's modem insect rearing methods provide healthy egg, larval, and adult stages of *Chrysoperla rufilabris* (green lacewing) for n biological control programs. We provide large quantities of each stage that are packaged according to your needs. Our shipping procedures ens of viable insects.

To advance Better Pest Management, we strive to provide applicable and practical technical information to our customers. We encourage t information to improve efficacy in the use of our products.

The purchase of *Chrysoperla rufilabris* eggs and the delivery of the egg stage of this effective predator is inc with *Chrysoperla* egg releases on a variety of pest species, including the grape leafhopper in California, the groves.

Figure 1

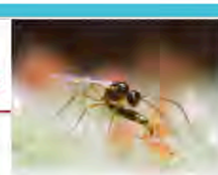
As new release methods for *Chrysoperla rufilabris* are developed, we will provide assistance to our custome products that achieve Better Pest Management at least cost.

***Chrysoperla rufilabris*** A green lacewing.

| Organism | Quantity | Price |
|---|---|---|
| *Chrysoperla rufilabris* **eggs** | | |
| Hanging egg card / 5,000 per card | 5,000 | $17.50 each |
| Eggs with food and carrier material | 10,000 | $29.88 |
| *Chrysoperla rufilabris* **larvae** | | |
| 1 bottle contains 1,000 crawlers plus food source | 1 bottle | $25.75 each |
| | 2 or more | $17.50 each |
| *Chrysoperla rufilabris* **adults** | Bucket with 100 adults | $33.50 |
| | Bucket with 250 adults | $62.50 |

Notes:

## Aphid parasitoids



***Aphidius colemani***
***Aphidius ervi***
***Aphidius matricariae***

Suppliers: 7

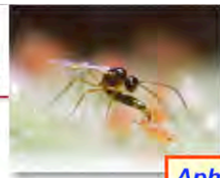
### Shipping

- Shipped either as adults in vials with a food source, or as pupae (aphid mummies).

### Shipment Quality

- Adults should be active and flying – not stuck to inside of container moisture.
- After adults emerge, mummies with holes can be counted to determine percent emergence.
- Smaller exit holes in mummies may indicate the presence of hyperparasites which are harmful and can impair your biological control program.

## Aphid parasitoids



***Aphidius colemani***
***Aphidius ervi***
***Aphidius matricariae***

Release methods/Issues

- Release adults as soon as possible. Hold mummies for 10-14 days until have emerged.

***Aphid parasites may be effective biocontrol agents in your orchard, but the appropriate species may not be commercially available!***

Notes:

## *Trichogramma* spp. (egg parasitoid)

***Trichogramma* species**
***Trichogramma brassicae***
***Trichogramma minutum***
****Trichogramma platneri (release west of the Rockies?)***
***Trichogramma pretiosum***

Suppliers: 4

Shipping

- Parasitized moth (previously-frozen *Ephestia*) eggs
- Eggs glued to cards that can be hung on trees; each card may contain several thousand parasitized eggs
- Eggs can be shipped loose in "shakers"
- Adult *Trichogramma* wasps begin to emerge within 2-3 days at 68-90º F.

Shipment Quality

- Correct species will be difficult to determine since the wasp is so small. Professional help would be needed.

Notes:

## *Trichogramma* spp. (egg parasitoid)

***Trichogramma* species**
***Trichogramma brassicae***
***Trichogramma minutum***
****Trichogramma platneri (release west of the Rockies?)***
***Trichogramma pretiosum***

Suppliers: 4

Shipping

- Parasitized moth (previously-frozen *Ephestia*) eggs
- Eggs glued to cards that can be hung on trees; each card may contain several thousand parasitized eggs
- Eggs can be shipped loose in "shakers"
- Adult *Trichogramma* was
68-90º F.

Shipment Quality

- Correct species will be di
small. Professional help v

| Product | Quantity | Price |
|---|---|---|
| *Trichogramma pretiosum, brassicae, platneri* | 1 card | $24.72 |
| 1 card = 100,000 | 2 or more cards | $17.50 each |

Notes:

Notes:

## *Trichogramma* spp.

Release methods/Issues

- Species selection critical
- Release may vary considerably, depending on the target caterpillar species, their density, the crop habitat, and the cultural practices in use.
- Place in orchard when pheromone traps or other methods indicate the presence of pest eggs.
- Use immediately upon receipt. Multiple shipments/releases may be necessary. Suspend cards out of direct sunlight (early morning/ evening).
- Do not touch eggs.
- Leave cards in place at least 7 days to allow emergence.
- The adult wasps live anywhere from 7 to 14 days, depending on temperature and moisture.
- Example from one company: 1 square/300 sq. ft. or 1 square/tree in orchards; 1/2 to 2 cards/acre weekly for 2-6 weeks. Each square on the card contains approx. 2,400 *Trichogramma* eggs.

Notes:

## Summary
### *Handing Commercial Natural Enemies*

- **Open the shipment** immediately and **inspect the contents** for freshness and living insects or mites. **Report any problems** to the supplier right away (dead product, fewer individuals than anticipated). Feedback is always encouraged!
- **Read all instructions** on holding and releasing the organisms and follow them. If the product can be held for a few days before release, make sure containers are held at the correct temperature and the insects/mites are provided with water/food if recommended.
- During **transportation to the field**, continue to hold the package in **correct temperatures.**
- **Follow all release recommendations**. Usually release directly on infected plants.

Notes:

## Overall Summary

✓ **Know your system**; get the right species to control your pest and learn everything possible about how to handle and release it. Consult all professional sources.

✓ **Release timing is crucial**. Knowledge of pest population dynamics is essential.

✓ **Natural enemies need a clean tree**. Pesticide residues from distant application can still impact predators and parasites.

✓ **Coordinate and communicate with your (reputable) supplier**. Provide feedback if quality or quantity is not what you are paying for. Producers and distributors need (and want) to know of any problems.

Washington State University | ars Agricultural Research Service | Oregon State University OSU | Berkeley

*Presentation 6: Conservation Biological Control through Habitat Modifications*


Notes:

## Conservation biological control

1. Provide alternate habitats for overwintering or off-season NEs
2. Provide alternate hosts or prey
3. Reduce practices cultural practices that disrupt BC agents (dust abatement)
4. Improved pesticide practices to minimize disruption of BC agents

Washington State University | ars | Oregon State OSU | Berkeley

Notes:

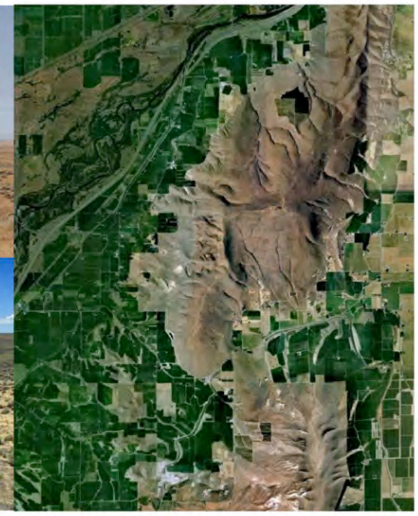
## California Oak Savanna

One of many non-agricultural habitats that may provide ecosystems services to crops.

Notes:

Notes:

## Central WA Shrub-Steppe



Notes:

## Riparian areas yield abundant ecosystem services

Willow psyllid on riparian willows support the psylla predator *Anthocoris antevolens* which can move into adjacent orchards

The parasitic wasp *Colpoclypeus florus* in roses in riparian habitats can move into orchards to parasitize leafrollers in spring

Notes:

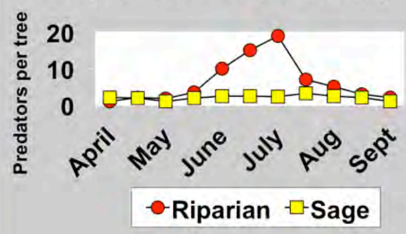
## Conservation biological control

- All habitats are not created equal but even very dry low diversity ones can provide the ecosystem services of important predators such as spiders

## Colonization of potted trees

| Riparian | Sage |
| --- | --- |
| Rose | Lupine |
| Cottonwood | Sage |
| Willow | Bitterbrush |

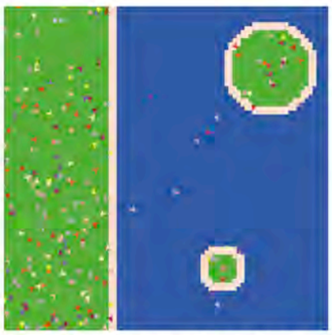
(From Rathman and Brunner)




| Predator types | Riparian | Sage |
| --- | --- | --- |
| Mites | 20% | 0 |
| Spiders | 18% | 65% |
| Beetles | 5% | 12% |
| Flies | 27% | 0 |
| True bugs | 10% | 17% |
| Lacewings | 20% | 6% |

[1]Rathman, R.J., Brunner, J.F., 1988. Abundance and composition of predators on young apple, *Malus domestica* Borkhausen, within sagebrush and riparian species pools in north central Washington. Melanderia 46, 66–81.

Notes:



**Island biogeographic model:**
- Large island collects more species than a small one
- Close island collects more species than a distant one
- Also more species become established as time passes
- Experimentally validated in many island studies

## Implications of geographic models for conservation biological control

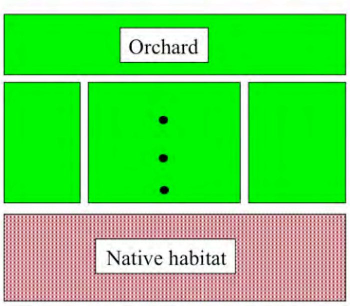
*Intuitive:*
- *Larger (and richer) surrounding habitats provide more natural enemies*
- *Closer surrounding habitats provide more natural enemies*

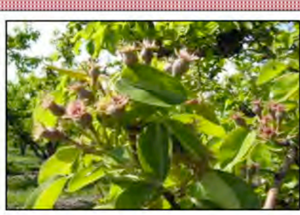
*Counter intuitive:*
- *Smaller orchards collect more natural enemies per area than large orchards because perimeter/area gets smaller with increasing size* ($2\pi r / \pi r^2$)

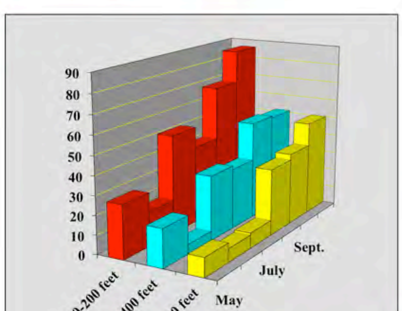
*Reality*
- *These concepts are largely untested in field studies*

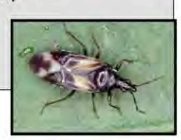
Notes:

## Colonization of orchards
*(from native habitat; Miliczky & Horton)*





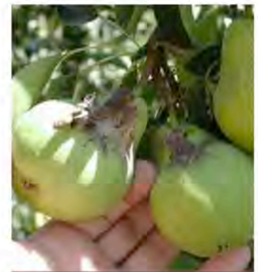
Notes:

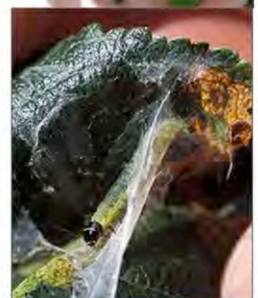
Notes:

## General principles may not be enough

*The leafroller problem*

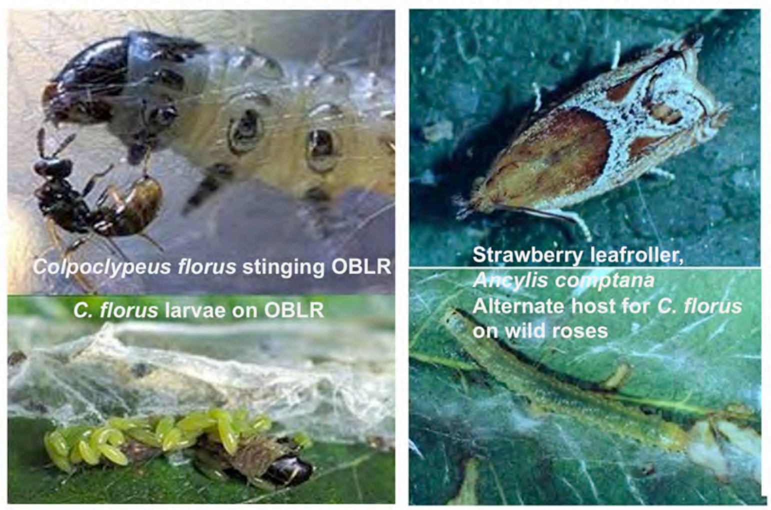
- *Choristoneura rosaceana,* OBLR, and *Pandemis limitata,* PLR, can damage more than 25% of a pear or apple crop
- LRs are often responsible for as much damage as codling moth
- One or two pesticide applications are often used
- There are many parasitoids that attack LRs but they arrive to orchards too late





Notes:

## From general principles to community design to create successful conservation biocontrol:




Notes:

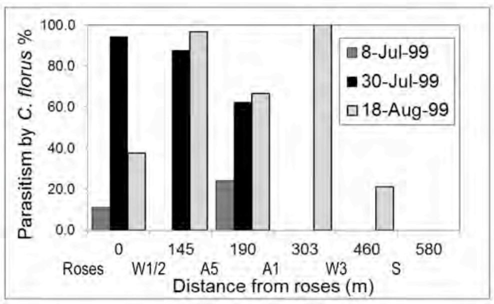
## Landscape observations on parasitism of leafrollers

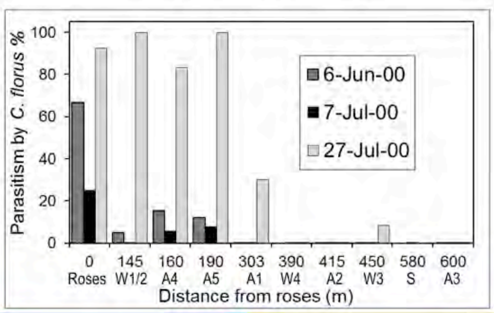
Orchards near to clusters of *Ancyllis*-infested roses show elevated parasitism by *C. florus*.

Washington State University · ars Agricultural Research Service · Oregon State University OSU · Berkeley


Notes:

Naturally-occurring parasitism by *C. florus* vs. distance from rose hedge




Notes:

**At this and a second orchard area next to *Ancylis*-infested rose thickets, we observed high parasitism of PLR/OBLR by *C. florus* in the nearby orchard.**

**Now we compare this situation to what is more typical.**

Washington State University World Class. Face to Face.

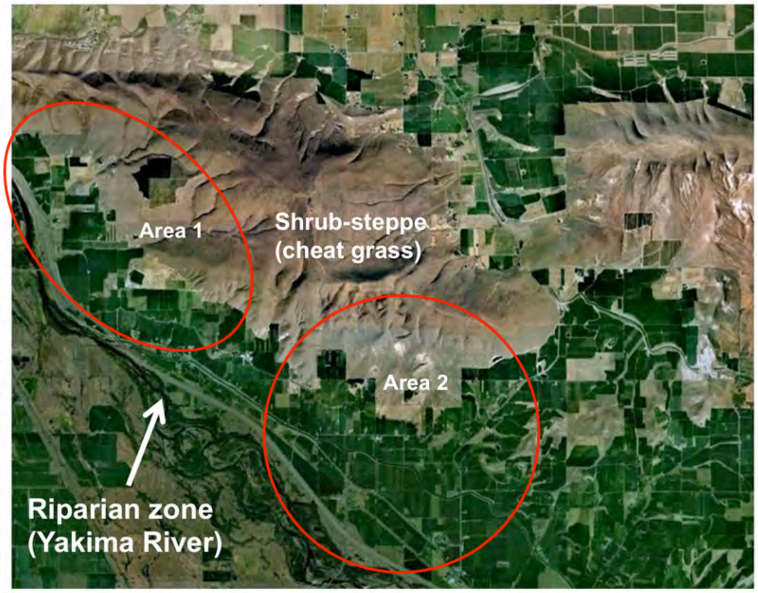
ars Agricultural Research Service

Oregon State University OSU

Berkeley University of California

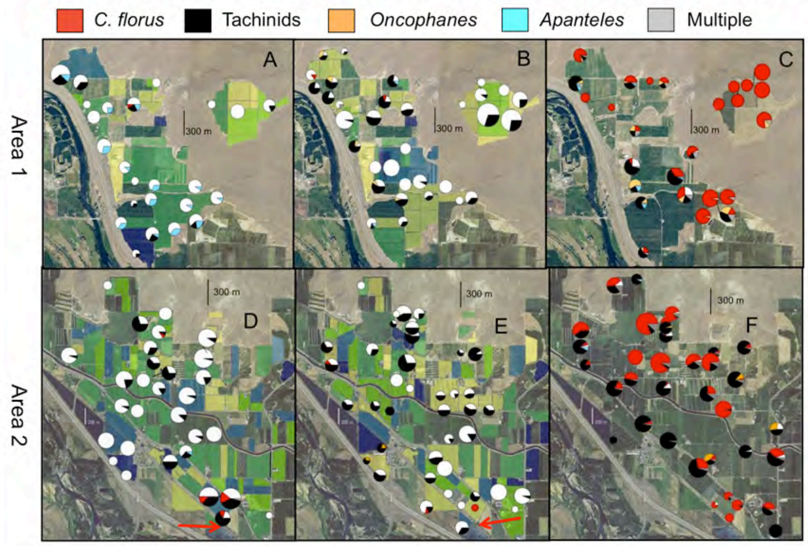
Notes:

Notes:



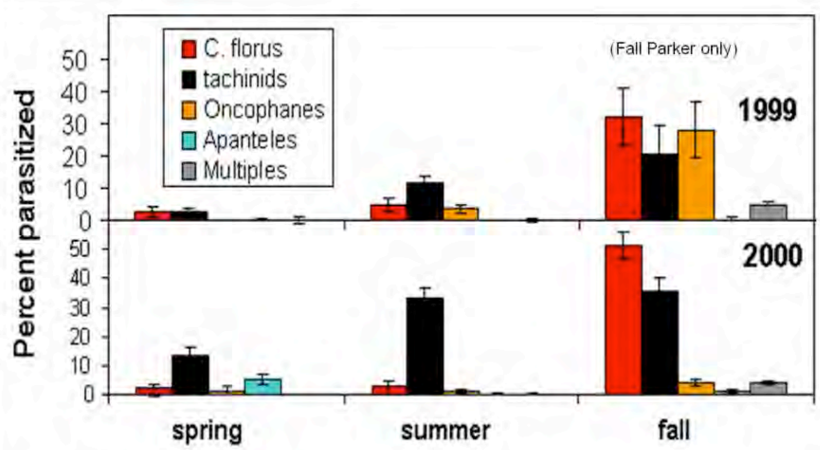

Notes:

## Parasitism in pie charts, pesticide use in colored orchards




Data from 2010; 1999 showed similar patterns

Notes:




Note: Fall parasitism of leafrollers in orchards is a consequence of our providing these hosts “out of season”. OBLR and PLR overwinter as small larvae (2nd or 3rd instar) and are not susceptible to parasitoids at this stage and timing. *C. florus* seeks large larvae on which to overwinter and *Ancylis comptana* is one leafroller species that has this biology.

## Analysis of patterns observed in landscape studies

- ✓ 10% parasitism in spring and 35% in summer (all species of parasitoids)
- ✓ Tachinids were the dominant parasitoids
- ✓ We identified areas, particularly those distant from the Yakima Rier, where no parasitism by *C. florus* was observed in two consecutive years
- ✓ Parasitism by *C. florus* was higher when closer to riparian habitats
- ✓ We identified 4 places to plant gardems of rose and strawberry to test if we could enhance *C. florus*

Washington State University · ARS Agricultural Research Service · Oregon State University OSU · Berkeley

Notes:

**We hypothesized that we could increase parasitism by *C. florus* by planting rose near to orchards……**

**We tried to choose sites where no parasitism was observed.**

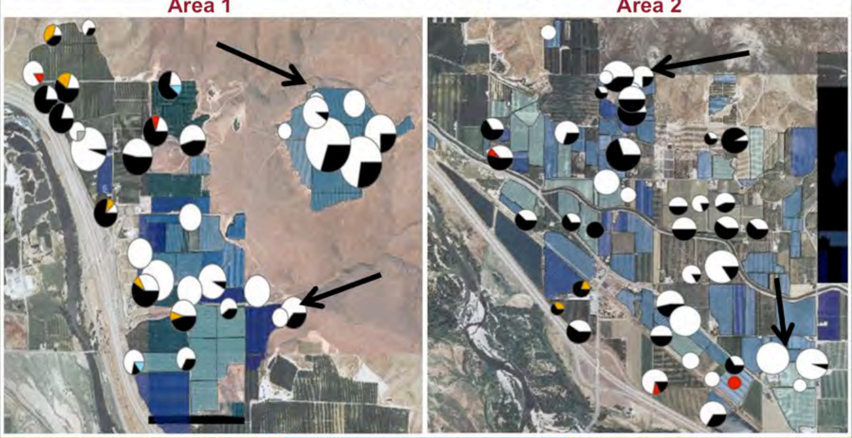
Washington State University · ARS Agricultural Research Service · Oregon State University OSU · Berkeley

Notes:

## The Gardens
## (summer 2000)

Garden location identified by white arrow failed and was dropped from study

Area 1 Area 2

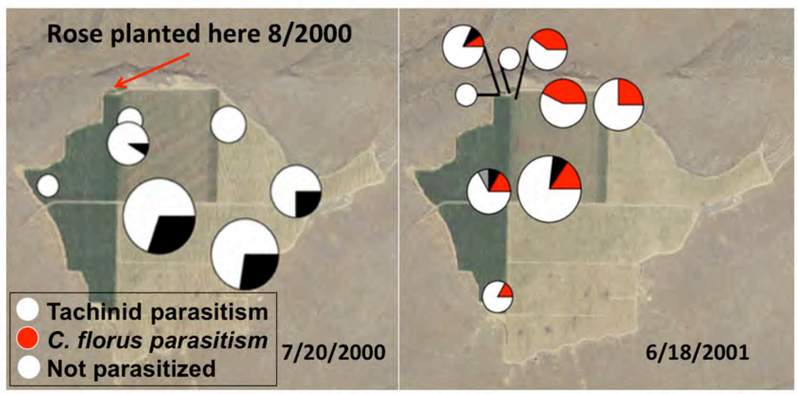


Notes:

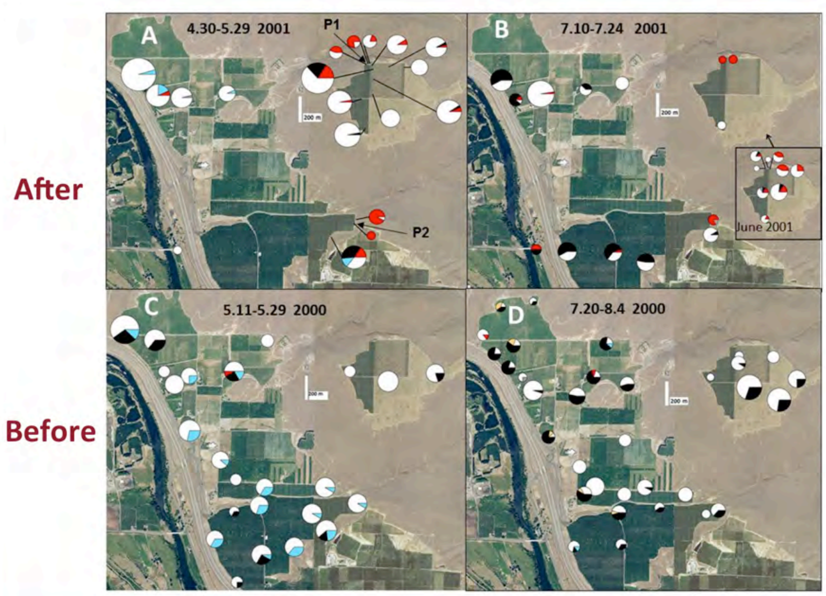
Notes:

Notes:

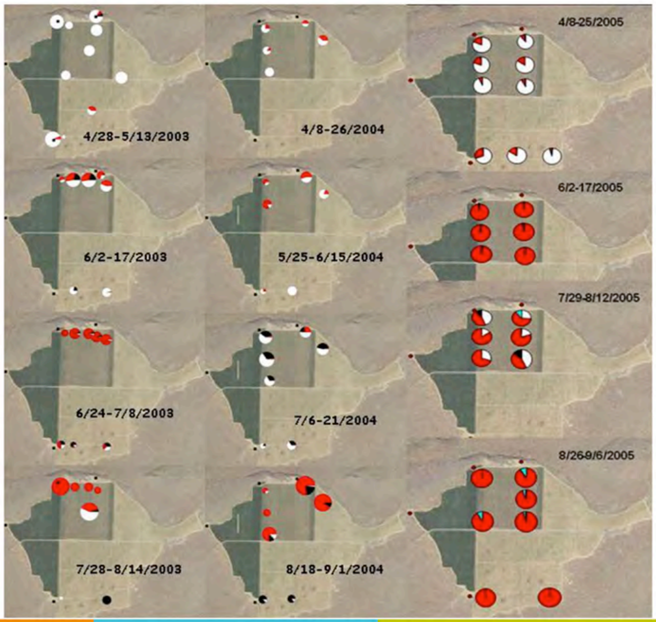
## Summary of parasitism by *C. florus* seen one year after planting of gardens at one site




Notes:



**Three year pattern in 100 acre block**




Notes:

## *C. florus* movement studies by Vince Jones

Major question addressed:

- What is the area of influence ("active space") of a rose/strawberry garden needed to bolster parasitism of leaf rollers.

Methods:

- Wasps marked with a protein when leaving roses and protein later detected using antibody techniques with wasps captured in adjacent orchard.

Washington State University · ars · Oregon State OSU · Berkeley

Notes:

**Mark and Capture Methods**

- Covered parts of gardens with netting and dusted plants and netting with soy flour
- Collected parasitoids in the orchard using traps
- Ran ELISA tests from Early May to Late August

Notes:

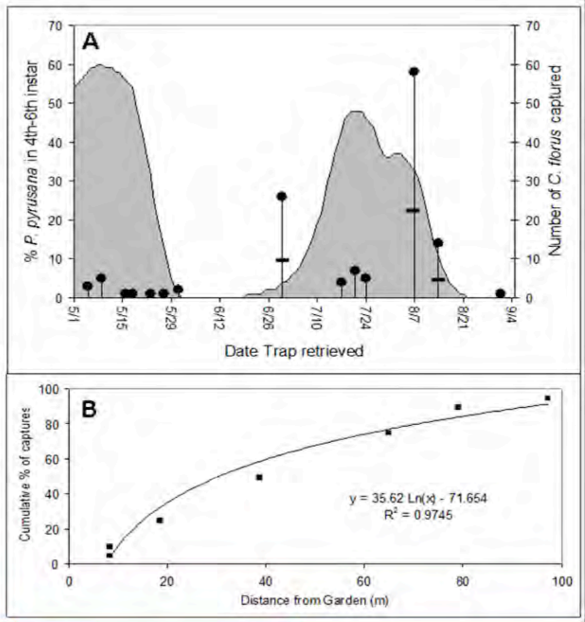
Notes:

## Both 2005 and 2006 studies show C. florus leaving roses and moving into the orchard


Notes:

A. Shows highly episodic nature of captures of marked *C. florus* in time. Most wasps were caught when PLR would be present (PLR phenology model represented in grey) but abundance of wasp and host do not correspond well.

B. Cumulative captures of marked *C. florus* are well described by a weakly logarithmic regression or even and simple linear regression, indicating we trapped well within the dispersal potential of the wasp.




Notes:

## Conclusions from marking study

- We didn't get out in front of the dispersal capacity of wasps
- Captured at 45 m of 50 m maximum distance in 2005 and 90 m with maximum trap distance of 95 m in 2006
- Phenology of captures were episodic and suggests the timing of *C. florus* dispersal into orchards may be suboptimal

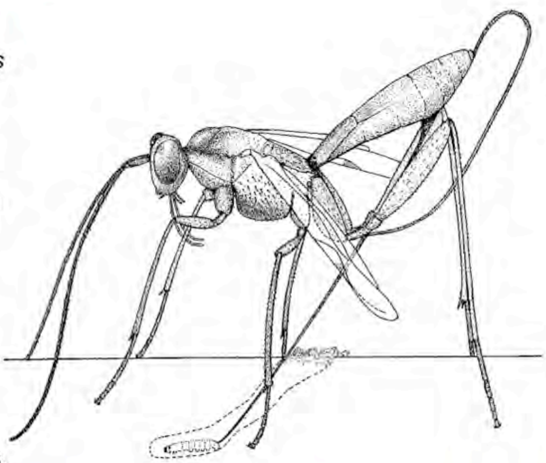
## Rose study conclusions

- Parasitism by *C. florus* may be enhanced with rose/strawberry gardens
- Relatively small gardens can have a large effect
- In most areas strawberries are needed to keep providing SLR
- Roses and strawberries should be separated from one another by dry habitat

Notes:

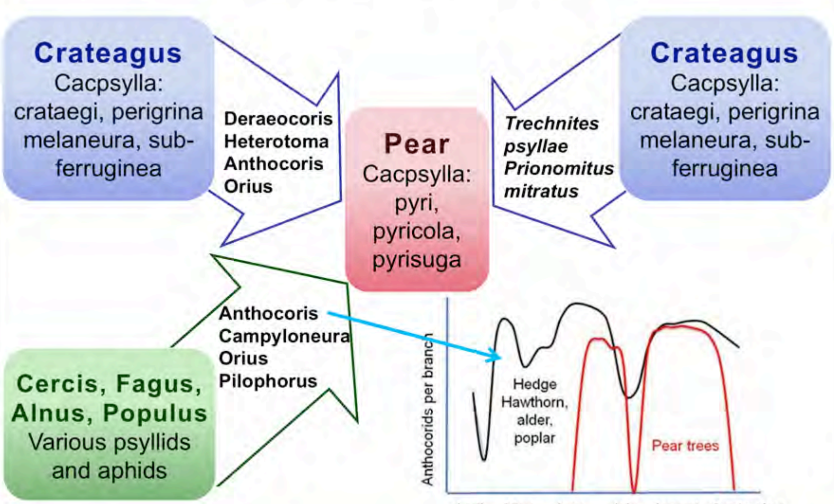
## A related system

*Macrocentrus ancylivorus* attacks and overwinters on strawberry leafroller on strawberries and blackberries (and other lepidoptera) and goes on to attack Oriental fruit moth in peaches and apples. Strawberry plantings in or near to peach orchards in New Jersey and in apples in California have shown increased parasitism of OFM and pest reductions.



Notes:

## Some other examples Biological Engineering




Nguyen, T. X., Delvare, G. & Bouyjou, B. 1984.

Petru Scutareanu et al. 1999 Ecological Entomology 24, 354-362

Notes:

Notes:

## *Anagrus* on leafhoppers
### *studies in California, New York, and Europe*

"Because grape leafhoppers overwinter as adults, and Anagrus species overwinter in host eggs, Anagrus species must rely on alternate host insects that overwinter as diapausing eggs in perennial plants" ….. Ex. L. William et al. 2000

Prune Trees provisioning vineyards in California

- Leafhopper eggs on prunes are attacked by *Anagrus* in fall and wasps colonize vineyards in spring.
- Increase in parasitism and capture of marked *Anagrus* was seen 50-100 meters from prunes trees in early spring. *Anagrus* becomes very abundant by summer and parasitism becomes very high even without prunes.

Wood lots provisioning vineyards in New York

- Roughly same trend: more *Anagrus* were captured and egg parasitism was higher on border vines than on vines farther inside the vineyard; differences largely disappear as the season continues

Notes:

**Bringing predators in to eat aphids and psylla in Washington Orchards**

| Common name | Habit, hardiness, growth | Host, prey, other | Caution/ bloom/ other values |
|---|---|---|---|
| multifloral rose | shrub, hardy, fast | aphids, **leafrollers** | invasive/ May/ mowable |
| thin leaf alder | Small tree, hardy, fast | aphids, **leafrollers** | /early spring/ nitrogen fixing |
| Schouler's willow | sm-tree, v. hardy, fast | aphids, leafrollers, **psyllids** | /early spring/ browse |
| antelope bitterbrush | shrub, very hardy, mod. slow | aphids, leafrollers, **psyllids** | hard to establish/ early spring/browse |
| buckwheat sulf, rock, snow | forb, hardy, fast | aphids, psyllids, **floral subsidy** | Hardy/ spring-summer/ avail.seed |
| Alyssum | annual, moderate, fast | **floral subsidy** | May need to reseed often/ late spring-summer/ avail.seed |
| strawberry | forb, hardy, mod | aphid, **leafroller** | needs weed control, thirsty/ na/ eat fruit |

Notes:

## How to make habitats that succeed

Meet the needs of the players --- an example

Early studies to supplement the *Anagrus* parasitoids of the grape leaf hopper using plantings of blackberries to support the black berry leafhopper as an overwintering host.

Scientists found that plantings and the insect fauna did not perform well in long hot and sunny California summers.

But blackberries in the shade of oak trees in California were productive.

We now can substitute structures of shade cloth above berry or rose hedges to meet this need of shade.

Growers need to kidnap an entomologist to test this in California vineyards and in Washington apples.

Next...

***Case Study #2: Designing BC Friendly IPM Programs for either apple or pear***

(Refer to exercise material on page 169)

***Case Study #3: Restoring BC After a Major Disruptive Event and dealing with a new invasive pest***

(Refer to exercise material on page 185)