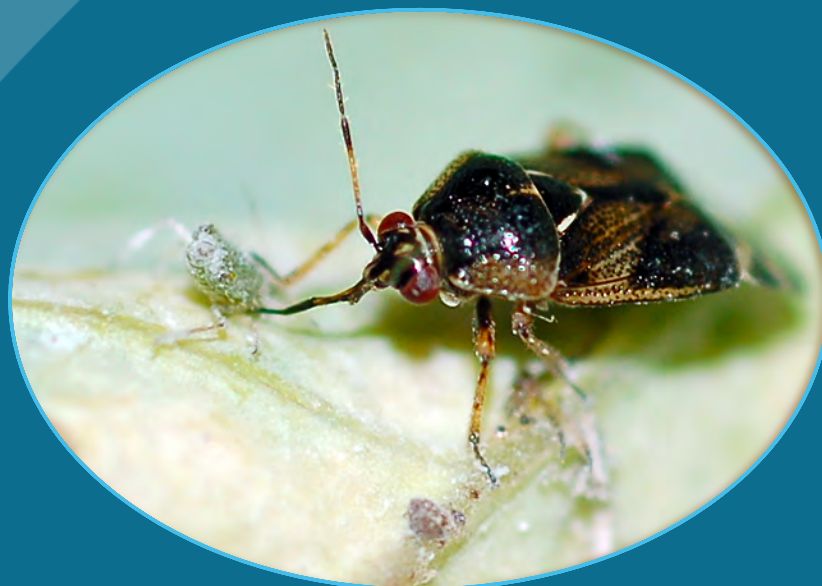


Interactive Short Course

Focusing on Tomorrow Today

Enhancing biological control in orchard cropping systems.

http://enhancedbiocontrol.org

February 7-8, 2012

Held concurrently at:

**CTC in Wenatchee WA;
ESD in Pasco, WA; and
The Pine Grove Grange,
Hood River, OR**

Table of Contents

Enhancing Biological Control in Western Orchards

USDA-NIFA SCRI grant #2008-04854 enhancedbiocontrol.org

Focusing on Tomorrow Today

- ✓ *Why does biological control matter?* – Learn about the economic impact of biological control for the grower.
- ✓ *Are pesticides and biological control compatible?* – Learn about the effects newer insecticides have on key natural enemies.
- ✓ *How do I know what's out there?* - Learn about new monitoring tools to determine natural enemy presence and importance.
- ✓ *Can we predict natural enemy presence in orchards to reduce their exposure to pesticides?* - Learn about new models that will help you conserve natural enemies.
- ✓ *Which predators are most valuable in reducing codling moth?* - Learn how to identify important natural enemies in your orchard.

These and more questions are the focus of a Specialty Crops Research Initiative grant-funded project to enhance biological control in western apple, pear and walnut orchards.

We invite you to our interactive workshop to learn more about natural enemies and novel tools to maximize biological control in your operation.

2-Day Interactive Short Course

Course highlights:

- Discuss general principles of biological control in perennial crops with examples from apple, pear and walnut orchards.
- Engage in understanding and solving issues related to secondary pest outbreaks and the impact of invasive pests on IPM practices.
- Practice developing IPM programs and strategies that support biological control.
- Learn how to identify key natural enemies and pests they control.
- Discover new tools for monitoring natural enemies.
- Explore web resources and how they can help you to integrate biological control into your management strategy.
- Learn from new research the effects of pesticides on natural enemies.
- Understand the economic consequences of natural enemy removal in orchards.

The information presented in this short course is helpful and relevant to most perennial cropping systems.

Meet the Experts: Presenters

Dr. Vincent Jones[1] *email:* vpjones@wsu.edu
Washington State University, Dept. of Entomology, Tree Fruit Research and Extension Center, Wenatchee, WA

Vince's program specializes in novel approaches to population ecology and behavior of tree fruit pests with a focus on strategies to enhance biological control through the development of phenology models for key NEs, development of attractants and improved monitoring.

Dr. Jay Brunner[1] *email:* jfb@wsu.edu
Washington State University, Dept. of Entomology, Tree Fruit Research and Extension Center, Wenatchee, WA

Jay's research focuses on tree fruit crop IPM with specialization in sampling methods and action thresholds, insect phenology and predictive modeling, evaluation of BC agents, and use of MD for management of Lepidoptera pest.

Dr. Nick Mills [1] *email:* nmills@berkeley.edu
University of California Berkeley, Dept. of ESPM

Nick's research is focused on biological control of insect pests and the ecology of insect parasitism and predation. One of the aspects of his work is to discover new elements of natural enemy biology providing a direct linkage to the implementation of improved biological control and a reduced reliance on pesticide intervention in IPM.

Dr. Thomas Unruh[2] *email:* thomas.unruh@ars.usda.gov
USDA-ARS, Wapato, WA

Tom's research focuses on biological control with emphasis on enhancement of natural enemies in orchard IPM systems, predator release practices, efficacy of attractants, augmentative BC and habitat manipulations.

Dr. Dave Horton[2] *email:* david.horton@ars.usda.gov
UDSA-ARS, Wapato, WA

Dave's research emphasis is on biorational management of temperate fruit insect pests, enhancing BC in orchard IPM systems, optimization of insect attractants and evaluation of HIPVs used for NE monitoring.

Dr. Peter Shearer[3] *email:* peter.shearer@oregonstate.edu
Oregon State University, MCARC, Hood River, OR,

Peter's research activities involve studies on the management of arthropod pests of pome and stone fruits by enhancing IPM strategies and tactics including chemical, cultural, and biological control. Current focus areas include: sublethal effects of new pesticides on natural enemies, insecticide resistance management and evaluating impact of pesticides on target and not-target arthropods.

Mr. Steve Castagnoli[3] *email:* steve.castagnoli@oregonstate.edu
Oregon State University, MCARC, Hood River, OR,
Steve is the Extension Horticulturist for Hood River County providing area growers with the tools they need to maintain an industry that is both economically and environmentally sustainable. Steve's main focus is supporting the area tree fruit industry with relevant educational programs through implementation projects, workshops, field days, informational meetings, and newsletters.

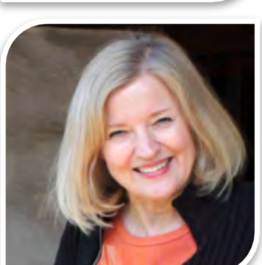
Dr. Karina Gallardo[1] *email:* karina_gallardo@wsu.edu
Washington State University, School of Economic Sciences, Tree Fruit Research and Extension Center, Wenatchee, WA
Karina is an Agribusiness Extension Specialist working in the area of enhancing value-added opportunities for specialty crops with a focus on consumer demand analysis and economics of technological change.

Dr. Angela Gadino[2] *email:* angela.gadino@wsu.edu
Washington State University, Dept. of Entomology, Tree Fruit Research and Extension Center, Wenatchee, WA
Angela is the Project Coordinator for SCRI project: "Enhancing Western Orchard Biological Control" and performs research and outreach aimed at promoting the adoption of sustainable ecosystem-based pest management strategies.

Dr. Ute Chambers[2] *email:* uchambers@wsu.edu
Washington State University, Dept. of Entomology, Tree Fruit Research and Extension Center, Wenatchee, WA
Ute is the Project Manager for the WSU Decision Aid System. Her research and outreach focuses on IPM strategies for orchard pests, insect phenology modeling and the impacts of microhabitat and thermoregulation behavior on insect development.

Dr. Gene Miliczky[2] *email:* gene.miliczky@ars.usda.gov
UDSA-ARS, Wapato, WA
Gene is an expert in insect and spider identification with a strong interest in insect life history, ecology, and pest management. He has been working in tree fruits with Dr. Dave Horton for the past 10 years investigating the role of extra-orchard habitats on the pest and natural enemy community in orchards. (Gene prefers pictures of his work.)

Dr. Marshal Johnson[1] *email:* marshall.johnson@ucr.edu
University of California at Riverside, Dept. of Entomology, Kearney Agric. Center, Parlier, CA
Marshall is an expert in biological control and is responsible for tree crop extension in the San Joaquin Valley. Recent research has focused on perennial tree crop pests with an emphasis on developing alternative pest management strategies minimizing pesticide use while providing growers practical and feasible control.



Dr. Lynn LeBeck[1] *email:* exdir@anbp.org
Association of Natural Biocontrol Producers (ANBP), Clovis, CA
Lynn is the Executive Director for ANBP, a non-profit organization that serves the commercial biocontrol industry in North America. Quality control and the effective use of beneficial predators, parasitoids, and entomopathogenic nematodes, are among their highest priorities.

Meet the Experts: Discussion Facilitators

Dr. Nadine Lehrer[2] *email:* nlehrer@wsu.edu
Washington State University, Tree Fruit Research and Extension Center, Wenatchee, WA
Nadine is a Rural Sociligist and is experienced in measures of adoption and diffusion of agricultural innovation, farm worker health education, environmental pesticide issues, and US agricultural policy development.

Ms. Karen Lewis[2] *email:* kmlewis@wsu.edu
Washington State University, Grant County Extension, Ephrata, WA
Karen is an Extension Horticulturist that works with industry and academic partners to identify, develop, and evaluate tools, technologies and practices that improve fruit quality that in turn increases consumer demand and the growers return on investment. Specific areas of interest include: Integration of people, technology and perennial systems, electric light duty farm vehicles, mobile platform and over the row technologies, mechanized thinning, and efficient orchard systems.

Ms. Wendy Jones[1] *email:* wendyej@wsu.edu
Washington State University, Tree Fruit Research and Extension Center, Wenatchee, WA
Wendy is a researcher working to gather, interpret and disseminate IPM and biological control information. She maintains several web sites including the Enhanced BC project site and the Pest Management Transition project site.

Dr. Clive Kaiser[3] *email:* clive.kaiser@oregonstate.edu
Oregon State University, Umatilla County Extension, Milton-Freewater, OR.
Clive is an Extension Horticulturalist based in the greater Walla Walla Valley. He works primarily in cherries, apples, soft fruit, wine grapes and viticulture. He specializes in problems relating to cherry crack, apple sunburn and overall orchard health.

Mr. Rick Hilton[3] *email:* Richard.hilton@oregonstate.edu
Oregon State University, Southern Oregon Research and Extension Center, Medford, OR
Rick works with a research program whose goal is to develop ecologically sound pest management strategies and tactics and to introduce and demonstrate those tools and techniques to growers and field managers.

Dr. Jeff Olsen[3] *email:* jeff.olsen@oregonstate.edu
Oregon State University, Yamhill County Extension, McMinnville, OR
Jeff is the Extension Horticulturalist for the counties in the northern part of the Willamette Valley, the area with most of the hazel orchards. His expertise covers all the horticultural crops grown in the area, including walnuts, chestnuts, cherries, pip fruit and nursery crops. He is also involved in U.S. and international horticultural extension organizations.

Key to footnote symbols

Numbers following people's name indicate which course location that person will be featured:

1 - CTC, Wenatchee, WA
2 - ESD, Pasco, WA
3 - Pine Grove Grange, Hood River OR

Presentations Day 1

Course Schedule

Time	Activity Type	Title
Morning Session		
8:00	Introduction	Welcome and Overview of Course
8:30	Presentation	General Overview and Introduction to Biological Control (BC)
9:10	Presentation	Principles of Pest/NE Interactions
9:50		**Break**
10:10	Presentation	Key Natural Enemy Groups: Life histories and peast control
10:45	Exercise	Identification of Key BC Agents
11:35	Review	Review of morning session with Q&As
12:00		**Lunch**
Afternoon Session		
1:00	Presentation	Natural Enemy Monitoring
1:25	Presentation	Natural Enemy Phenology
2:00	Presentation	BC Resources on the Web
2:25	Exercise	Windows of Opportunity
2:55		**Break**
3:15	Presentation	Effects of Pesticides on Natural Enemies
3:55	Exercise	***Case Study #1:*** Secondary Pest Problems – Why did they get out of control?
4:30	Review	Review of afternoon session with Q&As
4:55	Reception	**Social Hour and Poster Session of Day 1 Topics**
6:00		End of Day1 – dinner on your own

Day 1

Presentation 1: Overview & Introduction to BC

Notes:

General Overview and Introduction to Biological Control

Nick Mills, University of California, Berkeley
Vince Jones, Washington State University, Wenatchee

Notes:

Overview

- What is biological control and how can we implement it?
- What are natural enemies and why should we be interested in biological control?
- What is the role of biological control in IPM?
- What is the significance to current IPM in western orchards?
- How to enhancing biological control in western orchards?

Notes:

Approaches to Pest Management

Cultural
manipulation of the crop environment to reduce susceptibility to pests

Chemical
use of natural or synthetic pesticides

Biological
manipulation of pests or natural enemies to reduce damage

Notes:

What is Biological Control?

The suppression of pest damage through the action of one or more living natural enemies

Notes:

What are Natural Enemies?

Pathogens | Parasitoids | Predators

(Video on predators)

Notes:

Natural Enemies in Action: Predator

Courtesy of Prof. Urs Wyss, Kiel University – Entofilms.com

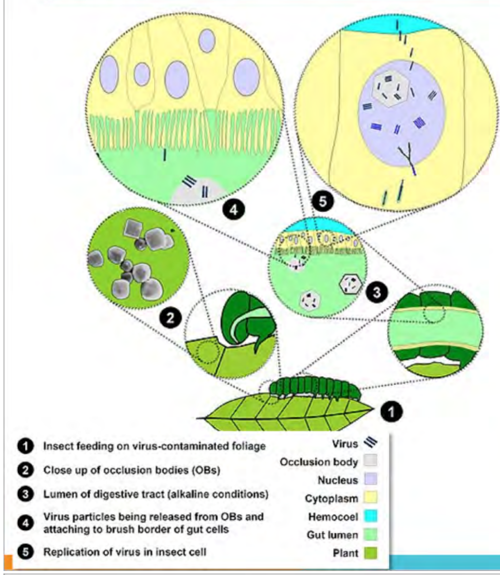
(Video on parasitoids)

Natural Enemies in Action: Parasitoid

Courtesy of Prof. Urs Wyss, Kiel University – Entofilms.com

Notes:

Natural Enemies in Action: Pathogen



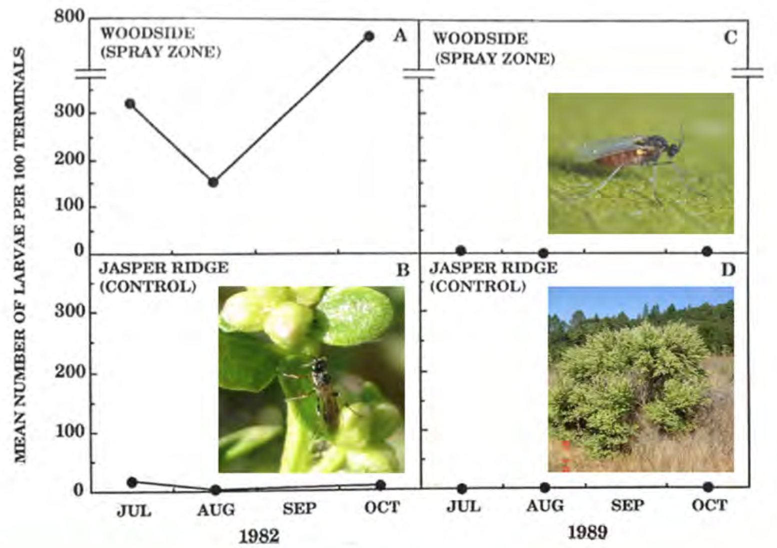
Notes:

Naturally-Occurring Biological Control

- Naturally-occurring biological control is present everywhere, but only detectable when disrupted
- Evidence for natural biological control in San Francisco East Bay during eradication of Med Fly 1981/82

Notes:

Notes:



Notes:

Applied Biological Control

Importation – import and establish specialized natural enemies from the region of origin of an invasive pest

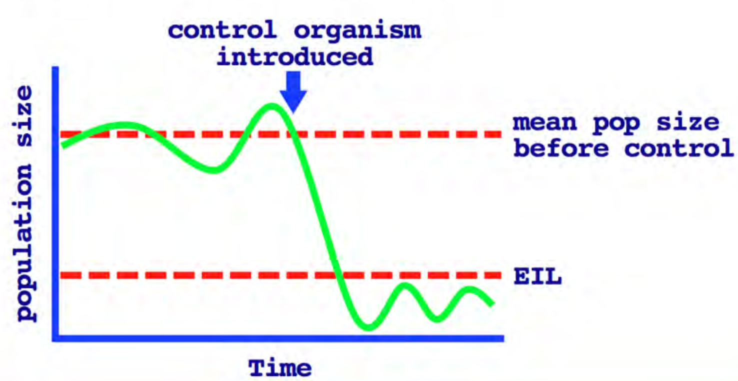
Augmentation – localized release of purchased natural enemies

Conservation – enhance the activity of natural enemies through modification of the crop environment

Notes:

Importation Biological Control

- Importation involves the use of specialized natural enemies from the region of origin of an invasive pest to reduce damage to a tolerable level



Importation Biological Control

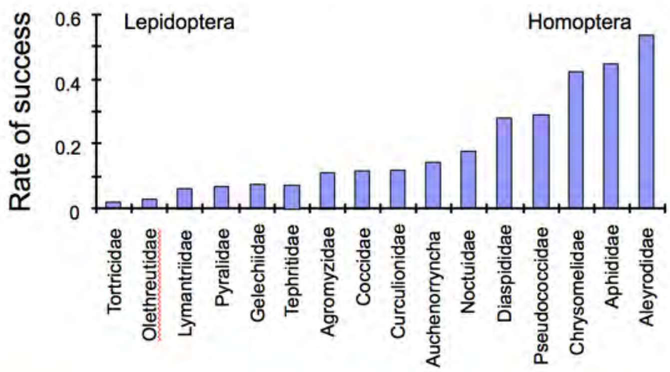
- Used against invasive pests only

- A public good exercise supported by governments, not implementable by growers or industry
- Outcome, if successful, is long-term sustainable control

Notes:

Importation Biological Control

- Variable success rates against different pest taxa



Patterns in CBC – Pest Taxonomy; Mills (2000)

Notes:

Augmentation Biological Control

- When natural enemies are not present, some species can be augmented locally through inoculation or inundation
- **Inoculation** is often used early season to overcome the delay in colonization of crops by natural enemies, where turnover from small releases provides season-long control
- **Inundation** is used at any stage of the season, where large releases of mass reared enemies provide immediate kill (biological pesticide) without persistence or turnover

Notes:

Notes:

Inundative Biological Control

- Natural enemies have been mass produced for over 80 years for use in pest management
- Results are often variable – sometimes used without even monitoring the impact
- What is the technical effectiveness of the selected natural enemy and can it be improved?
- Is mass production commercially viable? – advantage for some microbial products

Notes:

Inundative Biological Control

➢Limitations due to Ecology and Application

Ecology

- Match natural enemy to:
  - habitat (vertical stratification)
  - pest (preference)
  - climate
- Presence of intraguild predators

Application

- Commercial viability – market, cost
- Technical effectiveness – quality and persistence
- Dose-response curve – upper asymptote
- Ease of use – shelf life, duration of activity, delivery

Notes:

Conservation Biological Control

Two General Approaches

- Natural enemies limited by low tolerance of broad spectrum pesticides – conservation tactics include use of selective pesticides

- Natural enemies limited by lack of resources such as nectar and overwintering hosts – conservation tactics include floral subsidies and alternative hosts

Conservation Biological Control

Selective Pesticides

- New low risk insecticides that are replacing OPs are not always more selective with respect to natural enemies
- To enhance biological control we need to understand the selectivity of new classes of pesticides and periods of the season when key natural enemies are most active

Notes:

Conservation Biological Control

Floral Resources

- Lettuce aphids in California are managed by planting alyssum as a food supplement for syrphid predators

Notes:

Examples of Successful Applied Biological Control

- Western orchards provide some excellent examples of biological control that are often forgotten due to their continued success
- Such successes are providing natural pest control services to our orchard crops at no cost
- Failure to recognize these successes can lead to loss of control and an apparent need for increased insecticide usage

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Notes:

Notes:

Examples of Importation Biological Control

- Vedalia beetle imported from Australia for control of cottony cushion scale in California citrus in 1889
- First well-documented example of successful natural enemy importation worldwide


Notes:

Examples of Importation Biological Control

- Walnut aphid was a key pest of walnut production in CA in 1950s
- *Trioxys pallidus* was introduced from Iran in 1969
- Parasitism has provided sustained control of walnut aphid for > 40 yrs



Notes:

Examples of Augmentative Biological Control

- Fillmore Insectary, grower cooperative, produced *Aphytis melinus* for control of California red scale
- Served 250 growers and 8,000 acres of citrus
- 5,200 parasitoids/acre every 2 weeks from Feb to Aug
- Commercial success due to technical effectiveness and ease of use



Examples of Augmentative Biological Control

- Syngenta BioLine produces *Phytoseiulus persimilis* for control of two-spotted spider mites in strawberries in California
- Used on 50-75% of the 22,000 acres of strawberry in 1990s
- 10-10,000 *P. persimilis*/acre applied early season when spider mites pops. are low
- Commercial success due to technical effectiveness and ease of use

Notes:

Examples of Conservation Biological Control

- Strawberry leafroller infested roses can be an important overwintering site for the gregarious ectoparasitoid *Colpoclpeus florus*
- Parasitism of sentinel OBLR larvae approached 100% in WA apple orchards with adjacent patches of infested roses

Notes:

Examples of Conservation Biological Control

- Spider mites usually under effective biological control in western region by *Galendromus occidentalis*
- Stan Hoyt demonstrated that OPs, certain fungicides, and miticides disrupted BC causing mite outbreaks in 1960s
- Use of selective insecticides, lower dosages, improved timing restored BC by *Galendromus*

Notes:

Notes:

Biological Control – Evaluating Benefits

- Public good activity
- Reduces need for insecticide intervention
- Reduces risk of farm worker health issues
- Reduces risk of environmental pollution
- Preserves food, water and air quality

Notes:

Biological Control – Economic Benefits

- Annual benefit of walnut aphid control by *Trioxys pallidus* estimated to be $1.5 million
- Benefit to cost ratio of importation biological control estimated to vary from 15 to12,700
- Benefit to cost ratio of augmentative biological control estimated at 3 to 31
- Annual benefit of conserving predatory mites in apples is estimated to be $3 million

Notes:

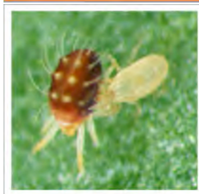
Summary

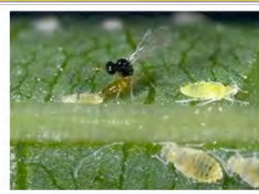
- Biological control is an economically valuable and naturally occurring pest control service provided by natural enemies that can play a pivotal role in the IPM of arthropod pests
- Natural enemies can be effectively manipulated to enhance BC through classical introduction (invasive pests only), augmentation and conservation

Summary

- Classical introductions of exotic natural enemies have proved dramatic long term successes in the BC of some types of invasive pests
- Conservation of NE activity through selective choice and use of pesticides provides an opportunity for sustainable pest management in western orchards with significant economic and environmental benefits

Notes:





Principles of Pest/Natural Enemy Interactions

Vince Jones, Nick Mills, Andrea Bixby-Brosi

Presentation 2: Principles of Pest/NE Interactions

Notes:

Overview

- Why is now the time for BC
- NE habitat and resource needs
- Predator/Prey Searching
- BC as a component in IPM
- BC in organic & conventional systems
- Summary

Notes:

Notes:

Loss of Guthion…..

- Used for 50+ years
  - Trial and error gave simple, stable IPM
- Many NE were resistant to it
  - Western Orchard Predatory mite
  - Parasitoid of western tentiform leafminer
  - *Trioxys pallidus* (walnut aphid parasitoid)
- Provided broad spectrum suppression of a number of 2° pests

Notes:

Registration of OP alternatives

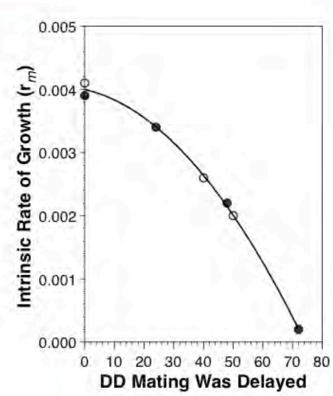
- Many different modes of action
- Resistance management for pests will disrupt NE developing resistance
- Effects on NE poorly known
  - Timing
  - Residual activity longer
  - Sub-lethal effects on reproduction/survival

Actara, DuPont™ Altacor®, Assail 70WP, DuPont™ Avaunt®, BELAY Insecticide, BELT, calypso, CYAZYPYR, CLUTCH Insecticide, Delegate WG, Entrust Naturalyte, Proclaim, Rimon 0.83EC, Esteem, Intrepid 2F, PROVADO 1.6, Success 480 SC

Notes:

Mating disruption…

- Highly specific and only affects CM
- Makes it hard for males to find mate
  - Delay in mating reduces reproductive rate
- Acts on a DD basis
  - Works best in hot times of year
- Affects all generations
- When used as the basis for IPM in apple, pear and walnut makes all control efforts better



Why BC now?

Future possibilities?

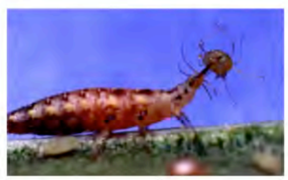
- "Pesticide replacement therapy"
  - Much more costly!
  - More problems with secondary pests
  - MRL issues for pome and stone fruits
  - "Toxic 12"
- Ecologically based IPM focused on BC
  - More information intensive
  - More stable, fewer 2° pest issues

Notes:

NE needs

Basic information on NE/Pests

- Predators
  - Typically free-living
  - Loosely association any prey stage
  - Many are generalists with multiple prey
  - Multiple prey items needed during life
- Parasitoids
  - Requires and kills only one host
  - One stage rigidly associated with host
  - May be responsible for killing many hosts
  - Both generalists and specialists
  - Female may host feed, killing many hosts

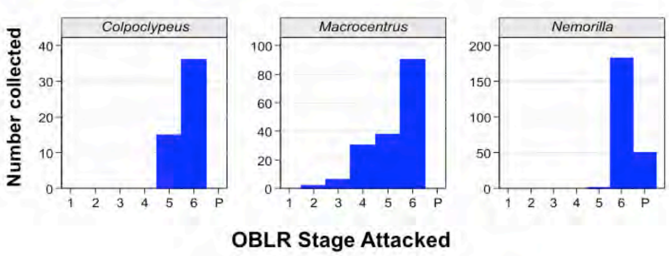


Notes:

NE needs

Synchrony with host/prey

- A parasitoid often attacks a specific stage
- Stage attacked varies considerably between parasitoid spp.
  - Parasitoids of adult insects are relatively rare
  - Egg, larval, pupal parasitoids are common

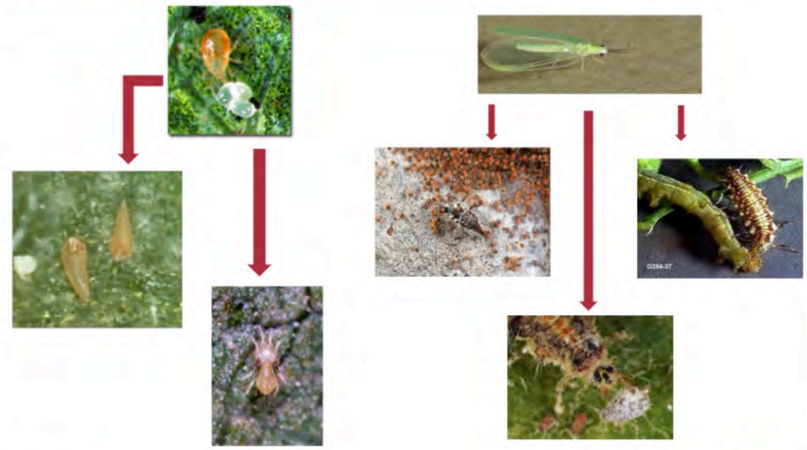


Notes:

Notes:

NE needs

Example alternate prey w/in orchard

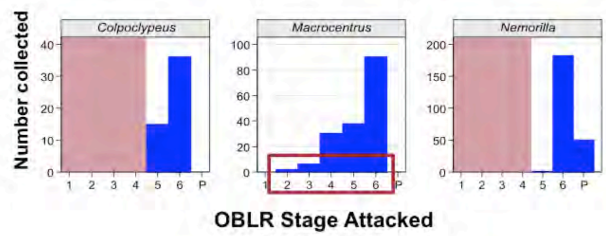


Notes:

NE needs

Overwintering /Extra-orchard hosts

- May need a different host to overwinter
- OBLR and PLR overwinter as instars 1-2
- Need synchrony of hosts/parasitoids

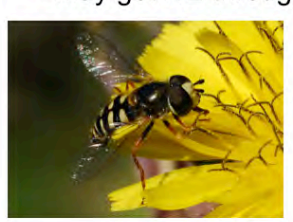


Notes:

NE needs

Nectar sources

- Adult stages may feed on pollen or nectar
- Increases longevity
- Increases reproduction
- May get NE through times w/ low prey/host density



Predator specificity

- Many predators are generalist feeders
  - May switch prey depending on abundance
- Tend to be important as general mortality factor of a number of pests
  - May not be able to regulate the pest
- Hard to quantify predator importance because they generally leave no trace
  - Requires direct observation
  - Molecular gut content analysis
  - Analysis of population dynamics

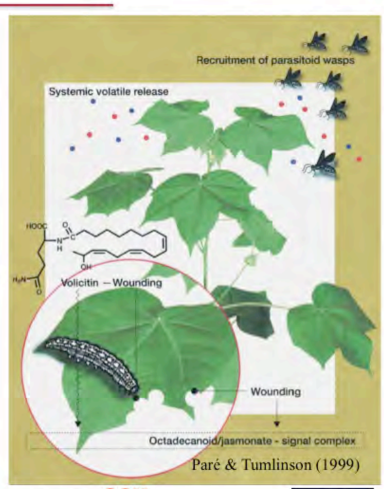
Notes:

Specific Predators

Notes:

How parasitoids find host

- Host habitat finding
  - Long-range volatiles
  - Visual silhouette
- Host finding
  - Herbivore-Induced Plant Volatiles (HIPV)
  - Sign of prey presence
- Host Acceptance
- Host Suitability



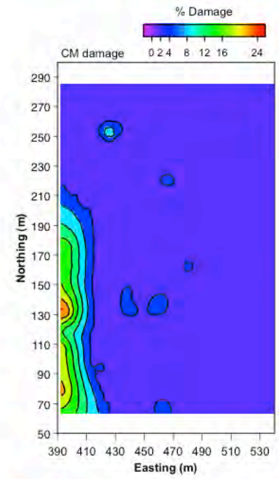
Notes:

Notes:

Predator/Parasitoid Searching

HIPV's and Host/Prey Search

- Distribution of pests:
  - Clumped at lower densities
  - Broadly distributed at high density
- Damaged areas = HIPV's release area
- Low density
  - HIPVs concentrate search
  - Dramatically improve efficiency
- High density
  - HIPVs are everywhere, not big help



Notes:

Predator/Parasitoid Searching

Host-Associated Cues

- Fecal matter
- Wing Scales
- Webbing for those that use silk
  - Leafrollers, spider mites
- Alarm pheromones of host
  - Aphids
- Substrate born vibrations
- Activity when probed

Notes:

BC as a component in apple, pear, walnut IPM

- BC will not control CM by itself
- Important to incorporate MD
- Biggest Benefits of BC:
  - 2° pest suppression
  - Improved worker safety
  - Lower residues in final product
  - Reduced environmental impacts
  - More stable IPM programs

Organic versus Conventional Systems and BC

- Both organic and conv. IPM can produce high quality fruit
- How are these systems different?

Factor	Organic Pesticide	Conventional Pesticide
Intensity of Mortality	↓	↑
Duration of Mortality	↓	↑
No. Times Applied	↑	↓
Importance of NE complex	↑	↓

- ***Does the organic way of applying mortality lead to less impact on NE and greater stability?***

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Notes:

Can we mimic the organic approach?

- Dose makes the toxin

Factor	Organic	Low dose Conventional	Conventional
Intensity of Mortality	↓	↓	↑
Duration of Mortality	↓	↓	↑
No. Times Applied	↑	↑	↓
NE complex	↑	↑	↓
Cost	↑	↓↓↓↓	↓
Residues	↓	↓↓↓↓	↑
Restrictions on production	↑	↓	↓

- Low dose strategy (= physiological selectivity)
  - ***Basis for Integrated mite management***

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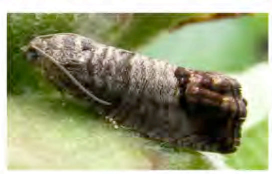
Notes:

Won't this increase resistance problems?

- **NOOOOOOOOO!**
- Resistance is driven by selection pressure
  - Duration and intensity of mortality factor
- Increased BC reduces selection for resistance
- MD is 1° CM control method
  - Reduces selection pressure on pesticide



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Notes:

Notes:

BC in conventional/organic

Evaluate low dose strategy

- 15 acres organic apples at WSU-Sunrise
- Sprays in first CM gen only
- MD across entire block
- One oil spray on entire block at 200 DD
- Break into 12 plots
  - 4 continue using organic control
    - Virus – 4x, (+10 days after oil (300 DD), then ≈ 10 d intervals)
  - 4 plots Delegate at 10% field rate
    - 4 x same time as organic
  - 4 plots Delegate at full rate
    - 2 x – +10 d from oil, +14 days (432 DD))

Notes:

BC in conventional/organic

Does low dose strategy work?

- So far no differences in damage by:
  - CM
  - Leafrollers
  - Spider mites
  - San Jose Scale
  - Aphids (WAA, GAA, RAA)
- Will continue for 3 more years
  - Also monitoring NE diversity/abundance
- Comparing 4 pairs of organic/conventional orchards for damage, NE diversity/ abundance

Notes:

Summary

- Transition period for IPM
  - Focus on incorporating BC
  - MD needs to be core for apple, pear, walnuts
- More information intensive
  - Understand NE needs and phenology
    - Alternate hosts, Nectar sources
  - Need better info transfer
- Protect NE from pesticides
  - Space
  - Time
  - Dose/Toxicant selection

Presentation 3: Key Natural Enemy Groups

Notes:

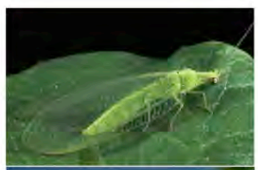
Key Natural Enemy Groups: Life Histories and Pests Controlled

Nick Mills, UC Berkeley
Dave Horton, USDA-ARS, Wapato

Notes:

Predators – Lacewing groups

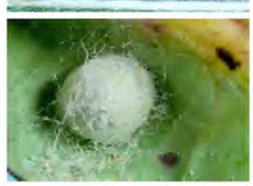
- Green lacewings (Chrysopidae)*Chrysoperla Chrysopa*
- Brown lacewings (Hemerobiidae) *Hemerobius*



Notes:

Predators – Lacewing biology

- Eggs protected on stalks
- *Chrysoperla* predatory as larva only
- *Chrysopa* predatory as adult and larva
- Larvae with hollow mandibles – extra-oral digestion
- Pupate in cocoons in curled leaves
- Parasitized as eggs, larvae and cocoons

Notes:

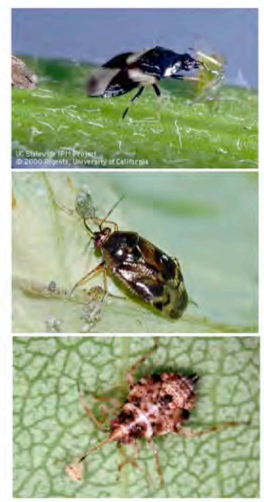
Predators – Lacewing prey

- Aphids
- Moth eggs/ young larvae
- Mealybugs
- Pear psylla
- Spider mites

Notes:

Predators – True bug groups

- Pirate bugs (Anthocoridae)
  Anthocoris and *Orius*
- Capsid bugs (Miridae)
  Deraeocoris and *Phytocoris*
- Assassin bugs (Reduviidae)
  Zelus



Notes:

Predators – True bug biology

- Predatory as adults and nymphs
- Eggs laid into plant tissue
- Piercing rostrum used to attack prey
- Seldom parasitized

Predators – True bug prey

- Pear psylla
- Aphids
- Scale insects
- Spider mites

Notes:

Predators – Ladybird beetles (Coccinellidae)

- Aphid feeders
  Coccinella, Hippodamia, Olla
- Scale feeders
  Chilocorus, Hyperaspis
- Spider mite feeders
  Stethorus

Notes:

Predators – Ladybird beetle life history

- Predatory as adults and larvae
- Eggs usually laid in batches
- Chewing mouthparts
- Pupate on foliage
- Parasitized as adults and pupae

Notes:

Notes:

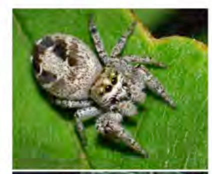
Predators – Hoverflies (Syrphidae) and life history

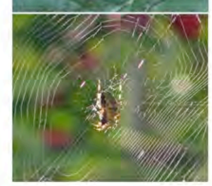
- Aphid feeders
  Eupeodes, Scaeva, Syrphus
- Predatory as larvae only
- White eggs laid singly
- Rasping mouthparts
- Pupate within curled leaves
- Often parasitized as larvae and puparia

Notes:

Predators – Spiders and life history

- Jumping spiders (Salticidae)
  Pelegrina, Phidippus, Sassacus
- Webbing spiders
  Dictyna, Theridion
- Single generation a year
- Feed less frequently than insect predators
- Hunt for, trap, or pounce on prey

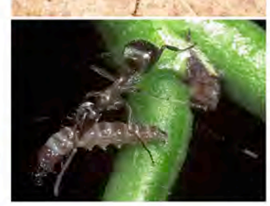




Notes:

Predators – Other groups

- Ground beetles (Carabidae)
  Pterostichus
  - Adults feed on ground at night
  - Larvae predatory in soil
  - Predators of moth larvae
- Ants (Formicidae)
  Formica
  - Ubiquitous, foraging as adults only
  - Many different types of insect prey
  - Farm honeydew producers and may damage nuts



Parasitoids of Moth Pests

- Ichneumonidae

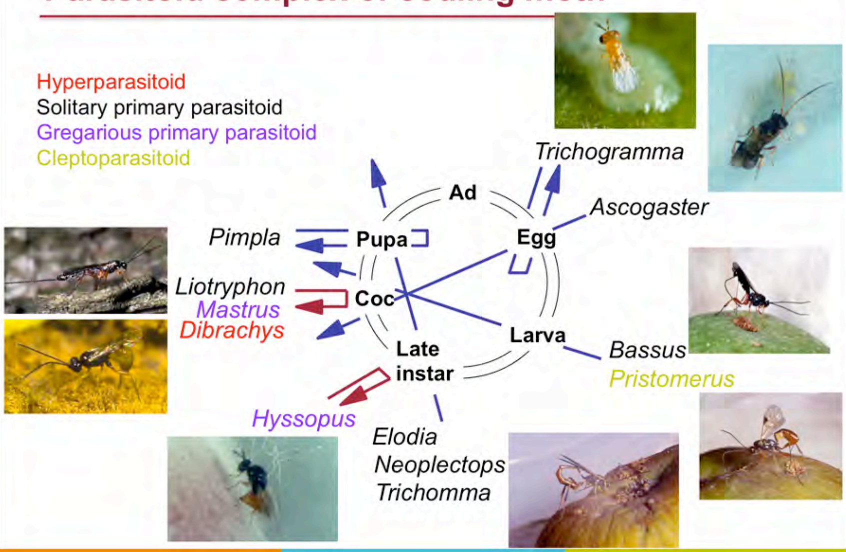
- Braconidae

- Chalcidoidea

- Tachinidae

Notes:

Parasitoid complex of codling moth



Notes:

Parasitoids of Aphids

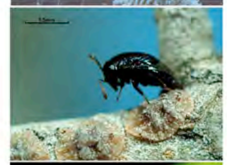
- Braconidae (Aphidiinae)
  Aphidius, *Ephedrus*, *Lysiphlebus*, *Trioxys*
- Aphelinidae
  Aphelinus

Notes:

Notes:

Parasitoids of Scale Insects and Mealybugs

- Encyrtidae
  Anagyrus, Leptomastix
- Pteromalidae
  Scutellista
- Aphelinidae
  Aphytis

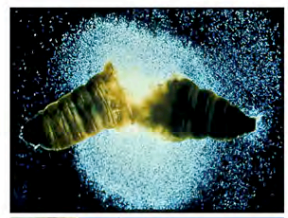


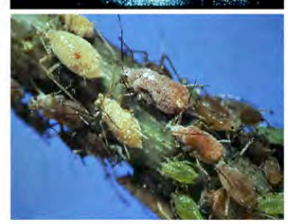
Notes:

Parasites and pathogens

- Entomopathogenic nematodes
- Bacteria
- Viruses
- Fungi

Presentation tomorrow on use of NPV's, Bt, and nematodes





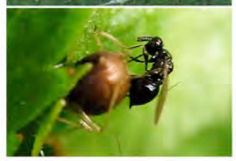
Notes:

Characteristics of Predation vs Parasitism

	Predator	Parasitoid
• Numbers consumed:	Many	One
• Physiological linkage:	None	Intimate
• Specificity	Low	High
• Foraging stage:	Juvenile + adult	Adult only

Forms of Parasitism

- Solitary versus gregarious
- Ecto- versus endo-parasitism
- Primary versus hyperparasitism



Notes:

Parasitoid life styles

➢ Endoparasitoids that allow the host to continue to feed and develop after attack

- Develop slowly from smaller eggs
- No host feeding
- Higher fecundity
- More specialized in host range

Notes:

Predator life styles (in orchards)

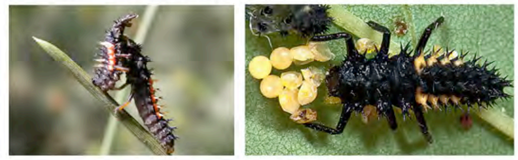
- Predation in larval stage only
  Chrysoperla, Hoverflies
- Predation in adult stage only
  Soldier beetles
- Predation in both juvenile and adult stages
  Ladybird beetles, *Chrysopa*, true bugs

Notes:

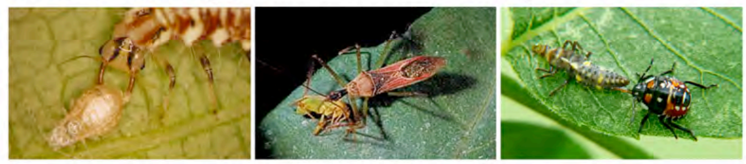
Notes:

Predator life styles

- *Cannibalism*:
  feed on other individuals of the same species



- *Intraguild predation*:
  feed on other species of natural enemy



Notes:

Predator life styles

- Chewing mouthparts
  No remains of prey
  Feeding time short

- Sucking mouthparts
  Leaves empty prey
  Feeding time longer

Notes:

Seasonality and phenology

- Overwinter as adults – flight in early spring
  Most ladybirds & true bugs, some hoverflies & parasitoids, *Chrysoperla plorabunda*

- Overwinter as mature juveniles – flight in summer
  Most lacewings & spiders, some hoverflies & parasitoids

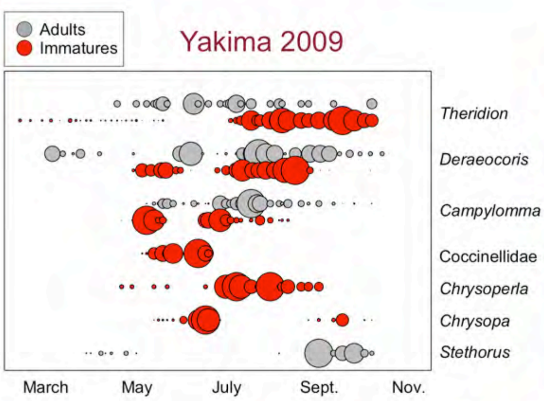
- Overwinter as eggs/young larvae – flight in summer
  Some true bugs & parasitoids

Seasonality and phenology

- Single generation each year
  - Spiders, some ladybirds & ground beetles
  - Slow recovery after disruption
- Multiple generations each year
  - Lacewings, hoverflies, true bugs, parasitoids
  - Within-season recovery after disruption

Notes:

Seasonality and phenology



Notes:

Summary

- Orchards support a high diversity of natural enemies that target different groups of arthropod pests as hosts or prey
- Two key groups of natural enemies are predators and parasitoids, and individual species vary from being highly specific on a few pest taxa to being highly generalized on numerous pest taxa

Notes:

Notes:

Summary

- Life history strategies of natural enemies can be complex and the seasonality and phenology of their activity (overwintering stage, timing and number of generations) are also highly diverse, which can complicate "management" of beneficials

Presentation 4: Exercise - Natural Enemy ID

Notes:

Natural enemy identification: Predaceous insects, parasitoids, and spiders

Gene Miliczky
USDA-ARS
Wapato, WA

Notes:

Natural enemies in orchards: Generalizations

- **Natural enemy diversity in orchards is high: for example – parasitoids, ladybeetles, spiders**
- **Order and family level ID relatively easy – can usually be done in the field**
- **Species ID of adults and immatures can be challenging – magnification needed**
- **Adults and their immatures may differ markedly**

Predatory true bugs: Order Hemiptera

- Piercing-sucking mouthparts / external digestion
- Front wings have a distinctive structure
- Adults and nymphs “similar” in appearance
- Order also contains many important pests

Notes:

Deraeocoris brevis: Hemiptera, Miridae

- Adult: shiny black; 3/16”
- Nymph: mottled white, grey, pink; rather spiny
- 5 nymphal stages: tiny to nearly as large as adult
- Prey: psylla, aphids, mites
- Similar size & shape to Lygus but black color distinctive

Notes:

Campylomma: Hemiptera, Miridae

- Adult: gray-brown to yellowish tan; ~ 1/10” long
- Nymph: pale green
- 5 nymphal stages: tiny to nearly adult size
- Prey: aphids, mites, psylla
- This species also has pest status in apples

Notes:

Notes:

Orius (pirate bug): Hemiptera, Anthocoridae

- Size of adult is < 1/10"; nymphs even smaller
- Oval (adult) or pear shaped (nymph); rather flattened
- Adult is black & white; nymph usually orangish
- Prey: thrips, mites, aphids, & other small items

Notes:

Anthocoris spp. – also a pirate bug

- Adults and nymphs similar in shape & color to Orius
- Adult size: ~0.1" – 0.2"; nymphs (5 stages): tiny to near adult size
- Common in pear orchards, less common in apple
- Prey: psylla, aphids, thrips, etc.

Notes:

Lacewings: Order Neuroptera

- Two types of interest: Green and Brown
- Adults and larvae very different in appearance
- Adults have chewing mouthparts
- Larvae have piercing mouthparts

Green lacewings: Chrysopidae

Delicate, green, weak-flying adult

Stalked eggs laid singly or in groups

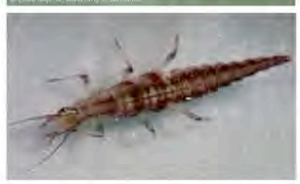
"Alligator-like" larva with large, pointed mouthparts

Cocoon contains larva or pupa

Notes:

Brown lacewings: Hemerobiidae

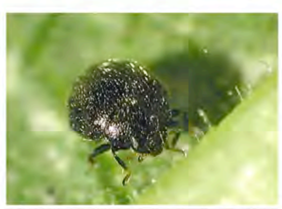
- Adults: delicate brown insects; rather weak flyers
- Larvae: elongate body; large, pointed mouthparts
- Eggs laid singly and are not stalked
- Prey: aphids, psylla, thrips



Notes:

Order Coleoptera: Beetles

- Largest insect order
- Front wings hard or leathery; not used for flight
- Adults and larvae: chewing mouthparts
- Larvae differ markedly in appearance from adults



Notes:

Notes:

Ladybird Beetles: Family Coccinellidae

- Many species are brightly colored
- Color pattern: varies little in some species but is highly variable in others
- Hemispherical or oval in shape
- Many are general predators of soft-bodied prey
- Some specialize on mites, scale, mealybugs
- Many species occur in PNW orchards (18+)

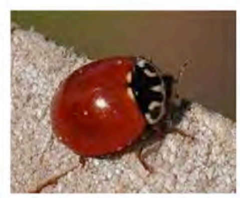
Notes:

Some common LB's in PNW orchards

Convergent

7-spot

Halloween

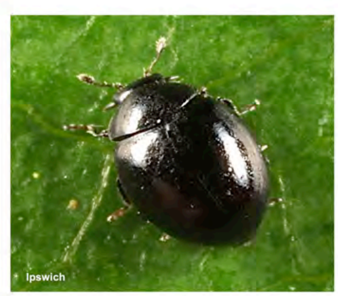


Polished

Notes:

Two specialist LB's in PNW orchards

Stethorus
mite predator



Microweisea
scale predator

Immature stages of Ladybird Beetles

Eggs spindle-shaped;
often yellowish;
laid in groups

Larva elongate with
spines & tubercles;
often has colorful markings

Notes:

Ground beetles: Family Carabidae

- Very large family of beetles
- Elongate, somewhat flattened
- Ground dwellers; rare in trees
- Adults and larvae predaceous; some may feed on codling moth
- Most are active at night
- Some species quite large: ½”+

Pterostichus – common on ground in orchards

Notes:

Order Diptera: true flies

- Front wings well developed for flight
- Hind wings much reduced; not used for flight
- Adults and larvae (maggots) differ in appearance, food preferences, and habitat

Notes:

Notes:

Family Syrphidae: flower- or hoverflies

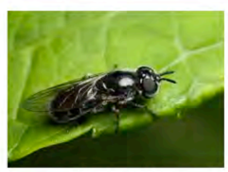
- Species of interest are aphid predators in the larval stage
- Larvae are typical maggots in appearance
- Adults of many species bear general resemblance to wasps or bees
- Adults feed on nectar and pollen and are of some benefit as pollinators

Notes:

Common syrphids in PNW orchards

Scaeva

Eupeodes



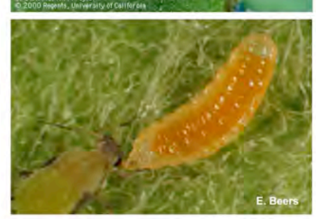
Heringia

Syrphid larva

Notes:

Cecidomyiidae: *Aphidoletes aphidimyza*

- Adult is a tiny, delicate fly; smaller than a mosquito
- Predaceous larva is orange and ~ 1/8” long
- Prey: aphids, thrips, mites, and other small insects



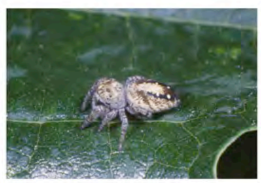
Spiders: Arachnida, Araneae

- Spiders have 8 legs and (usually) 8 eyes
- Spiders have 2 body regions
- All spiders are predaceous
- All spiders spin silk for webs, egg sacs, etc.
- Spider webs are highly variable in form but
- Many spp active hunters and do not spin webs
- Abundant/diverse in low insecticide orchards

Notes:

Common spiders in PNW orchards (1)


Jumper - *Phidippus*

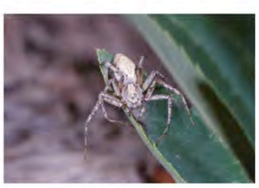

Jumper - *Pelegrina*


Crab - *Xysticus*

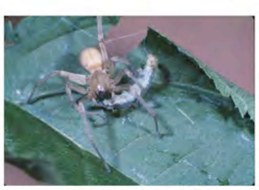

Crab - *Misumenops*

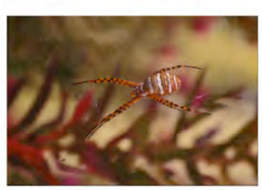
Notes:

Common spiders in PNW orchards (2)


Lynx spider - *Oxyopes*


Philodromus cespitum


Sac spider w / PLR


Orb-weaver in her web

Notes:

Notes:

Predatory mites: Arachnida, Acari

- Mites are relatives of spiders: have 8 legs and 2 body regions
- Most are tiny, barely visible to naked eye
- Predatory mites are the most important biocontrol agents of phytophagous mites
- Biocontrol of mites has several benefits

Notes:

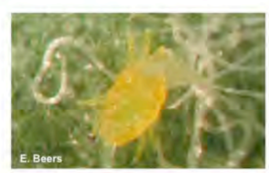
Typhlodromus occidentalis: western predatory mite

- Native to western U.S.
- Eggs are oval in shape
- Larval stage has only 6 legs
- Adult ~ 1/3 mm long and rather pear shaped
- Takes on color of recently consumed prey
- Prey: spider and rust mites

Notes:

Zetzellia mali: predatory mite

- Native to the U.S.
- Eggs are round and yellow
- Adults and immatures yellow but take on color of prey
- Oval in shape
- Prey: spider mites but will also take other predator mites



Insect parasitoids: general considerations

- Two important orders: Diptera & Hymenoptera
- Diptera represented by family Tachinidae
- Hymenoptera: 20+ families on trays and cards
- However, importance in orchard biocontrol, if any, of many of them is unknown
- Many of the Hymenoptera are very small and difficult to ID

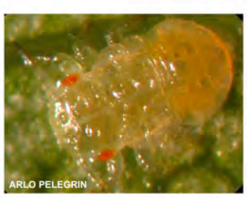
Notes:

Trechnites psyllae: pear psylla parasitoid

- Important pear psylla parasitoid in PNW
- Tiny wasp (~1/25") in family Encyrtidae
- Dark body, pale legs, metallic blue patch on dorsal surface
- Overwinters inside the host
- 1st gen. adults search flowers & buds for hosts
- Adults often stay on beat tray for some time

Notes:

Trechnites psyllae: pear psylla parasitoid



Pear psylla nymph

Trechnites adult

Parasitized nymph (mummy)

Notes:

Notes:

Aphelinus mali: wooly apple aphid parasitoid

- Primary importance is as a WAA parasitoid
- Tiny wasp (~1/25") in family Aphelinidae
- Black, non-metallic body w / pale band at base of abdomen
- Can be abundant in low insecticide orchards where the host is present
- Can be spotted on beat tray; may not fly immediately

Notes:

Aphelinus mali and its host

Aphelinus mali adult

WAA mummy showing *A. mali* emergence hole

Notes:

Colpoclypeus florus: leafroller parasitoid

- Wasp is native to Europe; established in PNW
- Adult is a tiny wasp (family Eulophidae)
- Several / many eggs laid per host
- Wasp larvae feed externally
- Hosts: PLR, OBLR, strawberry LR, et al.
- Best evidence for presence: Parasitized LR's
- Overwintering host is needed

Colpoclypeus florus: leafroller parasitoid

C. florus attacking OBLR

Feeding *C. florus* larvae

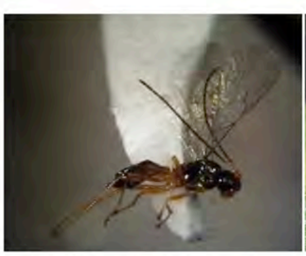
Notes:

Aphidiinae: aphid parasitoids

- Subfamily in the large family Braconidae
- All species are internal parasitoids of aphids
- Tiny, slender, brown or black wasps
- Parasitized aphids – “mummified” appearance
- Common rosy apple aphid parasitoids
- *Trioxys* sp. parasitizes walnut aphid in CA

Notes:

Aphidiinae: aphid parasitoids



Aphidiinae: *Trioxys* sp.

Aphid “mummy”

Notes:

Notes:

Tachinidae: parasitic flies

- Most important family of parasitoid flies
- Large group with 1000's of species
- Size varies greatly; have the "housefly" look
- Some have a marked "bristly" appearance
- Rarely show up on beat trays as they fly away
- Several species have been reared from our pest leafrollers

Notes:

Tachinidae: parasitic flies


Typical tachinid


Tachinid maggot and host

Presentation 5: NE Monitoring

NE Monitoring – Jones, Mills, Horton, Unruh, Shearer

Notes:

Overview

- Why monitor at all
  - Pests
  - Natural enemies
- Improving NE monitoring
  - "Messages" from monitoring
- SCRI accomplishments
  - Development of HIPV traps
  - Using traps to monitor management
- Summary

Notes:

HIPV Abbreviations

- AA – acetic acid
- AP – acetophenone
- GER - geraniol
- PAA – phenylacetaldehyde
- MS – methyl salicylate
- PE – 2 Phenyl ethanol
- GMP – GER + MS + PE
- SQ – squalene

Notes:

Notes:

Why monitor pests?

- Improved timing of treatments
- Spray only when & where needed
- Link severity of tactics to pest severity
- Decreased:
  - Management costs
  - Resistance potential
  - Export issues (MRL violations)
  - Secondary pest issues
- Improved
  - Worker safety
  - Environmental quality
  - Consumer acceptance

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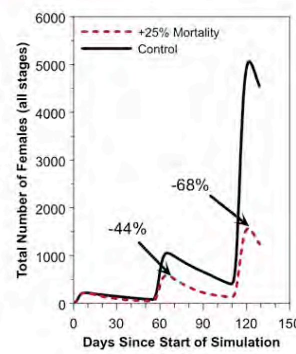
Notes:

Why monitor NE?

- NE provide pest suppression
  - Eliminate NE
    - Need to pay for mortality they provide
    - May affect multiple secondary pests
    - A small amount of mortality = big impact
- Timing of IPM tactics affects NE
  - Goal is to minimize impacts on NE
- Abundance and phenology of NE should guide tactics used



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Notes:

What you don't know can hurt you…

- Current NE sampling is inefficient
- Leads to false impressions
  - Nothing caught = BC unimportant
- Beating Trays
  - Samples insects only from the plant disturbed by the beat
  - Affected by daily activity patterns
  - Particularly poor for good fliers

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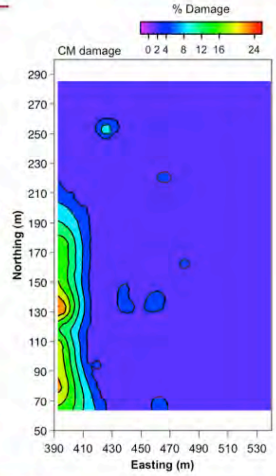
Can we improve NE monitoring?

- Herbivore-Induced Plant Volatiles (HIPVs)
  - Insect feeding = changed volatile bouquet
  - NE home in on certain volatiles
    - Restricts their search
    - Improves their ability to find pest at low density
    - Improved pest regulation
- HIPVs can often be bought off the shelf
  - Gives us ability to monitor NE



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Notes:

HIPV traps: *We have the technology..*

- Accumulate captures over time
  - Not sensitive to daily activity patterns
- Draw from entire active space
  - Within tree or between trees
- Very specific or very broad taxonomic response
  - Depends on lure/trap combination
- Primarily good for adult stages

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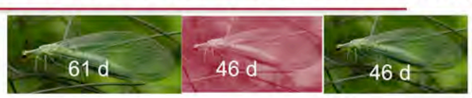
Notes:

Monitoring dictates perception and management



46 vs 153 days

Same 5 Orchards Sampled	Beating Tray	Attractant Traps
Sampling Frequency	2-3 times/wk	1 time per week
Sample Period	March-October	March-October
No. Samples per orchard	50 trees	4 traps
No. Caught	12	25,604
Message	Rare in space and time	Abundant throughout the season
Importance to BC & Management	None	Protect and use this NE!

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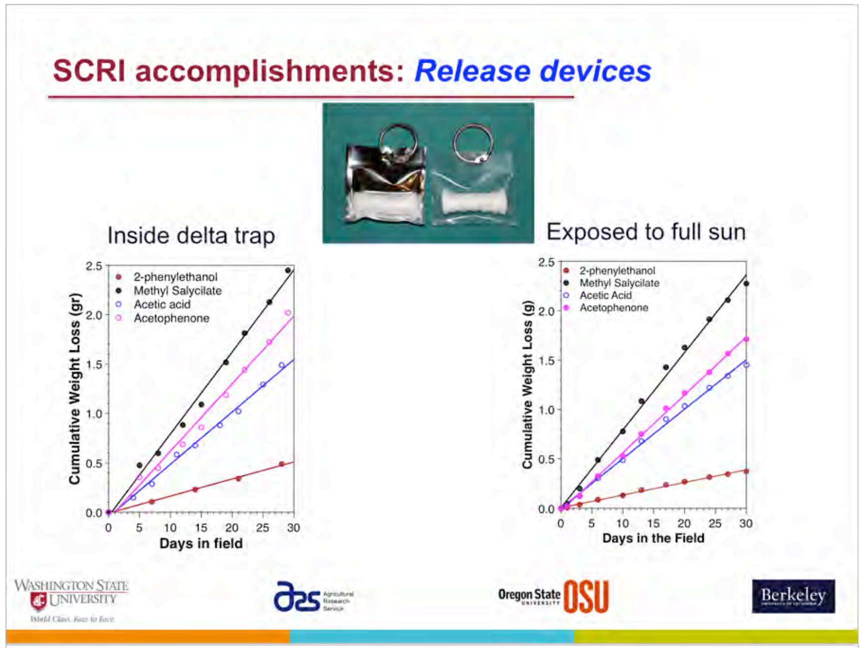
Notes:

Notes:



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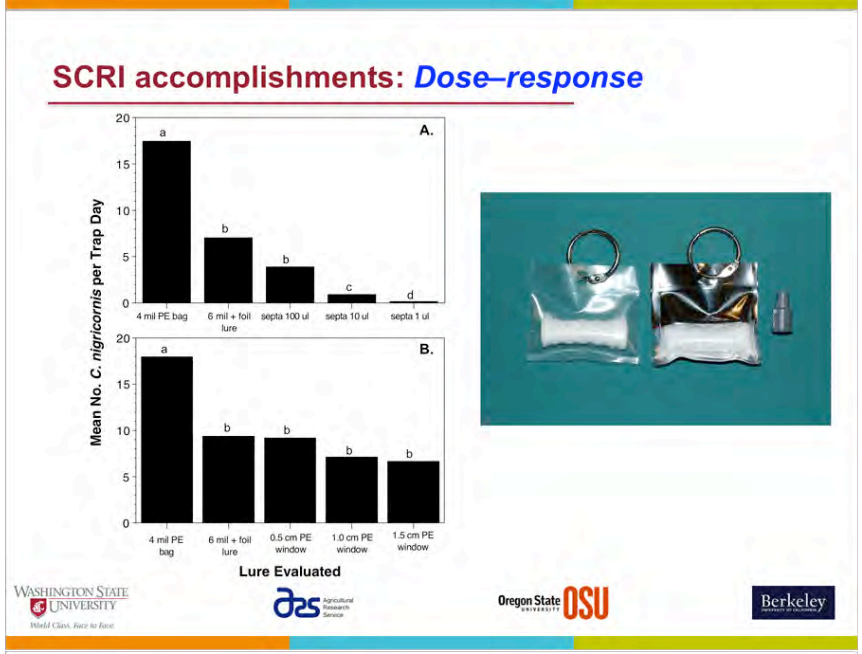

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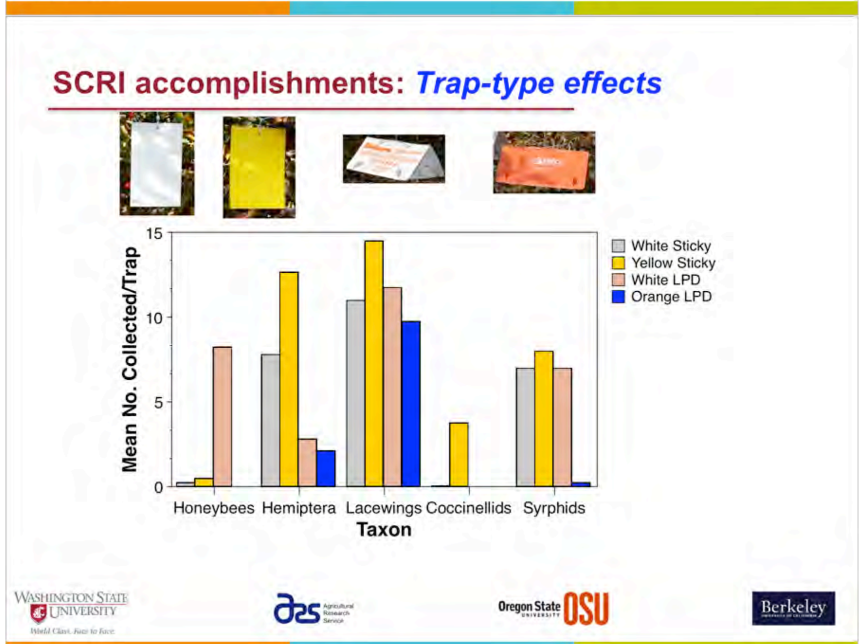
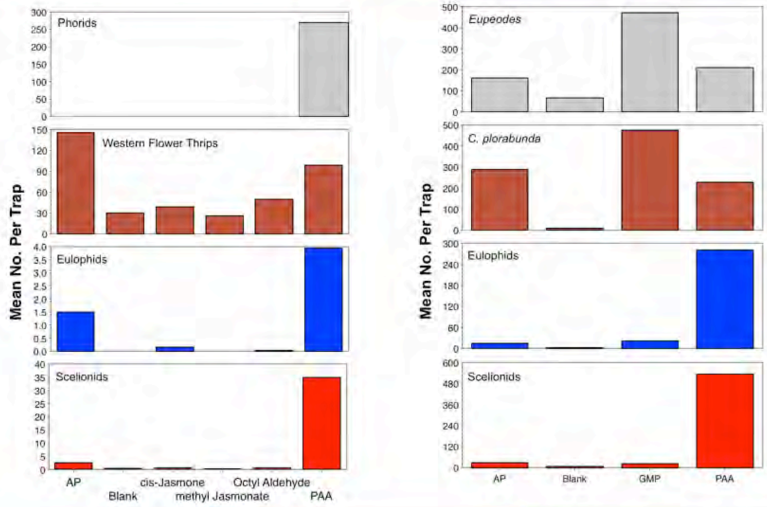
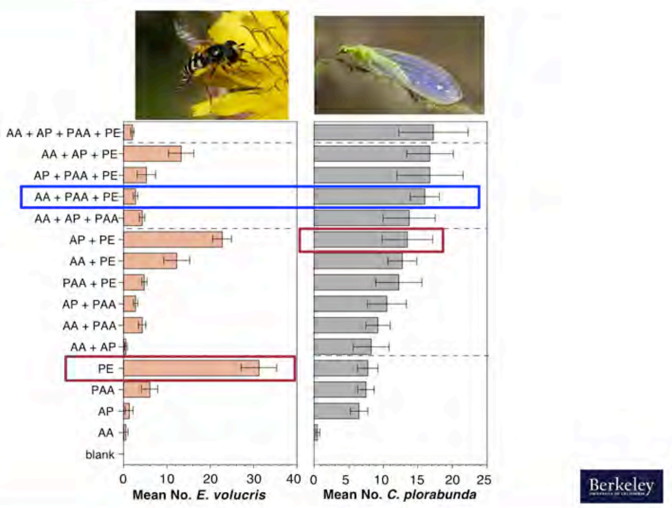


SCRI accomplishments: *Attraction of different NE*



Notes:

Importance of Blends – Factorial Experiments



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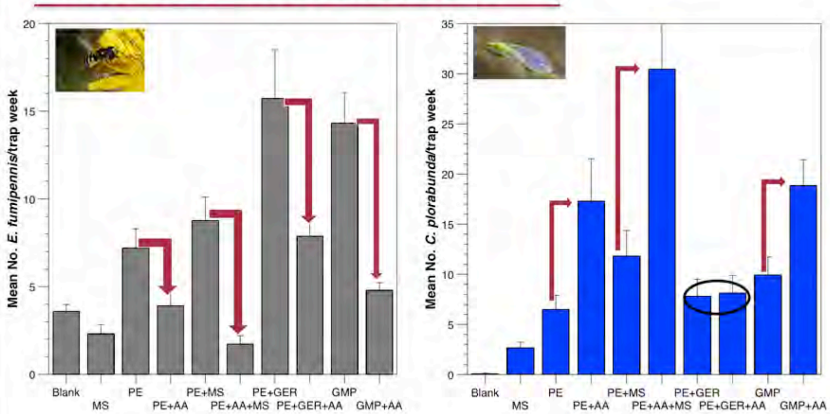
Notes:

Effect of AA – CA Walnuts 2011



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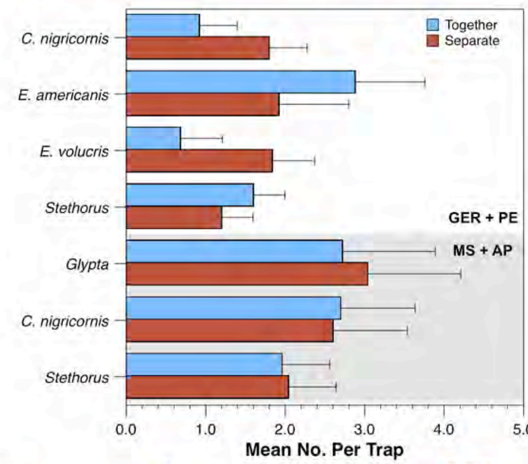
Notes:

Notes:

Mixing attractants – simpler lures



Notes:

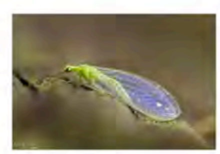
Attractants–Targets

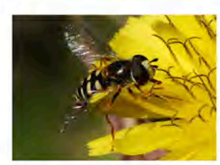
- Similar responses between crops
- Variability in response to attractants, even within closely related groups
- Specific
  - Squalene - only male *C. nigricornis*
- General
  - GMP
    - Lacewings
    - Syrphid flies
    - Broad diversity of parasitoids

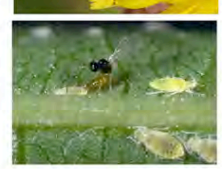
Notes:

Using general attractants

- Problem of information overload
- Focus on 1-few indicator species
  - Lacewings
  - Syrphids
  - Specific parasitoids
- Indicator species then can be used
  - Comparison of management tactics
  - Before-after pesticide treatments







Value of traps

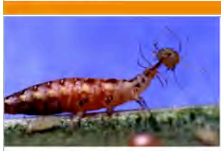
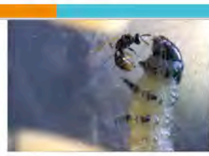
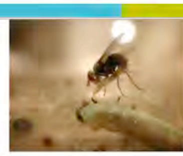
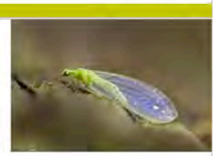
- You can readily see the "indicator" NE species
  - Brings the value of BC home!
- Evaluate how management effects NE complex
- Choose severity of tactics based on NE abundance
  - Act to correct imbalances in pest/NE

Notes:

Summary

- Monitoring is critical for stable IPM programs
- Good NE monitoring tools been developed
  - Looking for commercialization of lures
- Focus on several "indicator species"
  - Use to compare management programs
  - Before-After comparison for management tactics
- NE provide an important service
  - Stability of secondary pest populations
  - Eliminate NE, you must pay to replace their services
- HIPVs for NE monitoring ≈ pest pheromones for IPM

Notes:

Natural Enemy Phenology, Modeling, and IPM

Vince Jones

Department of Entomology, WSU-Tree Fruit Research and Extension Center, Wenatchee, WA

Presentation 6: NE Phenology, Modeling and IPM

Notes:

Notes:

Overview

- Why model NE?
- Differences in predator and parasitoid models
- Basis of models and how they are developed
  - Laboratory studies
  - Field studies
- Windows of opportunity
- SCRI grant contributions
- Getting the information to the pest manager

Notes:

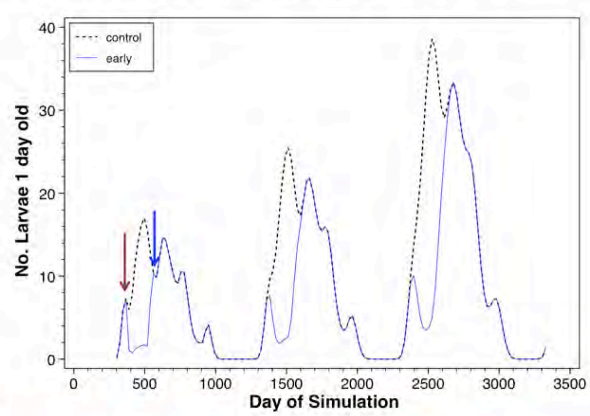
Why model NE?

- NE reduce pest pressure & stabilize system
  - Eliminate NE, expect to pay for it!
- Minimize exposure of NE to pesticides
  - In Space
  - In Time
- Only certain stages are exposed to pesticides
  - “Windows of Opportunity”
- Sensitive times in NE life history
  - “Windows of Trouble”
- New models provide more than just phenology

Notes:

Why are management programs unstable?

- Pesticides are applied at specific time for pest
- NE phenology unknown – effects are random



Why are management programs unstable?

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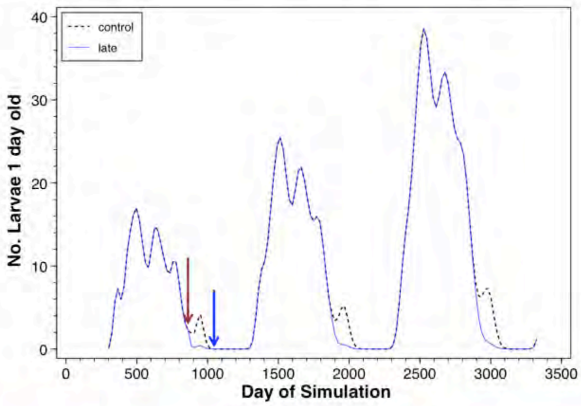
- NE phenology unknown – effects are random



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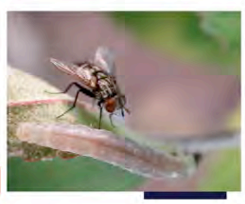
Notes:

Predator vs parasitoid models

- Parasitoids
  - Rigidly associated with a particular host stage
  - Some are very specific
    - Only certain ages/sizes attacked
    - Only certain pests attacked
  - Some are generalists
- May be able use the pest model
  - Avoid sprays when parasitoids are present
  - Windows of opportunity!



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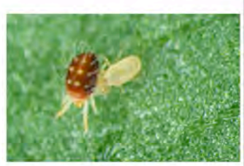
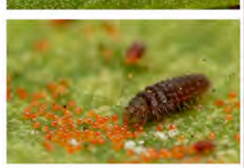
Notes:

Predator Models

- Free-living
- Often only loosely associated with prey
- May attack multiple pests
  - May switch depending on abundance
- Models are more difficult to develop
  - Harder to sample
  - Prey presence/absence may distort phenology
  - May have extensive overlap in generations





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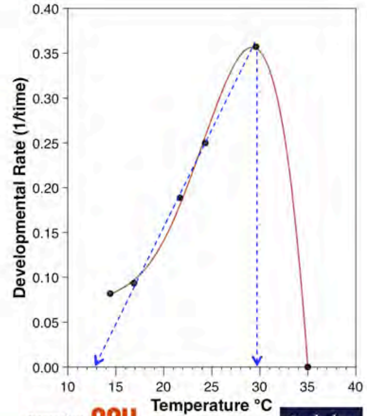
Notes:

Notes:

Laboratory Studies

How models work

- Insect temperature ≈ air temperature
- Development driven by heat
  - Amount needed is constant
  - Accumulation rate not important
- Thresholds
  - Lower
  - Upper
- Heat Units are Degree-Days

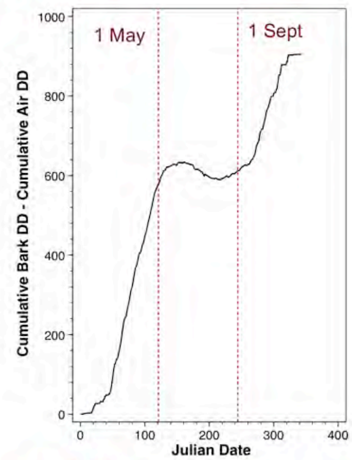


Notes:

Field Studies

Importance of Environmental Data

- Environmental data must reflect where insects are developing
  - Station placement
  - Solar radiation
- Orchard architecture/management
  - Tree density
  - Overhead cooling

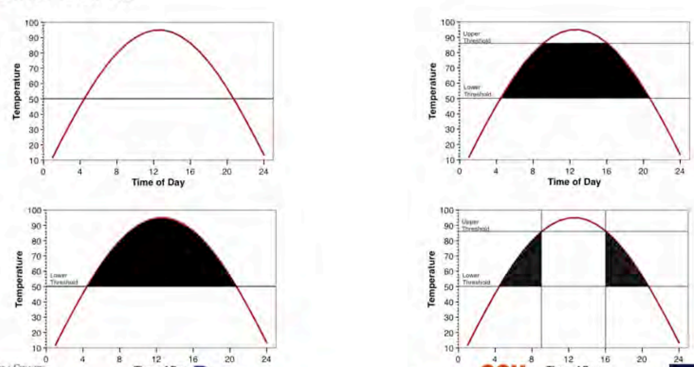


Notes:

Field Studies

Calculating Heat Units (Degree-Days)

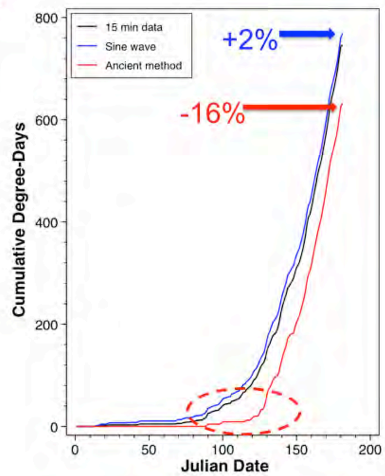
- Ancient Method
  - $DD = \frac{(\max + \min)}{2}$
- Sine Curve



Field Studies

Accuracy of Methods

- If 15 min data are the standard:
  - Sine wave over slightly
  - Ancient method grossly low
    - Particularly problem in spring
- Sine wave is broadly used
  - Data are easier to obtain
  - Accuracy loss is minimal
  - Most insect models have used this since late 1960's

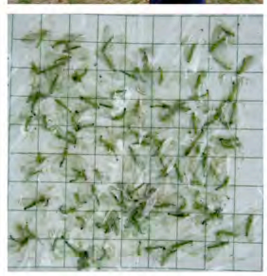


Notes:

Field Studies

Field Validation

- Need multiple years, multiple sites
  - Variability in conditions and weather patterns
  - Need pests for NE presence
- Reliable sampling method
- Unsprayed or "lightly" treated orchards
- Pesticides change apparent phenology



Notes:

SCRI Project Work

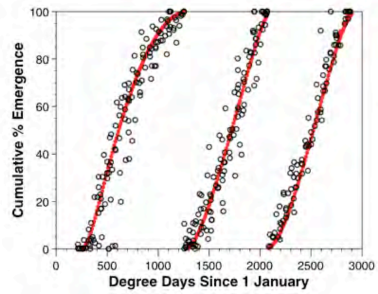
- Monitoring NE in apple, pear, walnut, sweet cherry
  - Multiple years, multiple sites/crop
- Temperature data in each location
- Some data sets are more restricted
  - Walnut aphid parasitoid
  - Woolly apple aphid parasitoid
- Most models have not been started
  - Expect models for lacewings, syrphid flies
  - Walnut aphid parasitoid
  - Woolly apple aphid parasitoid

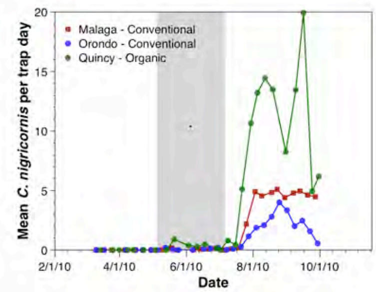
Notes:

Notes:

SCRI Contributions

Predator Models – *C. nigricornis*





apple, walnut, sweet cherry

sweet cherry is missing gen 1

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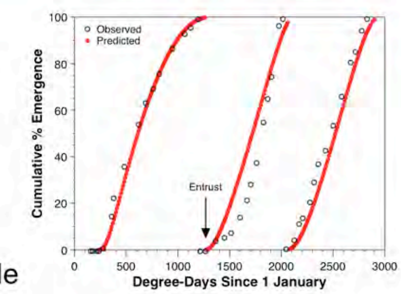
Notes:

SCRI Contributions

Distortion of phenology in field

- Distortion may be subtle
- Estimator of pesticide effects
- Multiple factors important
  - Amount of mortality
  - Duration of mortality
  - When mortality occurs
- Working on quantifying pesticide effects



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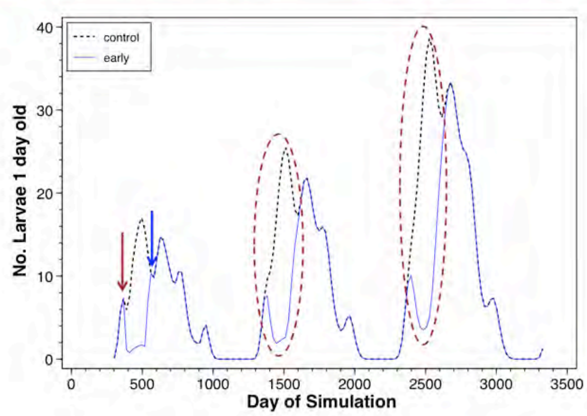
Notes:

SCRI Contributions

Timing effects and persistence of effects



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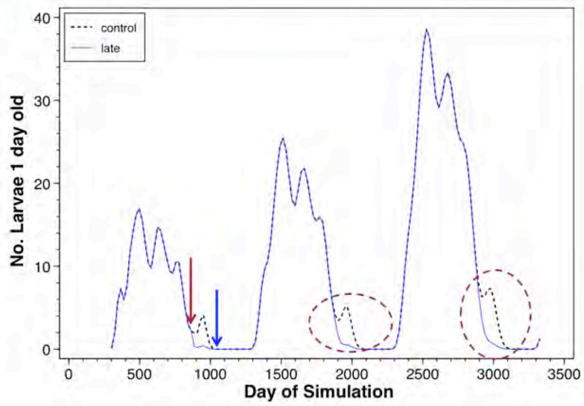
SCRI Contributions

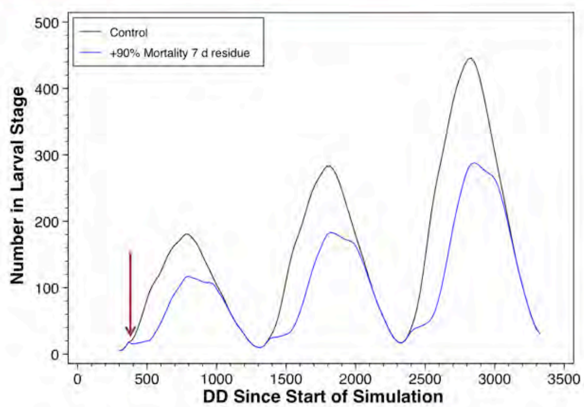
Timing effects and persistence of effects



Notes:

SCRI Contributions

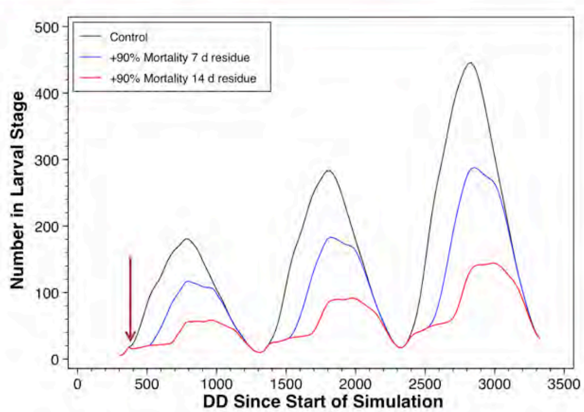
Longevity of Residue



Notes:

SCRI Contributions

Longevity of Residues



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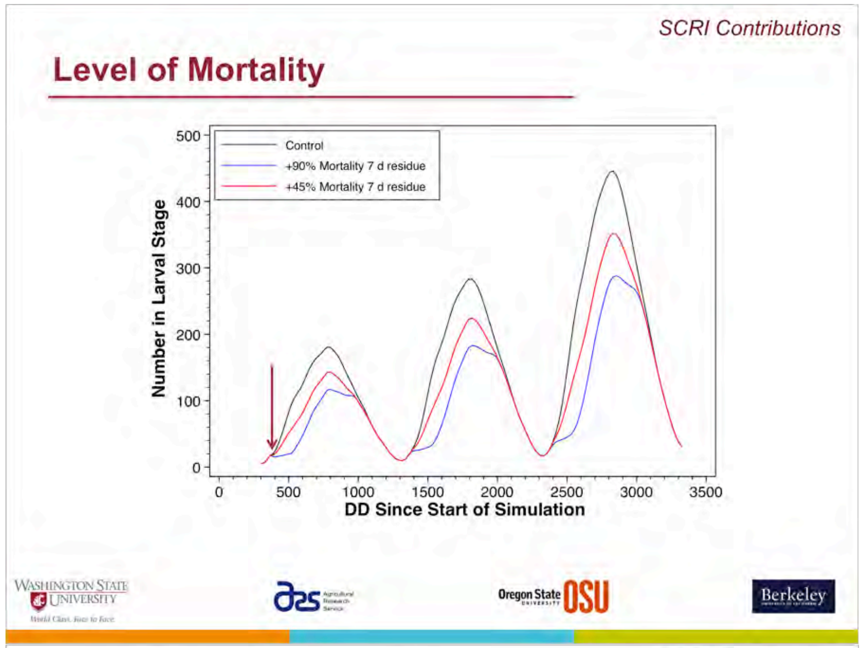

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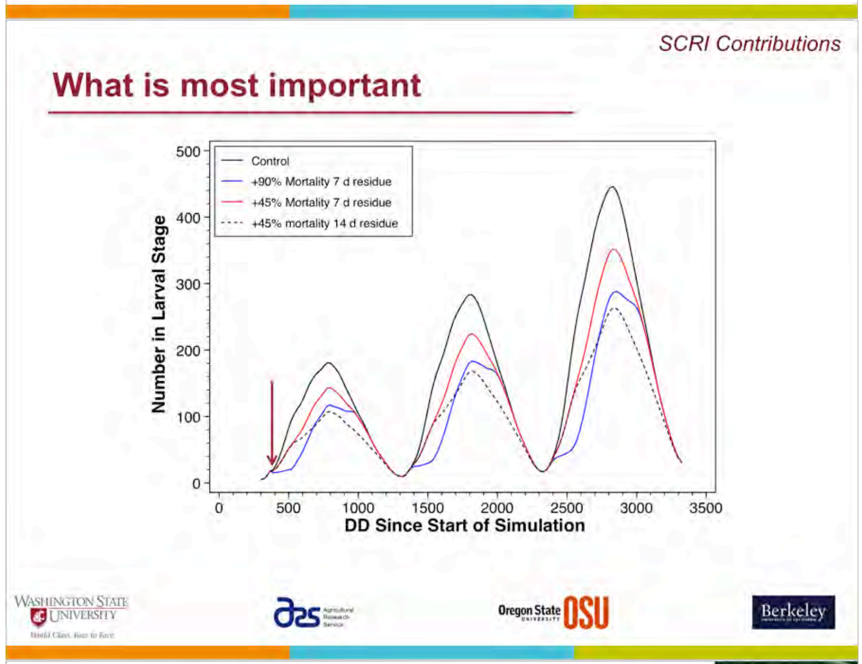

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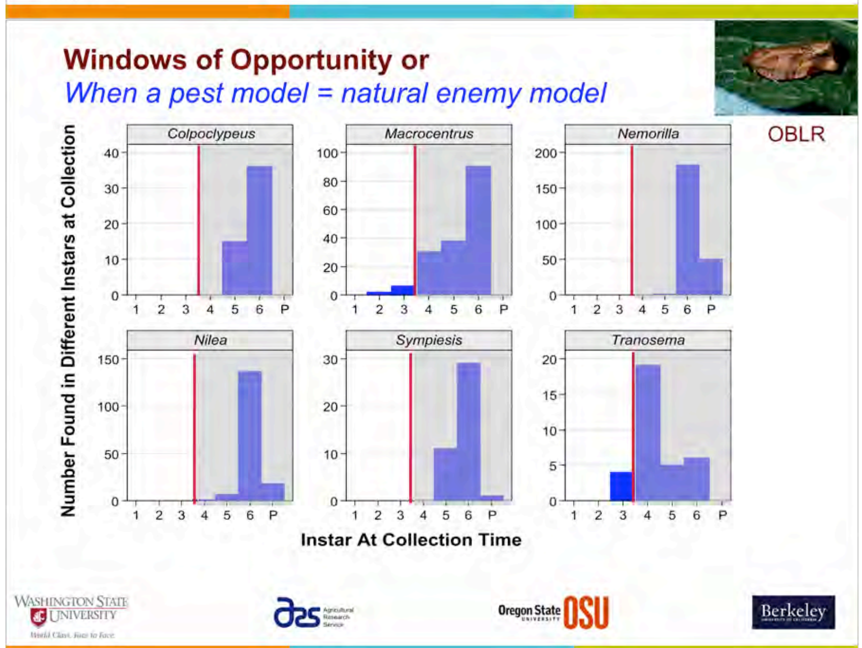
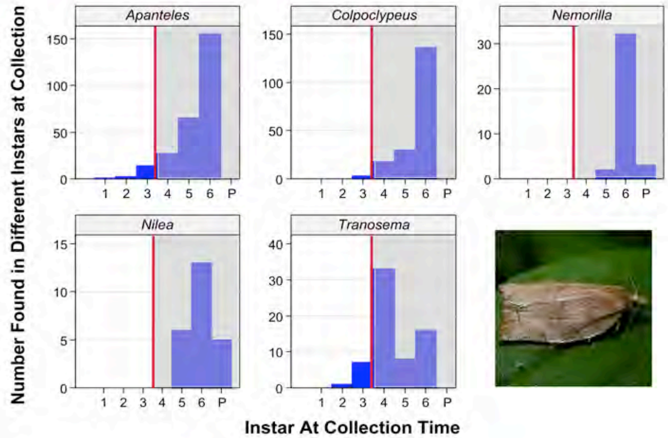


Windows of Opportunity



Notes:

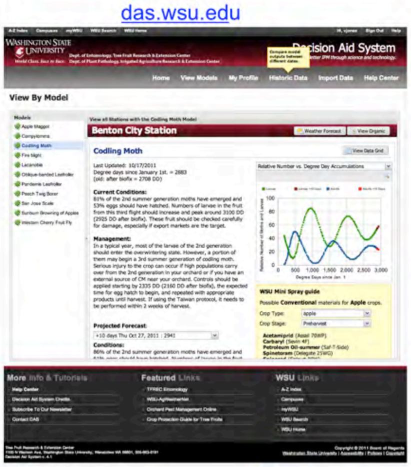
And the experts say…..

- Q1: You've used models for pests, do you think the same ideas will work for NE?
- Q2: Do you use the leafroller models on DAS and the recommendations to preserve NE?
- Q3: Would you be interested in NE phenology and how it could help your IPM program?
- Q4: How would you like information about NE phenology presented?

Notes:

Getting the information to pest manager

das.wsu.edu



enhancedbiocontrol.org

Notes:

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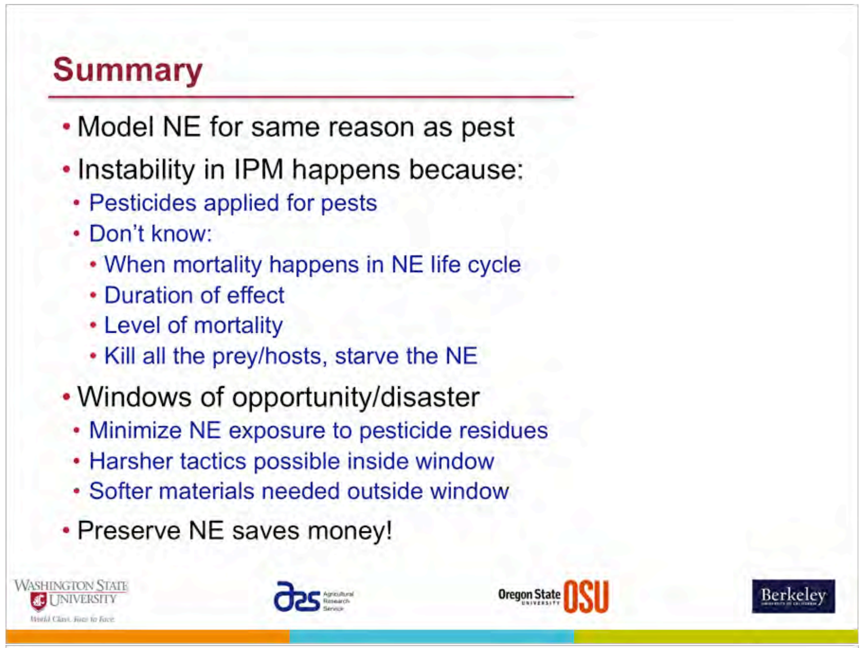
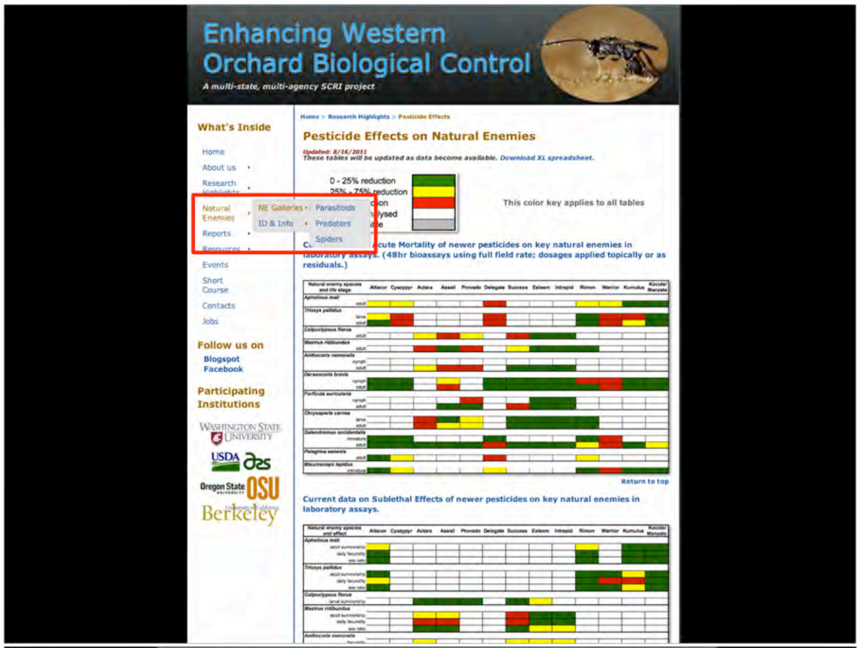


Presentation 7: BC Resources on the Web

Notes:

(A full list of web resources is on page 197 in this workbook.)

Notes:



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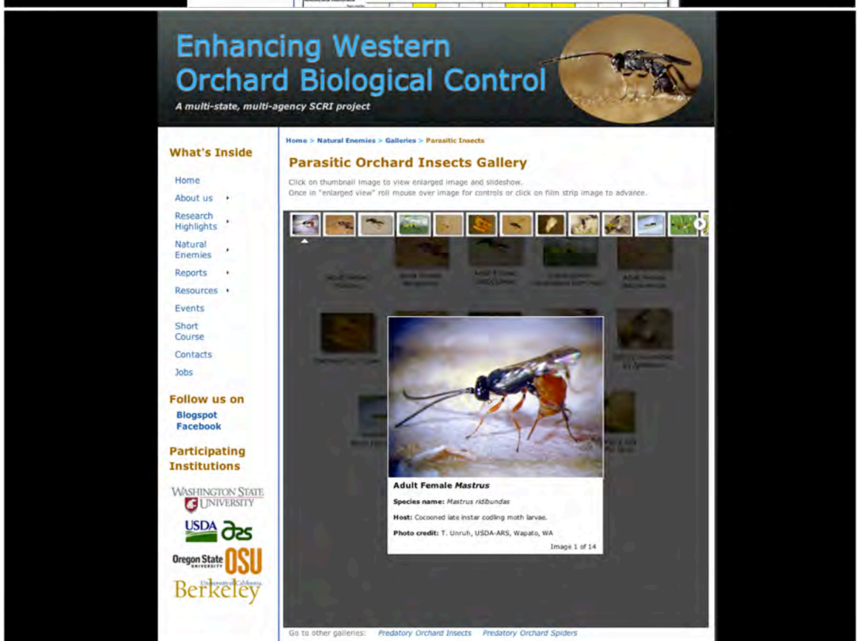

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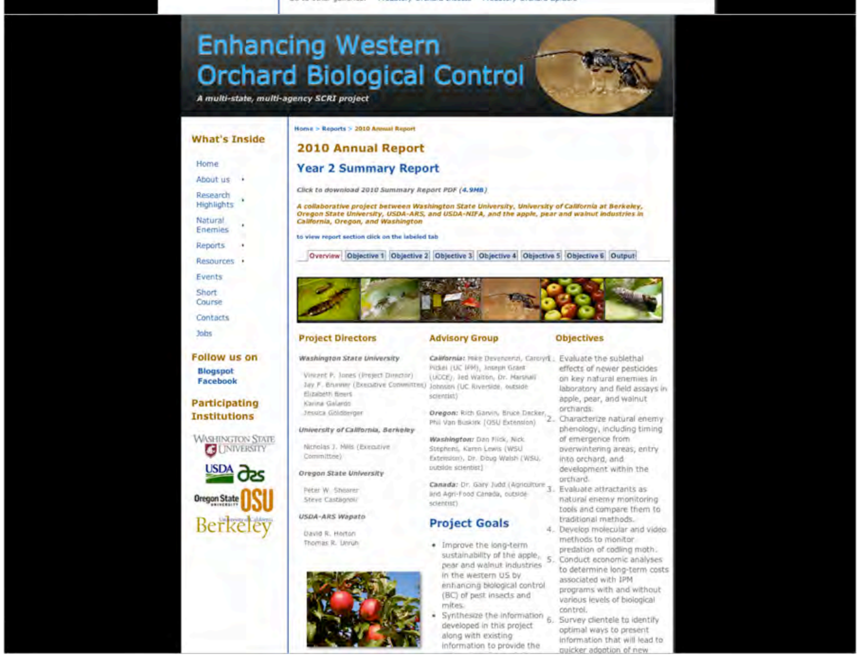

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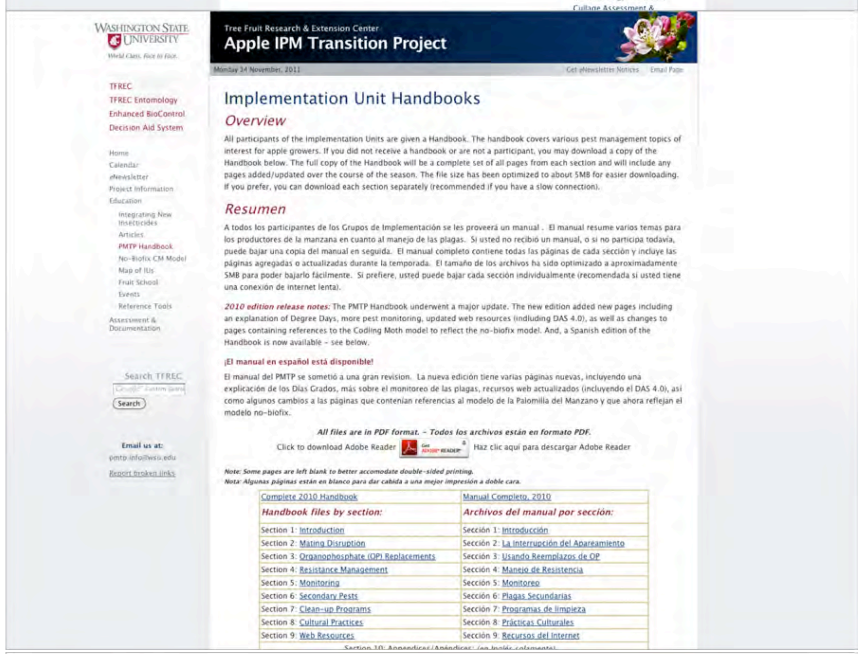

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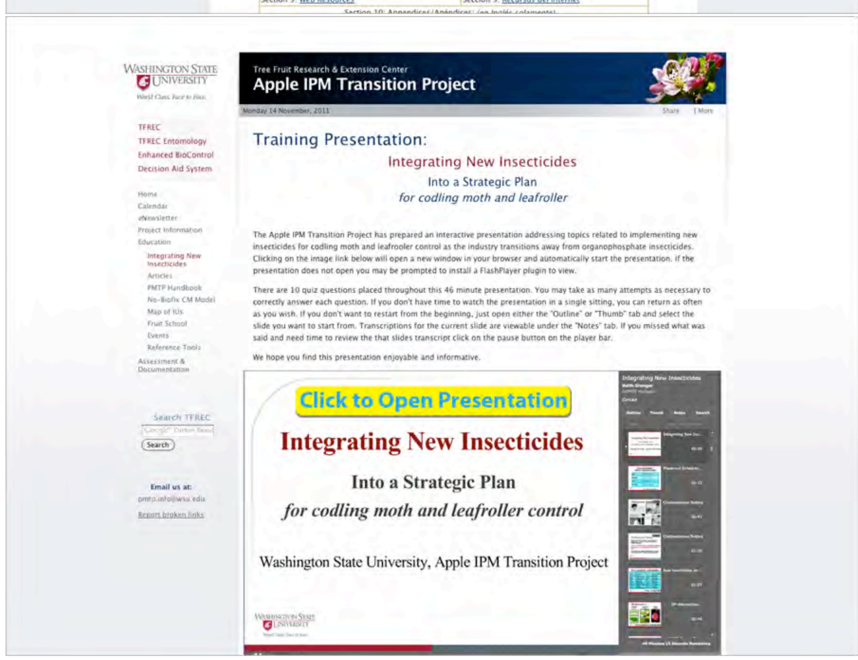
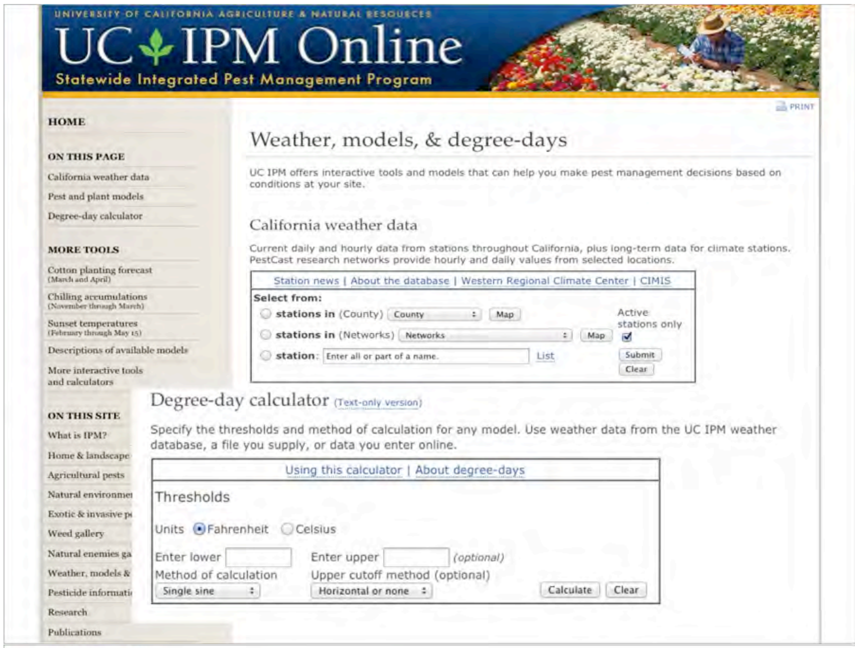



UNIVERSITY OF CALIFORNIA AGRICULTURE & NATURAL RESOURCES

UC IPM Online

Statewide Integrated Pest Management Program

HOME

ON THIS PAGE

California weather data

Pest and plant models

Degree-day calculator

MORE TOOLS

Cotton planting forecast (March and April)

Chilling accumulations (November through March)

Sunset temperatures (February through May 15)

Descriptions of available models

More interactive tools and calculators

ON THIS SITE

What is IPM?

Home & landscape

Agricultural pests

Natural environme

Exotic & invasive p

Weed gallery

Natural enemies ga

Weather, models &

Pesticide informati

Research

Publications

PRINT

Weather, models, & degree-days

UC IPM offers interactive tools and models that can help you make pest management decisions based on conditions at your site.

California weather data

Current daily and hourly data from stations throughout California, plus long-term data for climate stations. PestCast research networks provide hourly and daily values from selected locations.

Station news | About the database | Western Regional Climate Center | CIMIS

Select from:

stations in (County) County Map

stations in (Networks) Networks Map

station: Enter all or part of a name. List

Active stations only

Submit

Clear

Degree-day calculator (Text-only version)

Specify the thresholds and method of calculation for any model. Use weather data from the UC IPM weather database, a file you supply, or data you enter online.

Using this calculator | About degree-days

Thresholds

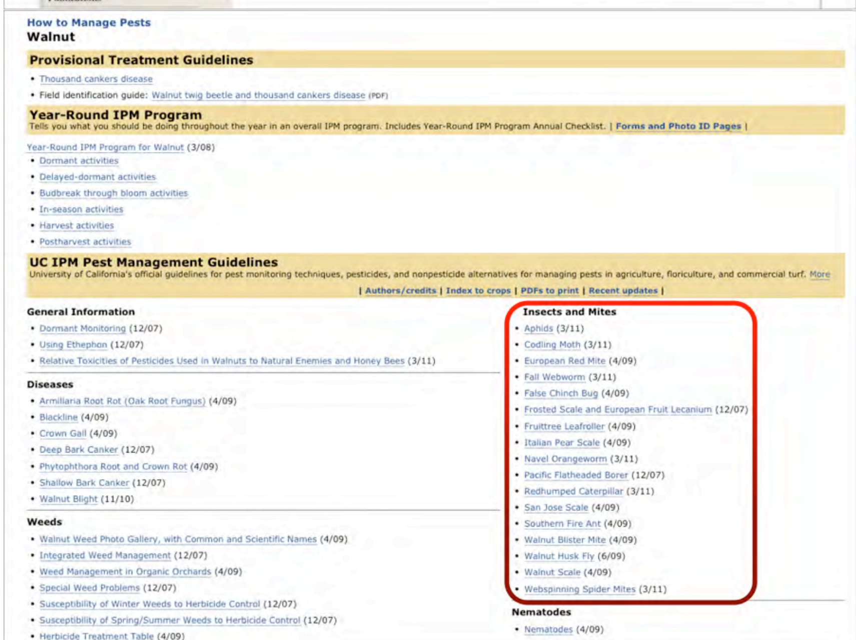
Units Fahrenheit Celsius

Enter lower Enter upper (optional)

Method of calculation Upper cutoff method (optional)

Single sine Horizontal or none Calculate Clear

Notes:


How to Manage Pests

Walnut

Provisional Treatment Guidelines

- Thousand cankers disease
- Field identification guide: Walnut twig beetle and thousand cankers disease (PDF)

Year-Round IPM Program

Tells you what you should be doing throughout the year in an overall IPM program. Includes Year-Round IPM Program Annual Checklist. | Forms and Photo ID Pages |

Year-Round IPM Program for Walnut (3/08)

- Dormant activities
- Delayed-dormant activities
- Budbreak through bloom activities
- In-season activities
- Harvest activities
- Postharvest activities

UC IPM Pest Management Guidelines

University of California's official guidelines for pest monitoring techniques, pesticides, and nonpesticide alternatives for managing pests in agriculture, floriculture, and commercial turf. More | Authors/credits | Index to crops | PDFs to print | Recent updates |

General Information

- Dormant Monitoring (12/07)
- Using Ethephon (12/07)
- Relative Toxicities of Pesticides Used in Walnuts to Natural Enemies and Honey Bees (3/11)

Diseases

- Armillaria Root Rot (Oak Root Fungus) (4/09)
- Blackline (4/09)
- Crown Gall (4/09)
- Deep Bark Canker (12/07)
- Phytophthora Root and Crown Rot (4/09)
- Shallow Bark Canker (12/07)
- Walnut Blight (11/10)

Weeds

- Walnut Weed Photo Gallery, with Common and Scientific Names (4/09)
- Integrated Weed Management (12/07)
- Weed Management in Organic Orchards (4/09)
- Special Weed Problems (12/07)
- Susceptibility of Winter Weeds to Herbicide Control (12/07)
- Susceptibility of Spring/Summer Weeds to Herbicide Control (12/07)
- Herbicide Treatment Table (4/09)

Insects and Mites

- Aphids (3/11)
- Codling Moth (3/11)
- European Red Mite (4/09)
- Fall Webworm (3/11)
- False Chinch Bug (4/09)
- Frosted Scale and European Fruit Lecanium (12/07)
- Fruittree Leafroller (4/09)
- Italian Pear Scale (4/09)
- Navel Orangeworm (3/11)
- Pacific Flatheaded Borer (12/07)
- Redhumped Caterpillar (3/11)
- San Jose Scale (4/09)
- Southern Fire Ant (4/09)
- Walnut Blister Mite (4/09)
- Walnut Husk Fly (6/09)
- Walnut Scale (4/09)
- Webspinning Spider Mites (3/11)

Nematodes

- Nematodes (4/09)

Notes:


Predators

A predator is an organism that attacks, kills, and feeds on several to many other individuals (its prey) in its lifetime.

Common name	Scientific name
Assassin bugs	Reduviidae family
Syrphid flies	Syrphidae family
Twicestabbed lady beetle	*Chilocorus orbus*
Vedalia beetle	*Rodolia cardinalis*
Western predatory mite	*Galendromus occidentalis*

Insect parasites (parasitoids)

Larval stages of insect parasites feed on or inside of other insects, killing their hosts. Adults are free-living wasps or flies.

Common name	Scientific name
Anaphes species	*Anaphes iole*, *Anaphes nitens*, and other *Anaphes* spp.
Aphidius species	*Aphidius* spp.
Aphytis spp., armored scale parasites	*Aphytis* spp.
Bracon cushmani, grape leaffolder parasite	*Bracon cushmani*
Citrus mealybug parasite	*Leptomastix dactylopii*
Cotesia medicaginis, alfalfa butterfly parasite	*Cotesia medicaginis*
Cottony cushion scale parasite	*Cryptochaetum iceryae*
Elm leaf beetle parasite	*Erynniopsis antennata*
Encarsia formosa, whitefly parasite	*Encarsia formosa*
Hyposoter exiguae, caterpillar parasite	*Hyposoter exiguae*
Lysiphlebus testaceipes, aphid parasite	*Lysiphlebus testaceipes*
Tachinid flies	Tachinidae family
Trichogramma spp., egg parasites	*Trichogramma* spp.
Trioxys pallidus, walnut aphid parasite	*Trioxys pallidus*

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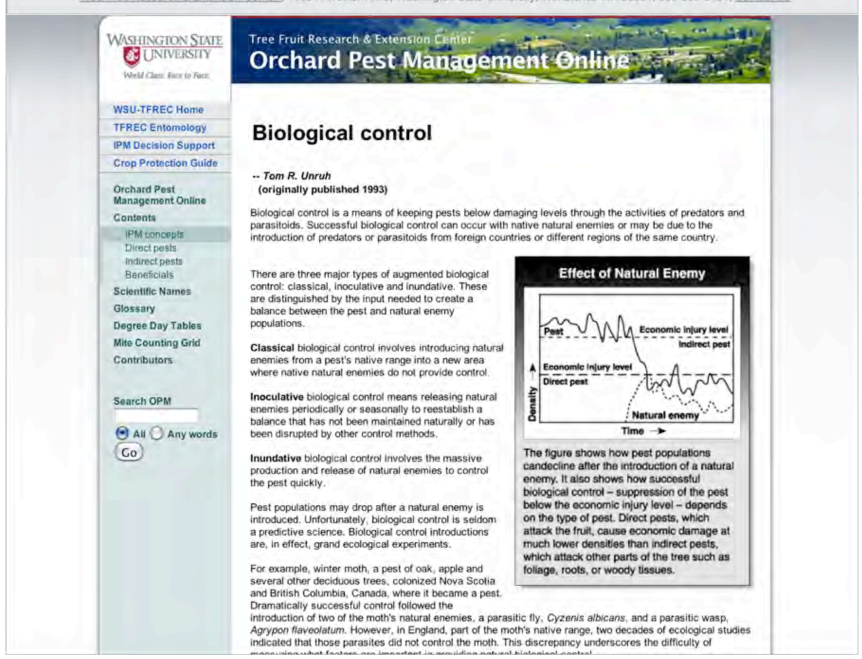

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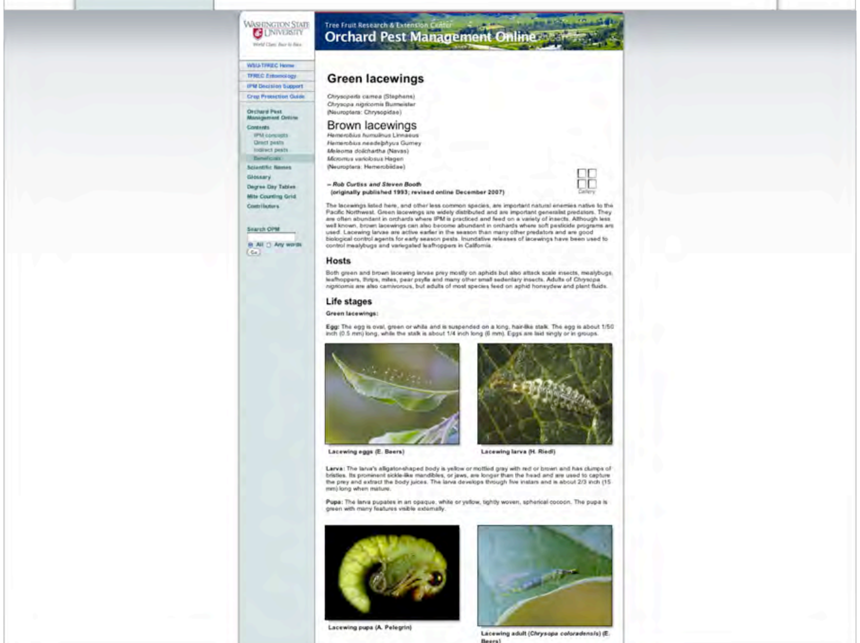

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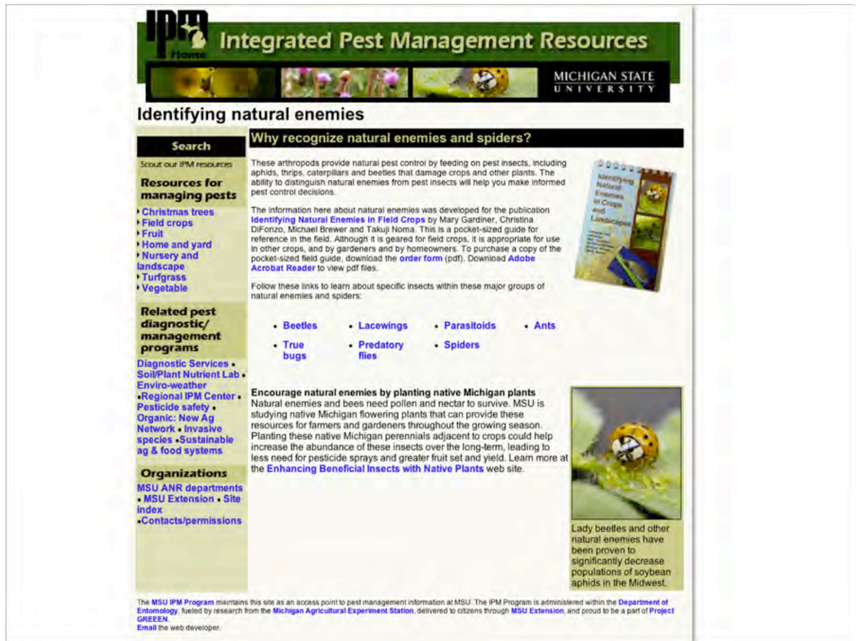

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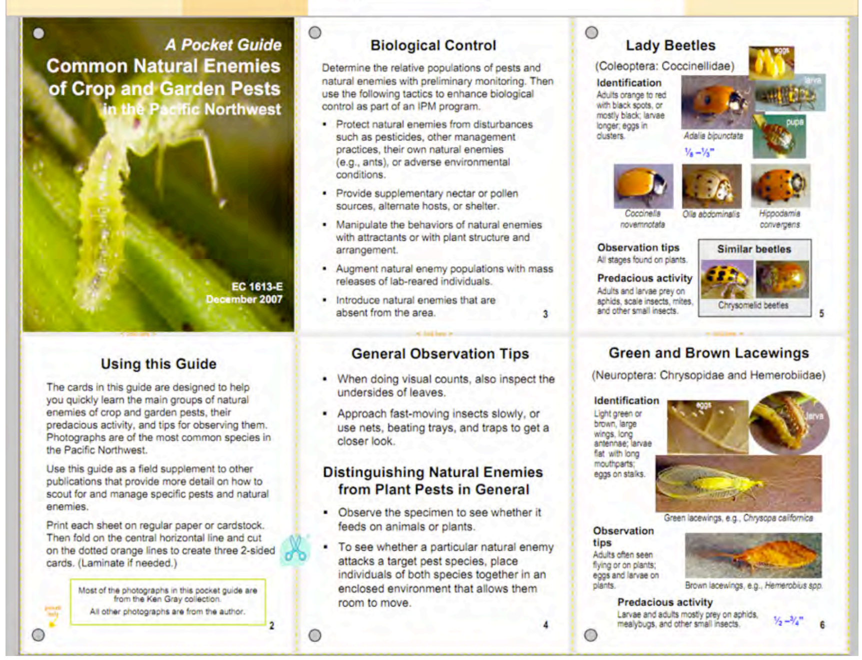

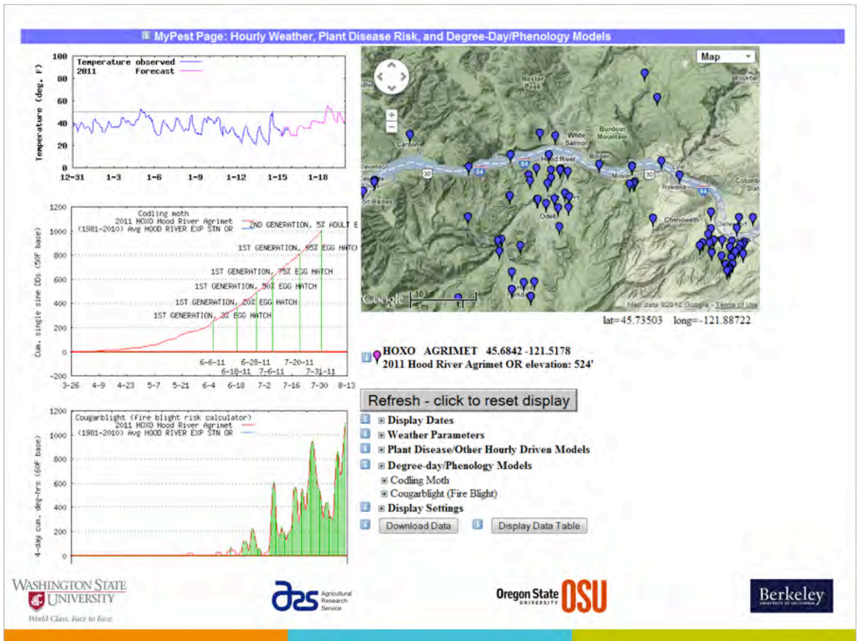

Notes:

2011 Pacific Northwest Insect Management Handbook

Chapter: Tree Fruit Section: Pear

http://pnwpest.org/pnw/insects

Pear—Pear psylla

(Cacopsylla pyricola) **ID photos:** A D E I fact page (pdf):

Pest description and crop damage Pear psylla is one of the major pear pests in commercial orchards.

The adult resembles a miniature cicada. Adults have two distinct forms, a summer and winter form, which differ in appearance. Winterform adults are 0.1 inch long, dark in appearance, with transparent wings held rooflike over the body. Summerform adults are 0.08 inch long, greenish to brown, with a similar wing appearance to winterform. The nymphs pass through five growth stages, each stage being larger, flatter, and more oval than the last. The first stage is creamy yellow, the last is dark green or brown. All stages have conspicuous red eyes. During the first three stages, the nymphs are encased in a drop of honeydew. Nymphs and adults suck plant juices, producing honeydew that drips onto leaves and fruit. This encourages growth of sooty mold, which causes russetting of the skin. Blackening and burning of leaf tissue also is typical of psylla infestations. Large numbers of psylla can stunt and defoliate trees and cause fruit drop.

Biology and life history Pear psylla overwinter in a dormant state as winterform adults on a variety of fruit trees. They return to pears and begin laying eggs at bud swell. The eggs are shaped like grains of rice and are yellow-orange at maturity. These are laid at the base of buds and in other rough places on small twigs. Egg laying continues for some time. Later eggs are laid along leaf midveins and petioles, and on stems and sepals of blossoms. The nymphs hatch and feed on the opening blossoms and young leaves, forming droplets of honeydew on both leaf surfaces. There may be two to three generations before the winterform generation appears in the fall.

Scouting and thresholds Monitor adults by placing a white cloth or paper under a limb and then jarring the limb to knock them onto the paper, starting in March. Check with a hand lens for eggs and nymphs on young shoots and leaves.

Management—biological control

A number of natural enemies attack psylla, including parasitic wasps, adults and larvae of ladybeetles, lacewings, and earwigs, as well as predacious plant bugs and minute pirate bugs. If natural enemies are conserved within the orchard, biological control of this pest often can be significant. Temperatures above 90°F may inhibit egg-laying and desiccate nymphs.

Management—cultural control

Avoid promoting unnecessary vigor with excess fertilizer and/or water. Remove suckers from the interior of the trees, which removes psylla eggs and nymphs and increases spray coverage.

Management—chemical control: HOME USE

Dormant-season spray

Use enough water to cover all of the tree thoroughly including small limbs and shoots. Spray timing can vary from early February to late March depending on location. Apply only during dormant or delayed-dormant period.

1. lime sulfur mixed with superior-type oil

2. superior-type oil

Growing-season spray

1. azadirachtin (neem extract)—If control is not satisfactory, add minimal rates of superior oil. Products containing neem extract may be phytoxic to some pear cultivars.

Notes:

2011 Pacific Northwest Insect Management Handbook

Chapter: IPM, Symps, Biocontrol, Slugs Section: Biological Control

< Previous . . . Next >

Biological Control

Amy J. Dreves, Leonard Coop, Mario Ambrosino, and Jeff Miller

Last reviewed—12/10

Introduction

Biological control (or biocontrol) is a key component in establishing an ecological and integrated approach to pest management. We define biological control as "the decline in pest density as a result of the presence of natural enemies." The degree of pest decline might result in partial or complete pest suppression. We use the terms "natural enemies," "beneficials," and "biocontrol agents" synonymously to refer to predators, parasites (or parasitoids), and diseases of pests.

Normally, natural enemies reproduce on their own and are self-sustaining, compatible in combination with other integrated control tactics, and are not harmful to other aspects of the ecosystem. Generalist natural enemies (such as most aphid predators) can switch readily among alternative food sources. Thus, when pest numbers are low, the generalist natural enemies may maintain population numbers by consuming other prey. Specialist natural enemies(such as most parasitic wasps) depend on one or a few food choices and usually increase and decline with the pest population (after a certain lag period). Thus, natural enemies, especially a combination of generalists and specialists, can be an extremely useful part of pest management programs that recognize and encourage their activity.

On the other hand, natural enemies can be disrupted by chemicals, can struggle in poor habitat with low pest numbers, are in some cases difficult to sample, and may be incapable by themselves of suppressing pests below damage thresholds.

In addition to the philosophy of "doing nothing" in order to allow natural biological control to work, there are three principal approaches involving human activity:

1. Classical biological control

2. Augmentative biological control

3. Conservation biological control

Classical biological control

Classical biological control is the importation of natural enemies for release and permanent establishment in a new region. In the Pacific Northwest, we have had very few cases of highly successful classical biocontrol in agriculture. One successful biocontrol agent, the filbert aphid parasite, *(Trioxys pallidus)* , was imported from Europe and introduced (in small numbers) by OSU scientists in the mid-1980s. Since then, this tiny wasp has spread throughout the growing region and increasingly maintains the filbert aphid below treatment thresholds. In another case, the spread of and damage by the apple ermine moth, *(Yponomeuta malinellus)* , has been greatly reduced by the successful introduction of a wasp parasite, *(Ageniaspis fuscicollis)* in the late 1990s. An egg-larval parasitoid, *(Ascogaster quadridentatus)* (Braconidae) was introduced as a control for the codling moth, a key pest of apple and pear. Economic success of this introduction is unknown; however, recovery of this parasitoid has been reported from codling moth bodies.

Ongoing PNW classical biocontrol efforts include programs directed at cereal leaf beetle, Russian wheat aphid, orchard leafrollers, larch casebearer, and cherry bark tortrix.

Augmentative biological control

Augmentative or supplemental biological control typically involves the mass-production and repeated releases of natural enemies. This approach is used most often for slow-moving pests such as mites and aphids, in enclosed spaces such as greenhouses, by home gardeners, and in organic agriculture where few disruptive chemicals are used. Consider matching the dispersal capability of the natural enemy with the situation. For example, many homeowners have wasted money using ladybird adults to control their aphids, only to see them disperse within minutes. If biocontrol agents are native, then a release can be directed to augment and improve the rate of natural colonization and control. If the natural enemy is non-native, then overwintering success is not expected, and only within season benefits will occur. Since natural enemies are all specialized to some degree, it's important to know the pest and which agent(s) are appropriate for the given situation. Table 1 lists some target pests commonly found in home garden and agricultural systems, and the associated commercially-available beneficial organisms. Steps for acquisition and release of biocontrol agents must be planned carefully and followed. Release guidelines depend on an understanding of the biology of the pest, the natural enemy, and the influence of the host plant on both. Conservation efforts (below) can in some cases greatly enhance the outcome of augmented biocontrol agents.

Conservation biological control

Conservation biological control refers to the manipulation and/or protection of habitat and resources to support and encourage natural enemies in order to increase their numbers and effectiveness. This may include the use and encouragement of the natural enemies' needs, such as nectar and pollen, alternative hosts, and certain types of non-disrupted habitat. These resources all can potentially enhance the fecundity, longevity, and survival of natural enemies.

Some tactics for conservation biological control include:

Careful use of pesticides and tillage to avoid disturbing natural enemies. Many pests are "secondary pests" in that they only reach economic pest levels

Notes:

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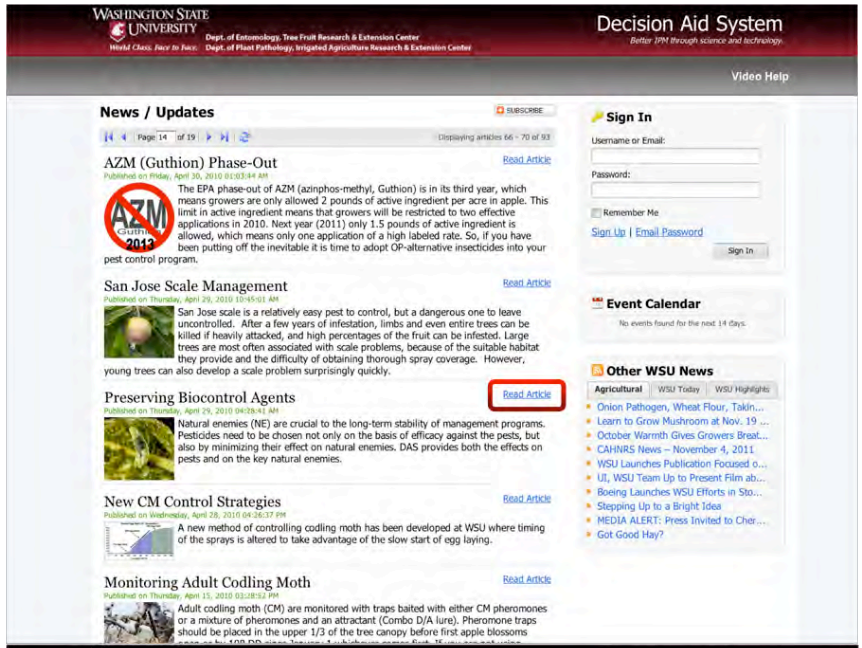

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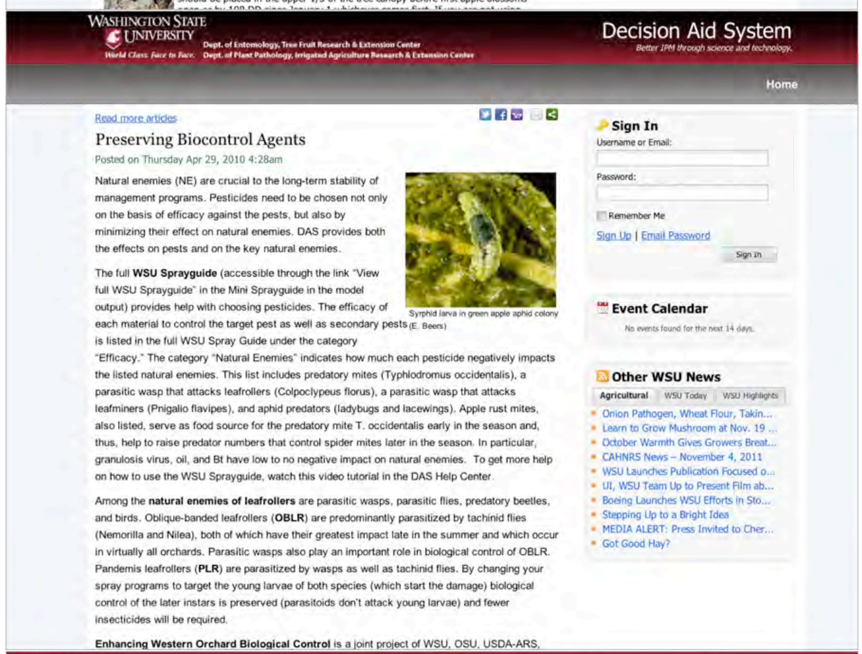

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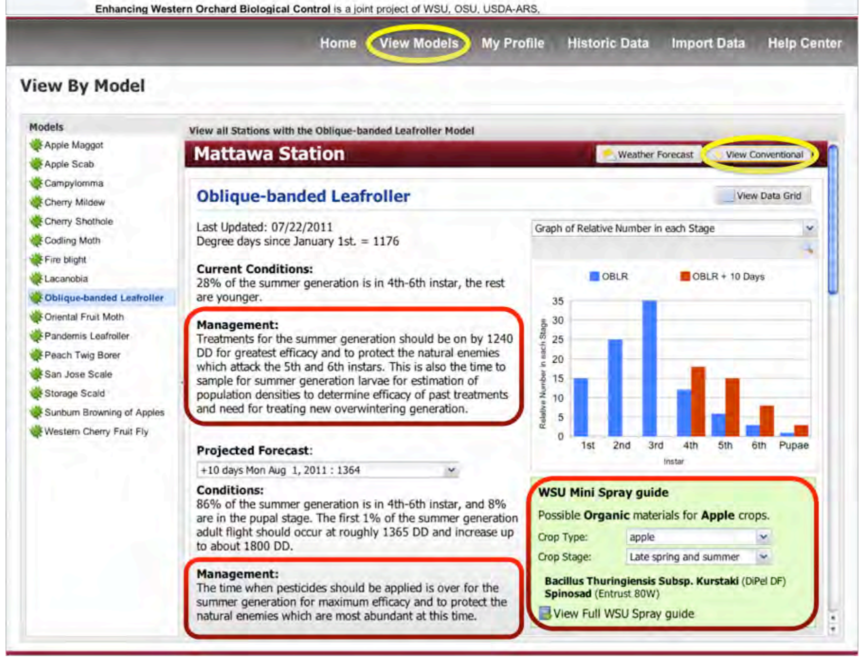

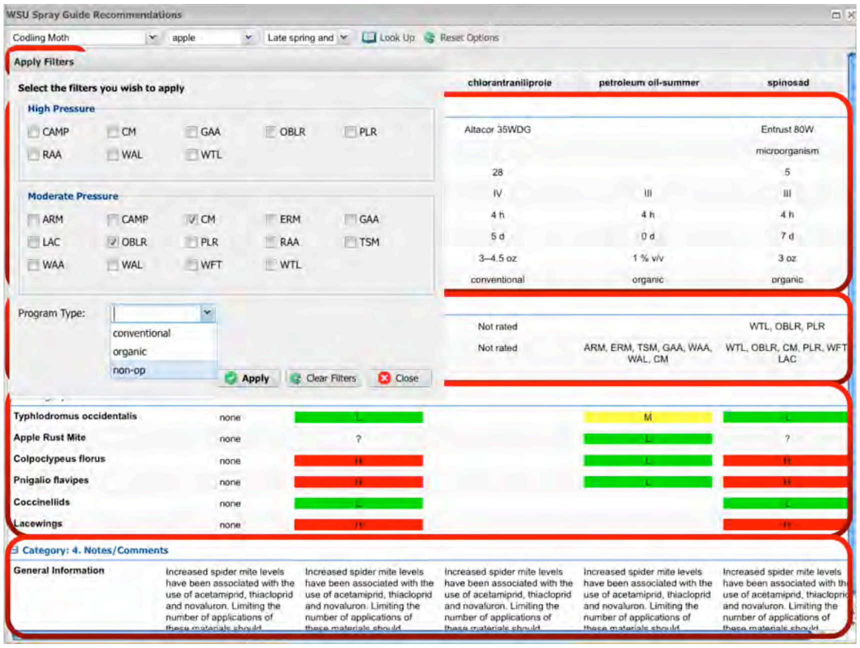

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Presentation 8: Exercise - Windows of Opportunity

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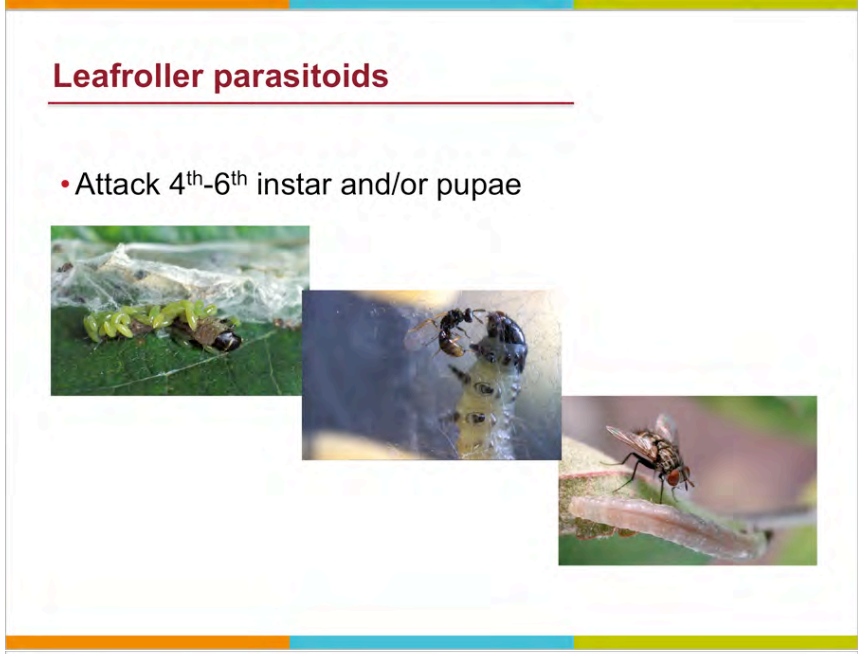

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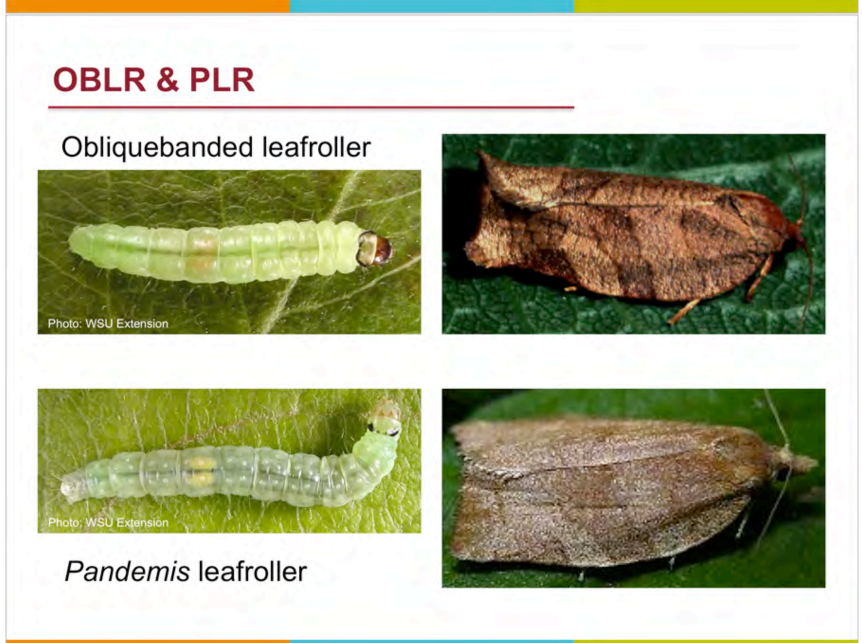
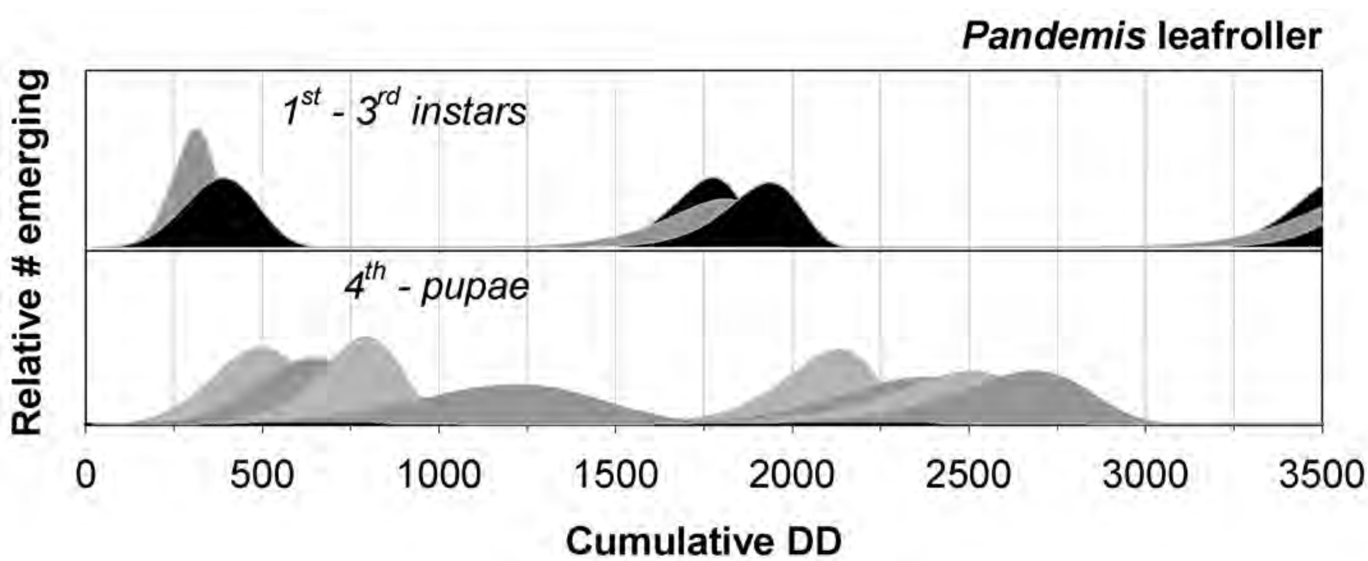


Short Exercise Task #1: Windows of Opportunity for PLR & OBLR

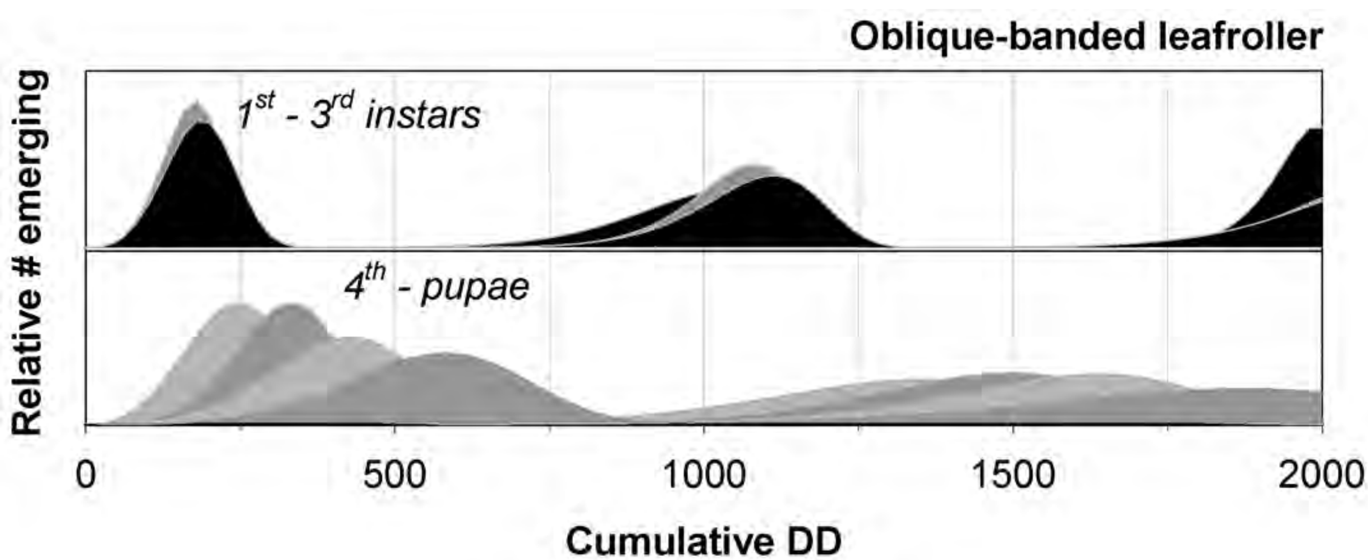
Task 1a: On the chart below, mark when parasitoids are present and when you should avoid sprays; then mark when sprays can be applied without harming PLR parasitoids.

PLR Phenology



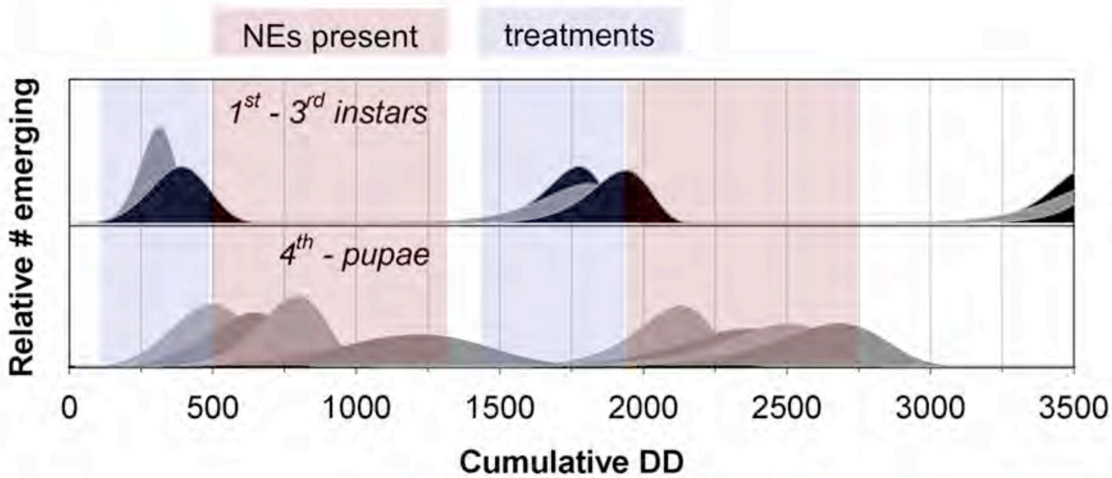
Task 1b: On the chart below, mark when parasitoids are present and when you should avoid sprays; then mark when sprays can be applied without harming OBLR parasitoids.

OBLR Phenology

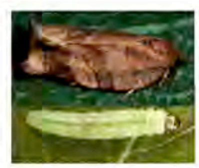


Windows of Opportunity for PLR

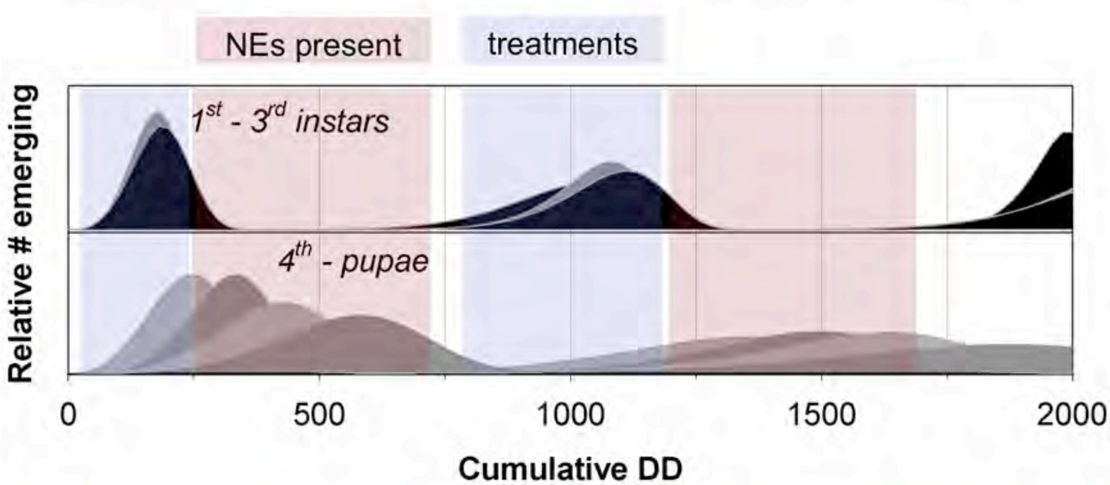
- 29% mortality in overwintering gen., 45% in summer gen.



Windows of Opportunity for OBLR



- 19% mortality in overwintering gen., 29% in summer gen.



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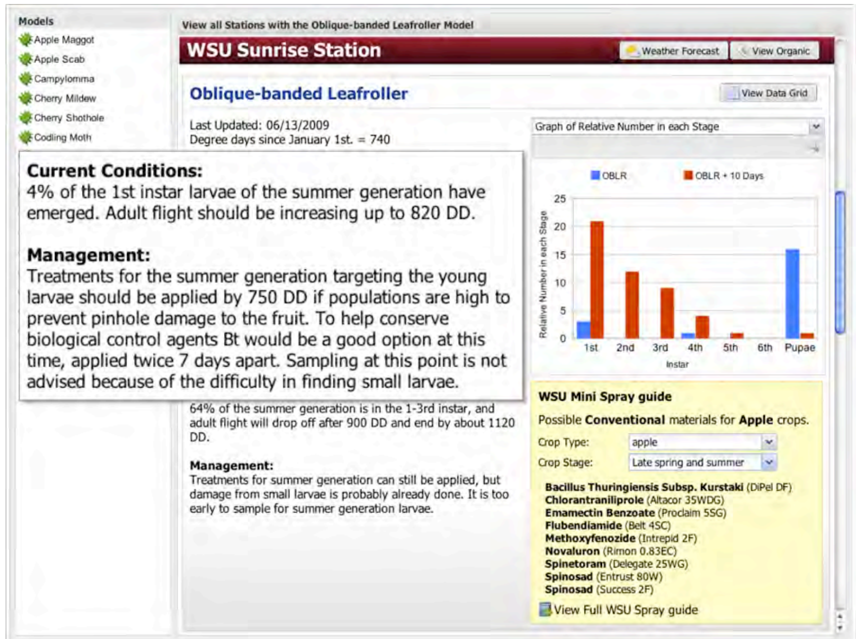

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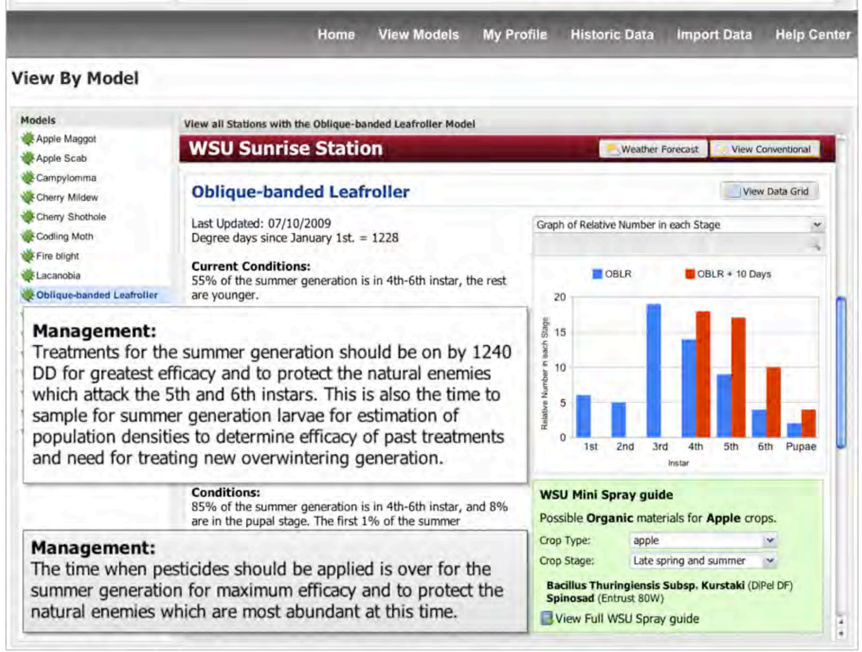


Notes:

When and how to monitor leafrollers

- Pheromone traps
- Sampling (summer generation)
  - 25 shoots from 1 tree per 1.5 acres, count # of larvae
    - larvae in upper half of tree, esp. when more than 10 feet tall
  - Retreat when more than 2% of shoots with live larvae
- Overwintering generation
  - between green tip and tight cluster – collect buds (6 buds each from 25 trees in 5 acres) – examine under magnification

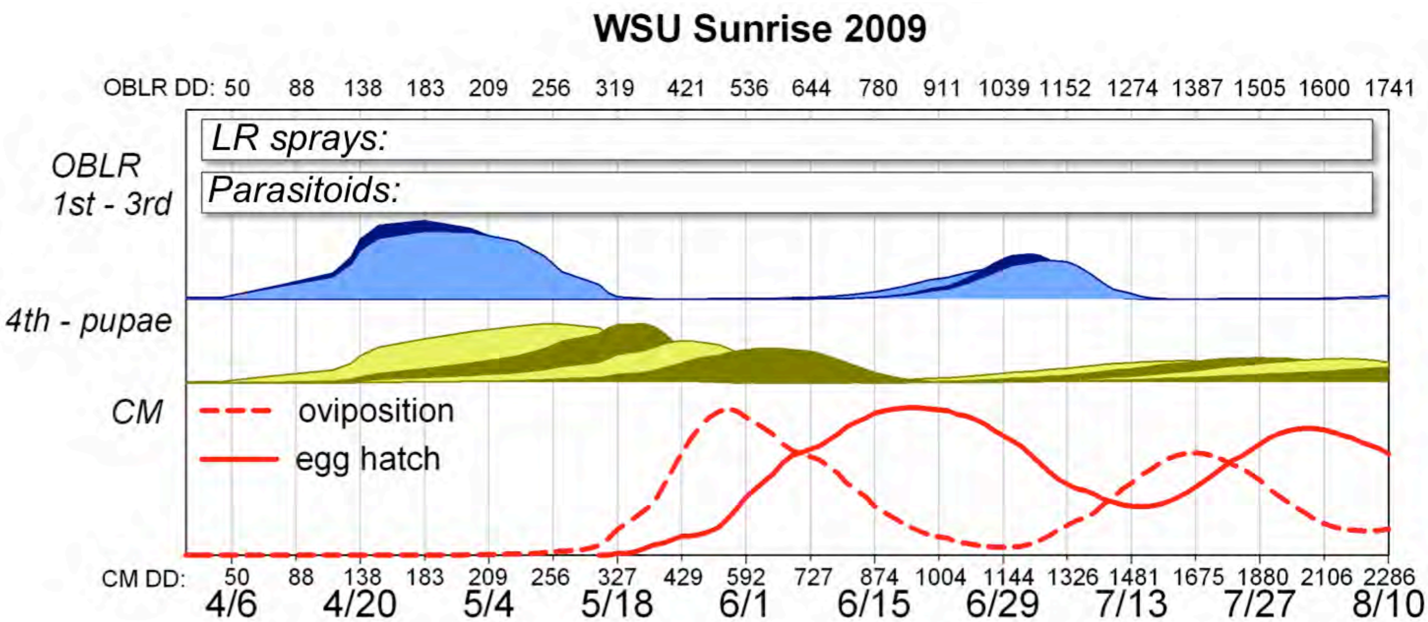
Washington State University · ars Agricultural Research Service · Oregon State University OSU · Berkeley

Short Exercise Task #2: Timing of LR control treatments

Task 2a: On the chart below, mark the period when LR parasitoids are active in the orchard.

Task 2b: On the chart below, mark when OBLR treatments are recommended using DAS (for overwintering and summer generations). When are LR parasitoids affected?

Use the information from the DAS screen shots on the next page to complete this exercise.



View all Stations with the Oblique-banded Leafroller Model

WSU Sunrise Station

Weather Forecast | View Organic

Oblique-banded Leafroller

View Data Grid

Last Updated: 05/11/2009
Degree days since January 1st. = 256

Current Conditions:
About 33% of the overwintering generation is in the 4th instar and 22% are in the 5th instar.

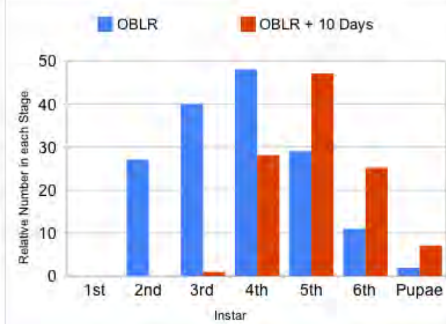
Management:
Sample to determine population levels between 180-280 DD. If treatments are needed, apply before 370 DD so that less than 10% of the overwintering generation is in the pupal stage (pupae are insensitive to the pesticide); if using Esteem the first spray must be on between 250-300 DD. For every 20 DD delay in the application, the portion of the population controlled decreases by 3-5%.

Projected Forecast:
+10 days Thu May 21, 2009 : 342

Conditions:
69% of the overwintering generation is in the 5th and 6th instars. 8% of the population is in the pupal stage, and first adults should appear at roughly 550 DD.

Management:
If treatments are needed, apply before 370 DD so that less than 10% of the population is in the pupal stage (pupae are insensitive to the pesticide); if using Esteem the first spray must be on between 250-300 DD. For every 20 DD delay in the application, the portion of the population controlled by Esteem decreases by 3-5%. If sprays are not required for the first generation, sampling can be continued during this period to help determine if the summer generation larvae need to be treated.

Graph of Relative Number in each Stage



WSU Mini Spray guide

Possible **Conventional** materials for **Apple** crops.

Crop Type: apple
Crop Stage: Bloom

Bacillus Thuringiensis Subsp. Kurstaki (DiPel DF)
Methoxyfenozide (Intrepid 2F)

View Full WSU Spray guide

View all Stations with the Oblique-banded Leafroller Model

WSU Sunrise Station

Weather Forecast | View Organic

Oblique-banded Leafroller

View Data Grid

Last Updated: 06/10/2009
Degree days since January 1st. = 675

Current Conditions:
2% of the 1st instar larvae of the summer generation have emerged. Adult flight should be increasing up to 820 DD.

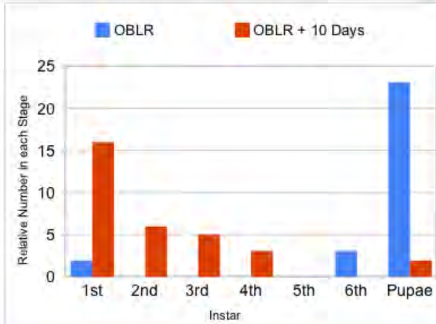
Management:
Treatments for the summer generation targeting the young larvae should be applied by 750 DD if populations are high to prevent pinhole damage to the fruit. To help conserve biological control agents Bt would be a good option at this time, applied twice 7 days apart. Sampling at this point is not advised because of the difficulty in finding small larvae.

Projected Forecast:
+10 days Sat Jun 20, 2009 : 887

Conditions:
53% of the summer generation is in the 1-3rd instar, and adult flight will drop off after 900 DD and end by about 1120 DD.

Management:
Treatments for summer generation can still be applied, but damage from small larvae is probably already done. It is too early to sample for summer generation larvae.

Graph of Relative Number in each Stage



WSU Mini Spray guide

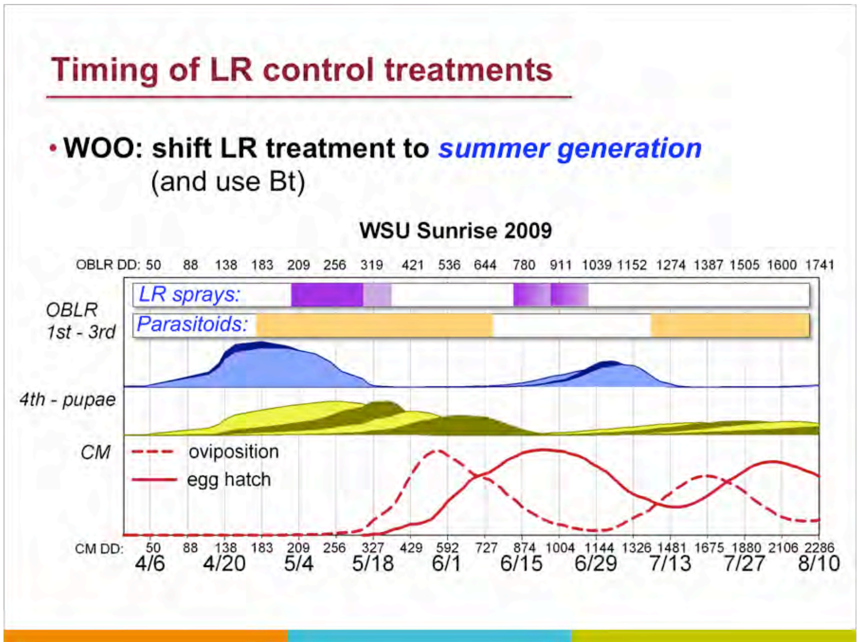
Possible **Conventional** materials for **Apple** crops.

Crop Type: apple
Crop Stage: Late spring and summer

Bacillus Thuringiensis Subsp. Kurstaki (DiPel DF)
Chlorantraniliprole (Altacor 35WDG)
Emamectin Benzoate (Proclaim 5SG)
Flubendiamide (Belt 4SC)
Methoxyfenozide (Intrepid 2F)
Novaluron (Rimon 0.83EC)
Spinetoram (Delegate 25WG)
Spinosad (Entrust 80W)
Spinosad (Success 2F)

View Full WSU Spray guide

Also see pages 198 & 199 in this workbook



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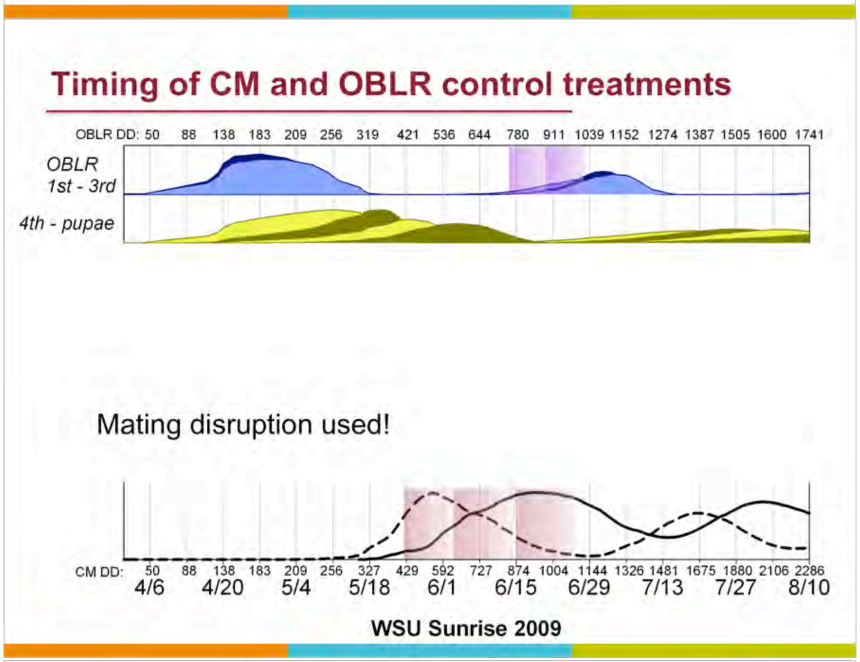

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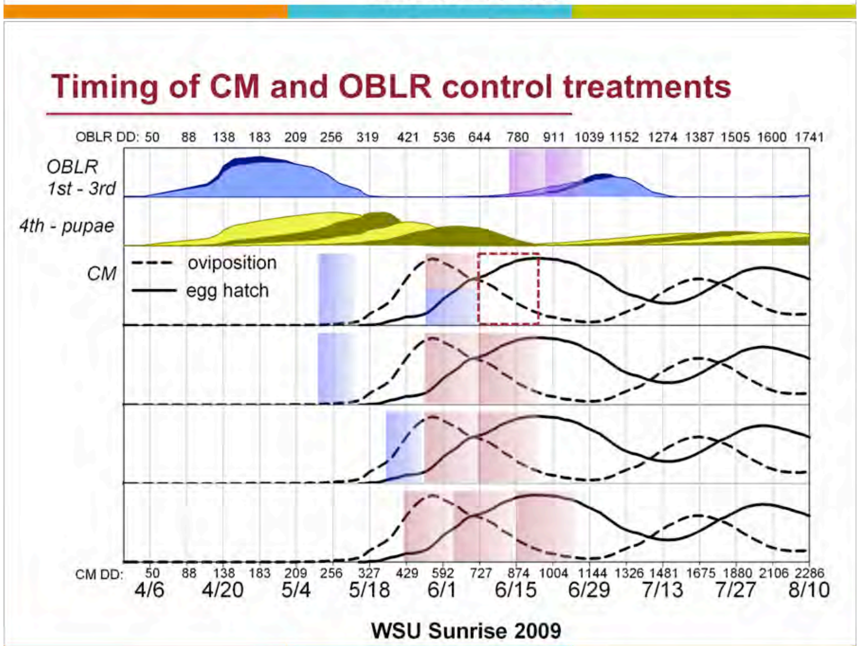


Notes:

(A larger version of this chart can be found in the Resources of this workbook on page 202.)

Notes:

LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Petal fall 225-275 DD (50-100 DD pbf)	375 DD (200 DD pbf)	1^{st} cover 425 DD (250 DD pbf)	Delayed 1^{st} cover 525 DD (350 DD pbf)	2^{nd} cover 625-675 DD (450-500 DD pbf)	Delayed 2^{nd} cover 725-825 DD (550-650 DD pbf)	3^{rd} cover 875-925 DD (700-750 DD pbf)
Proclaim Success Delegate Belt Bt	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus
Proclaim Success Delegate Belt Bt	→ Oil	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	
Altacor Intrepid Rimon Esteem	→	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	
Altacor Intrepid Rimon Esteem	Tank mix →	→	Delegate Entrust Assail Calypso virus + Altacor Intrepid Rimon Esteem		May not need 2^{nd} cover	

pbf = post biofix
Source: Pest Management Transition Project Handbook (*http://pmtp.wsu.edu/handbook.html*)

Notes:

Timing of CM and OBLR control treatments

Protect natural enemies:

- **Delay CM cover sprays (larvicides) by treating eggs;**
  - ➥**Decreases # of sprays**
- **Tank-mix larvicides and ovicides for 1^{st} delayed cover spray**
  - ➥**may not need 2^{nd} delayed cover**

➥**Fewer sprays to impact NEs**

Notes:

Windows of opportunities: secondary pests

- Why is it more complicated for aphids and mites?
  - Overlapping generations
  - ➥ no simple timing of stages as in LR
  - ➥ their predators and parasitoids can be present for longer periods

Windows of opportunities for generalists

- Why is it more complicated for predators?
  - Not as intimately linked to specific prey species and/or stage as parasitoids (generalists)
  - Different stages predatory
  - Phenology not fully known

Notes:

Summary – Windows of Opportunity

- LR management
  - OBLR/PLR: avoid pesticides during 4-6th instars & pupae
  - Shift LR sprays to summer generation (1st-3rd instars)
- CM management
  - Delay CM cover sprays (larvicides) by treating eggs
  - Tank-mix larvicides & ovicides for 1st delayed cover spray
- Overlapping generation & general predators add complexity
- Resources: DAS (das.wsu.edu)

Washington State University World Class. Face to Face. DAS Agricultural Research Service Oregon State University OSU Berkeley University of California

Notes:

Presentation 9: Effects of Pesticides on Natural Enemies

Notes:

Effect of Pesticides on Natural Enemies

Nick Mills, University of California, Berkeley

Betsy Beers, Washington State University, Wenatchee

Tom Unruh, USDA-ARS, Wapato

Peter Shearer, Oregon State University, Hood River

Notes:

Overview

- Why do pesticides impact natural enemies?
- Pesticides and natural enemies tested
- Experimental approach:
  laboratory bioassays and extrapolation
- Bioassay results
  acute and sublethal
- Ranking for field verification
- Summary

Notes:

What is IPM?

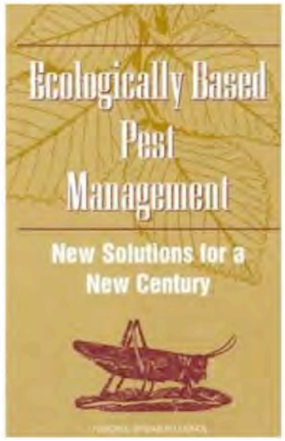
- Scheduling pesticide applications based on monitoring and economic thresholds

- Stern et al. (1959) 'The ideal material [pesticide] is not one that eliminates all individuals of the pest species . . . [It] is the one that shifts the balance back in favor of natural enemies'

What is IPM?

- NRC (1996) recommended use of Ecologically Based Pest Management

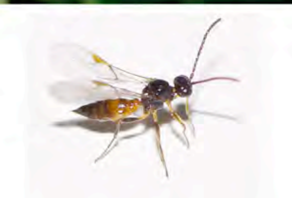
  which 'will seek to manage rather than eliminate pests' in ways that are 'profitable, safe, and durable'



Notes:

Natural enemy susceptibility to pesticides

- Natural enemies are more susceptible to pesticides than pests because:
  - they experience greater exposure due to great mobility
  - unlike plant pests they don't have general enzyme systems for detoxification



Notes:

Pesticides tested

- Fungicides – targeting powdery mildew/walnut blight

  Kumulus, Kocide-Manzate

- Insecticides – targeting codling moth

  Diamides - Altacor, Cyazypyr

  Spinosyn - Delegate

  Chitin synthesis inhibitor - Rimon

  Pyrethroid - Warrior

Notes:

Notes:

Natural enemies tested

- Mite predator
  Galendromus occidentalis
- Spiders
  Misumenops lepidus
  Pelegrina aeneola
- Green lacewing
  Chrysoperla carnea
- Psylla predator
  Deraeocoris brevis
- Aphid predator
  Hippodamia convergens
- Aphid parasitoids
  Aphelinus mali, Trioxys pallidus

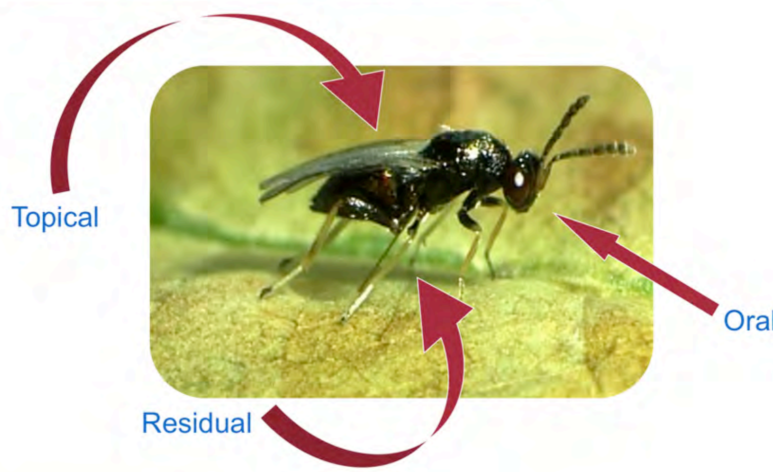
Notes:

Experimental approach

- Laboratory bioassays in simple glass arenas of direct (acute) and indirect (sublethal) effects of pesticides on natural enemies, incorporating multiple routes of exposure
- Extrapolation of the response of individuals to pesticides in lab bioassays to probable effects of natural enemy populations in the field

Notes:

Multiple routes of exposure



Probable effects in the field

➢ Why not avoid the difficulty of extrapolation and simply test effects on natural enemies directly in the field?

- Few materials can be tested simultaneously
- High cost
- Issues of scale (plot size) and replication
- Issues of whether natural enemies will be present

Notes:

Lab-based bioassays

Acute assays → Topical or residual exposure → Full field rate and 10% field rate → *Endpoint* - acute mortality after 48 h

Sublethal assays → Multiple modes of exposure → Highest rate with <75% acute mortality → *Endpoint* – population growth rate based on observed impacts on individual life history parameters

Notes:

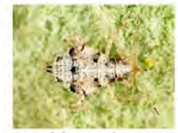
Acute bioassays

- Topical or residual application with Potter tower
- Anaesthetize the natural enemies with CO2
- Natural enemies placed singly into glass arenas

Notes:

Notes:

Sublethal bioassays



Multiple Routes of Exposure

Adults (Males and Females)

Potter Spray Tower

Insects (Topical)
Arenas (Residual)

Nymphs (Second Instars)

Drenched

Ephestia eggs [food] (Oral)
Green beans [moisture] (Oral)
Cheese cloth lids (Residual)

Environmental Growth Chamber

23°C, 60% RH, and 16:8 h (L:D)

Notes:

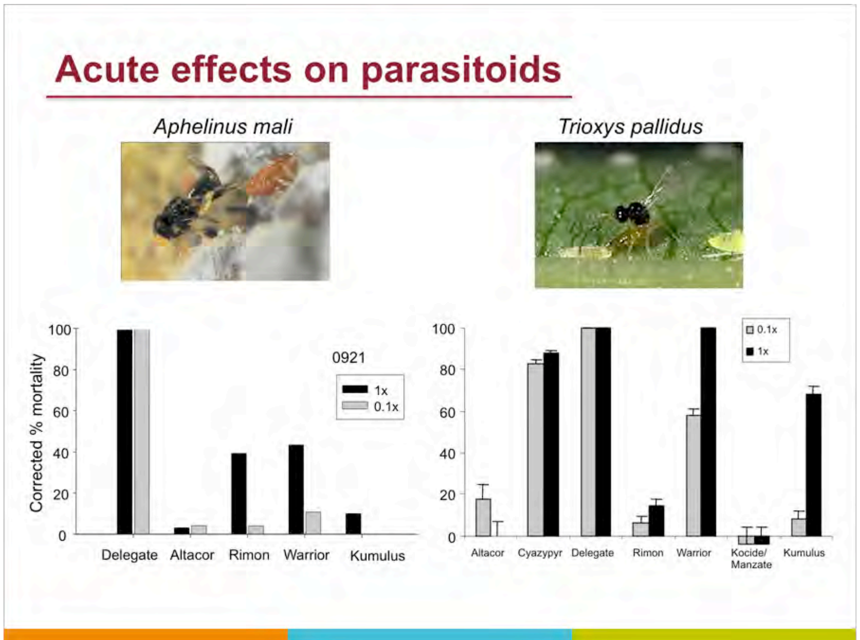
Endpoint measurements from bioassays

- Direct (acute) effect
  - Mortality within 48h of exposure
- Indirect (sublethal) effects
  - Reduced survivorship of adults or juveniles
  - Reduced per capita daily fecundity
  - Reduced egg hatch
  - Prolonged development time of juveniles
  - Altered sex ratio of progeny

Notes:

Extrapolation from Bioassays

- Direct effects
  - 48h acute mortality
- Indirect effects
  - A series of life history parameters
- Extrapolation
  - Demographic matrix models
  - Integrate mortality and life history measurements into a single index - population growth rate



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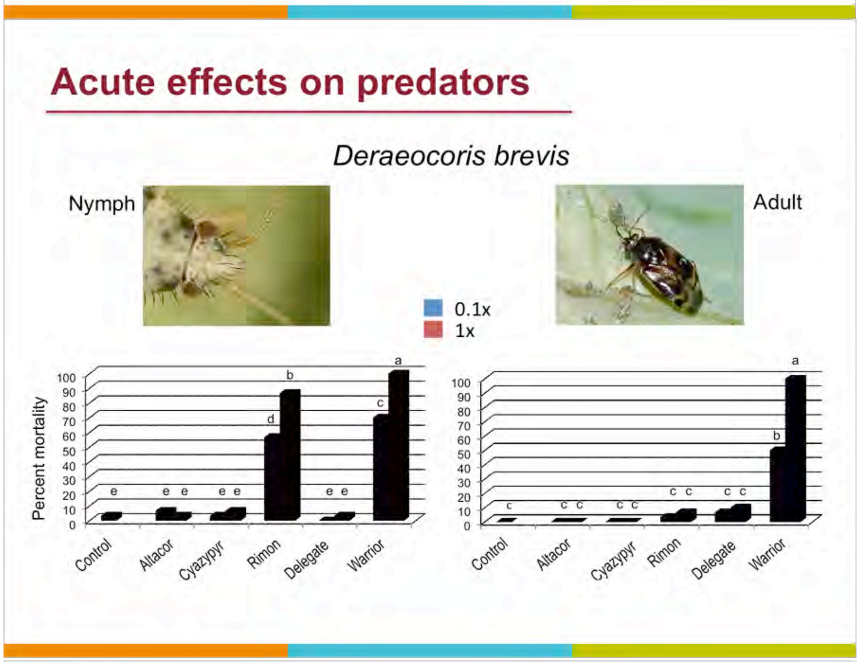

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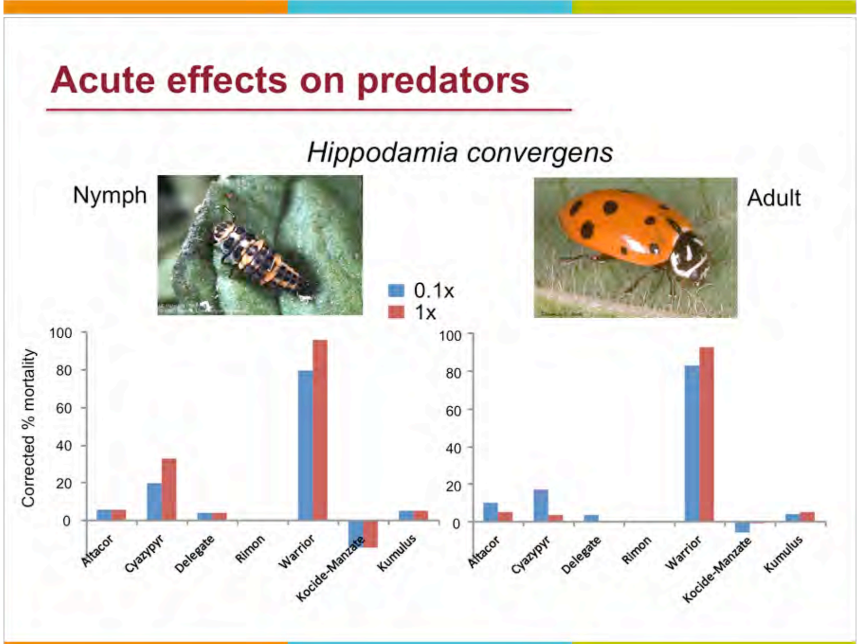

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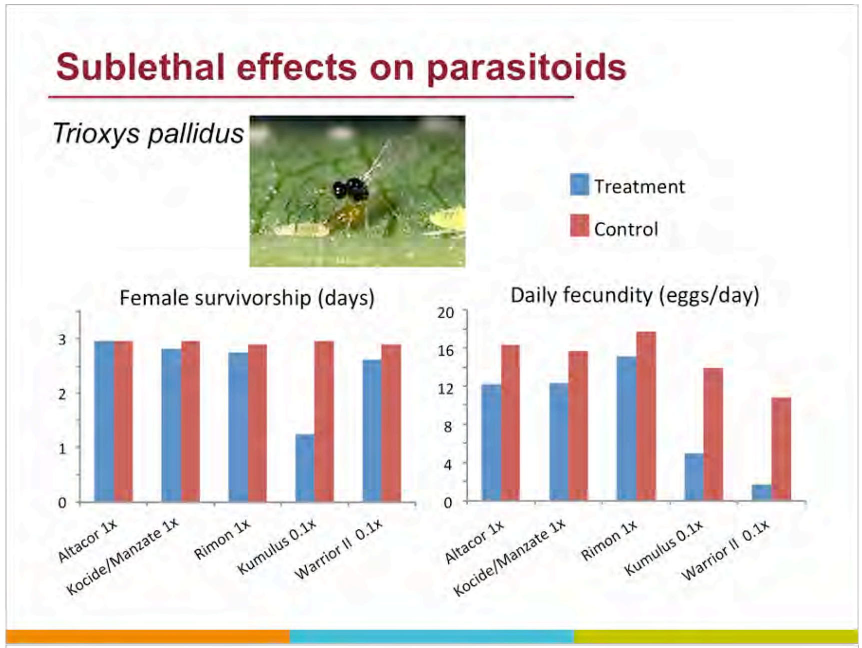

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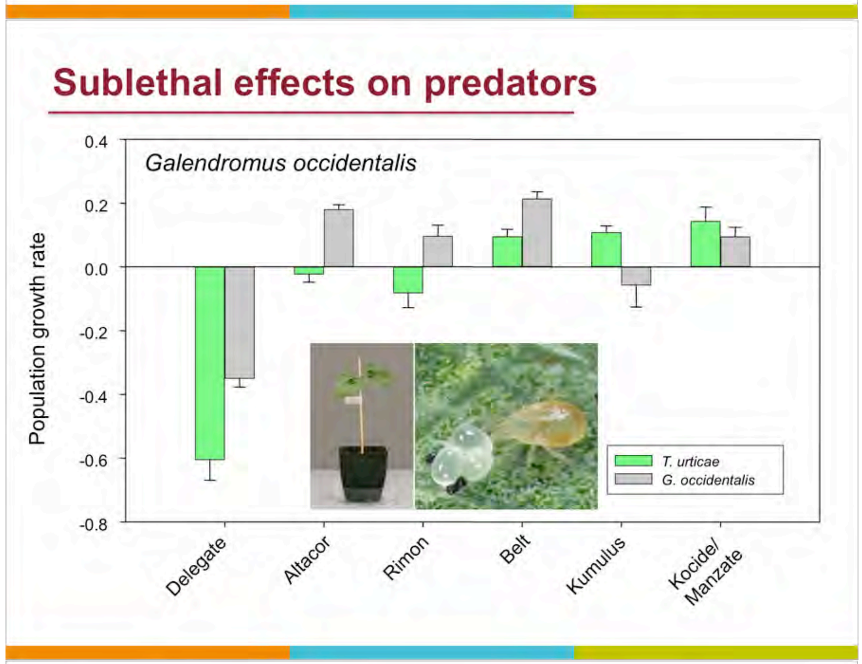

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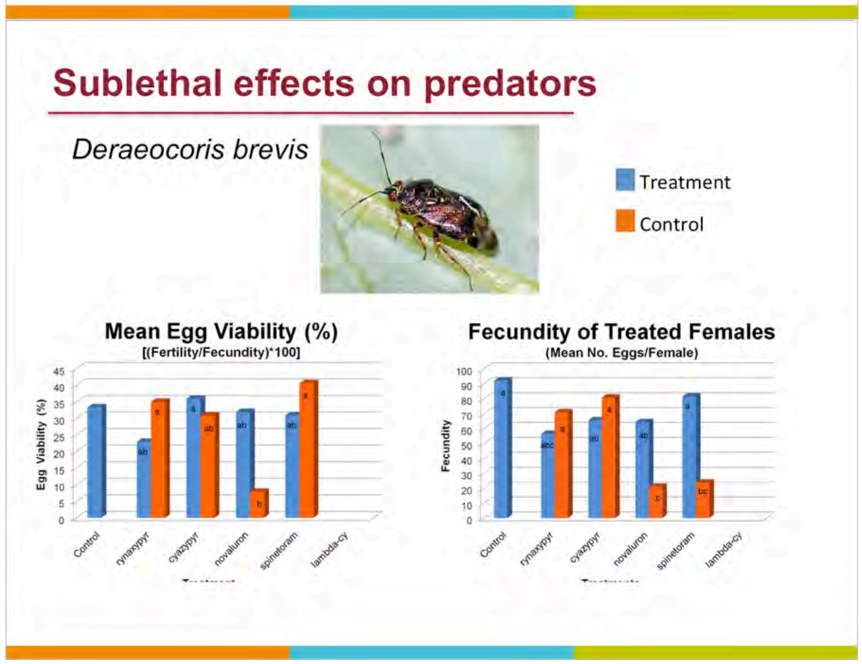

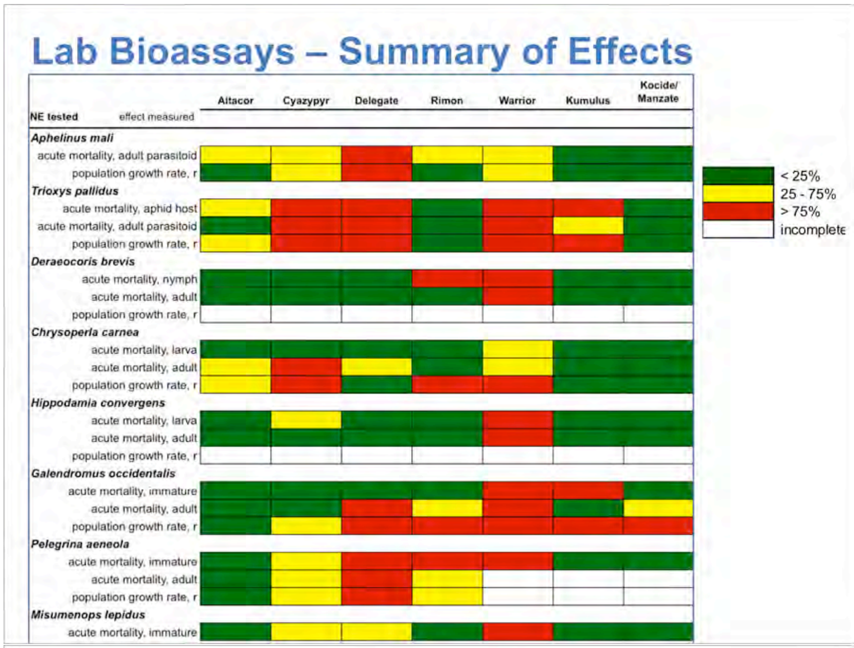

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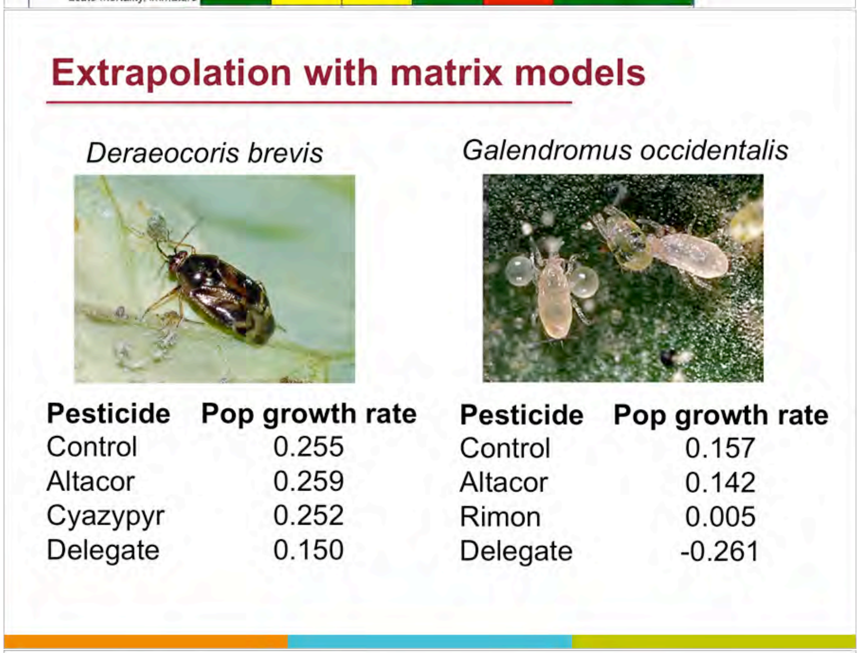

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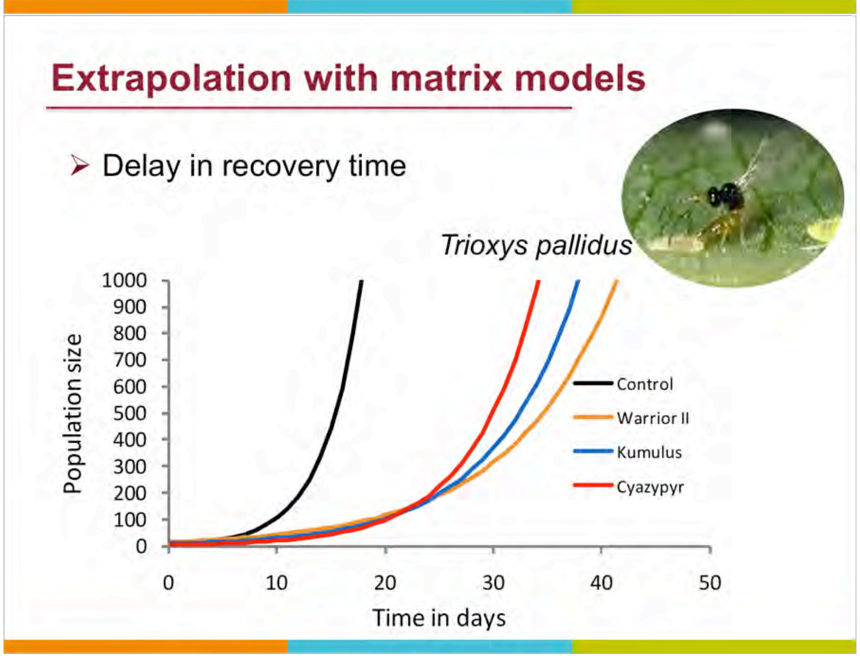


Notes:

Notes:

Field Verification

- Lab bioassays suggest the following ranking for the potential of the tested pesticides to cause disruption of NEs:

Warrior, Delegate

Cyazypyr, Kumulus, Rimon

Kocide/Manzate, Altacor

Notes:

Summary

- Some of the new “low risk’ pesticides are not compatible with biocontrol due to sublethal as well as acute effects
- Lab bioassays are a quick way to screen a large number of pesticides for disruptive effects, and are less expensive that field testing
- Population growth indices from ‘worst case’ lab bioassays can be used to rank potential disruptive effects of pesticides for further field verification

Next...

Case Study #1: Secondary Pest Problems - Why did they get out of control?

(Refer to materials starting on page 165)

End of Day 1 Presentations

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

Presentation 1: Effects of Pesticides in the Field

Effects of pesticides in the field

Peter Shearer, Oregon State University, Hood River OR

Elizabeth Beers, Washington State University, Wenatchee, WA

Notes:

Effects of pesticides in the field

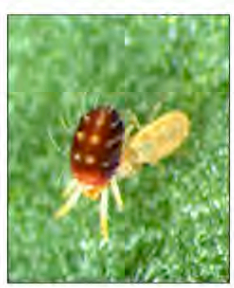
Peter Shearer, Oregon State University, Hood River OR

Elizabeth Beers, Washington State University, Wenatchee, WA

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:

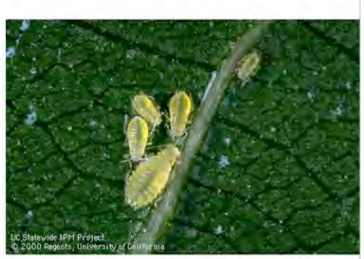
Insecticide-induced disruption

- 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

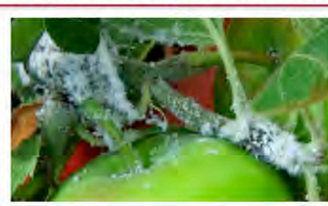
Notes:

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

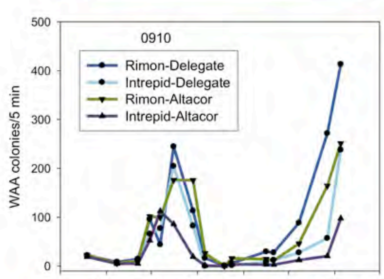
Notes:

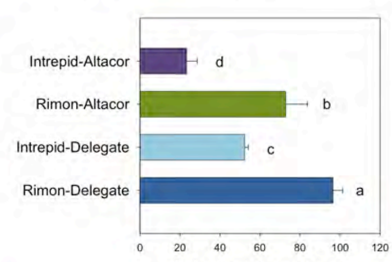
Examples of insecticide-induced disruption: Apple



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

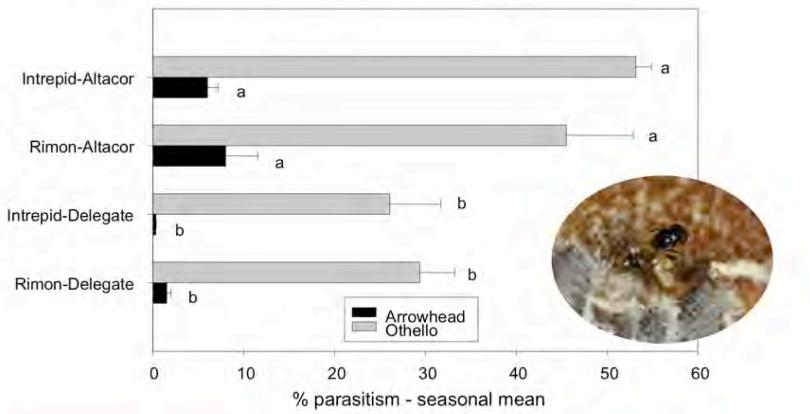
Woolly Apple Aphid Populations





Examples of insecticide-induced disruption: Apple

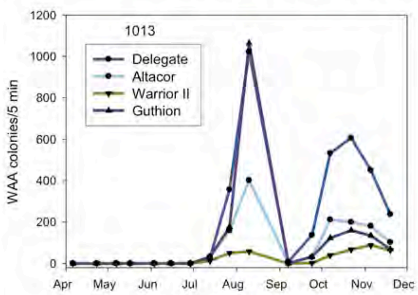
Reduction in WAA parasitism by *Aphelinus mali*

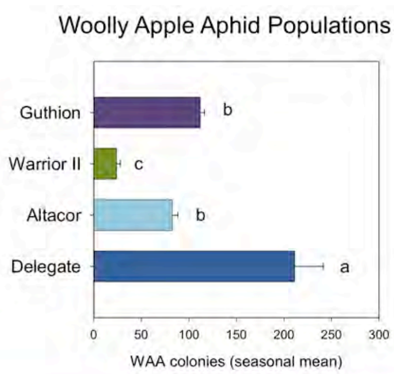


Notes:

Examples of insecticide-induced disruption: Apple

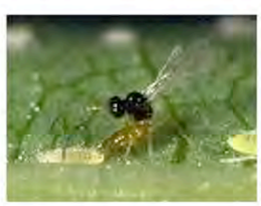
4 trts x 4 one-acre reps – Othello, 2010

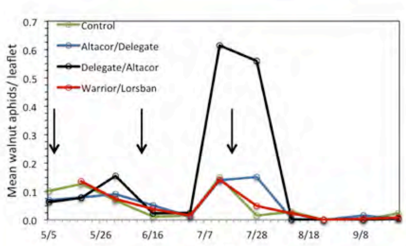


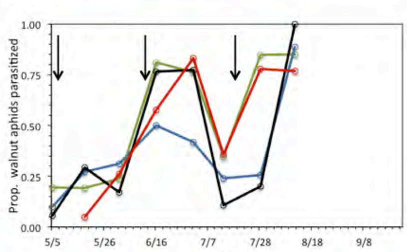


Notes:

Examples of insecticide-induced disruption: Walnut







Mills, 2011 (CA)

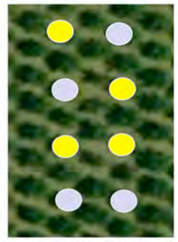
Notes:

Notes:

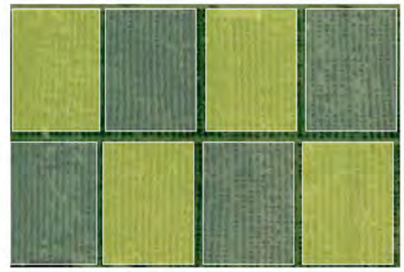
Studying insecticide selectivity in the field

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)

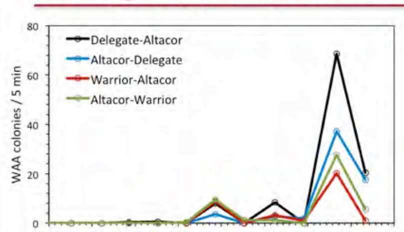
Treatments:

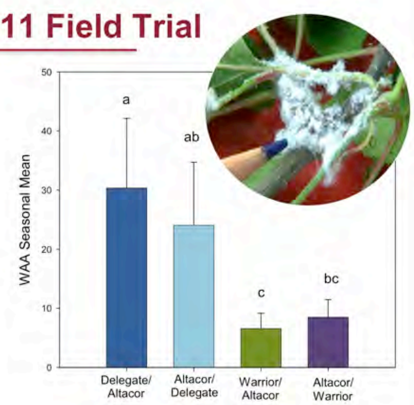
- 2 apps of Delegate 1st gen
- 2 apps of Altacor 2nd gen.
- All had Intrepid at PF

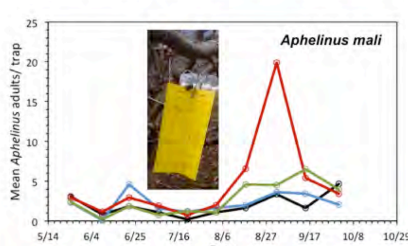
Sampled secondary pests and NEs sampled every 1-3 wks

Notes:

Woolly Apple Aphid - 2011 Field Trial







Replicated field trials: 2011 (OR)

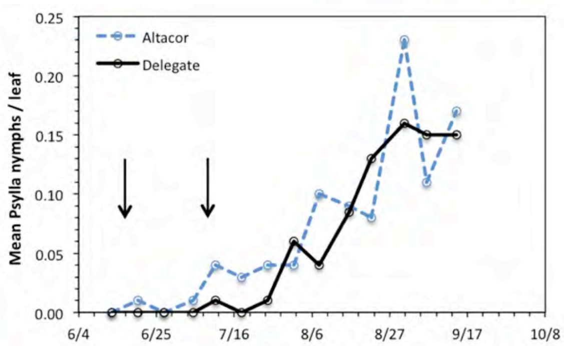
0.6 acre plots, d'Anjou pear
- Hood River, OR
- 4 replicate blocks

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

Notes:

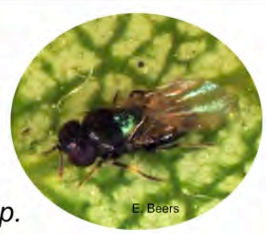
Measuring natural enemy impact

1. Measure pest density



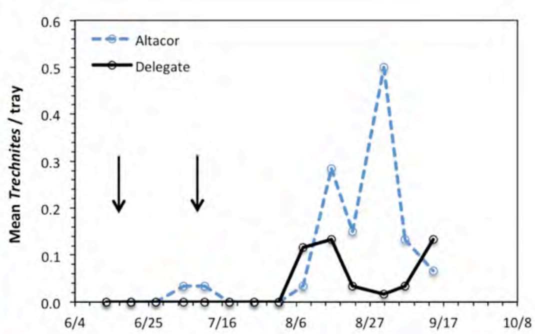
Notes:

Measuring natural enemy impact



2. Measure natural enemy density

Trechnites spp.



Notes:

Notes:

Measuring natural enemy impact

3. Relate NE abundance to pest density
= Natural enemy / prey ratio

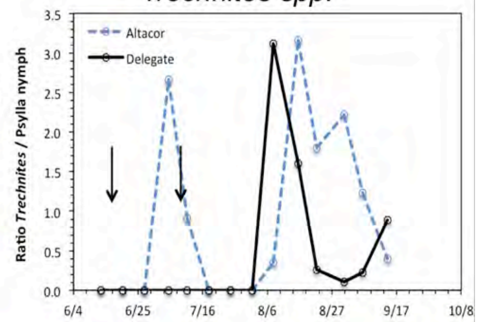
To calculate:

- Divide NE density by prey density

Can show short- and long-term impacts of insecticides

- We know Delegate is toxic to parasitic wasps
- In this instance, *Trechnites* was able to recover within a season

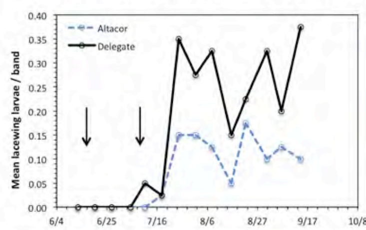
Trechnites spp.

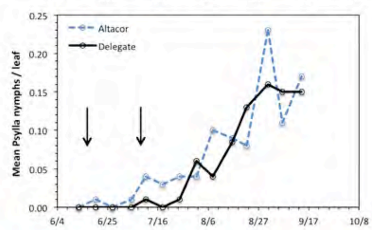


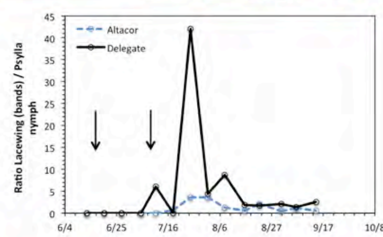
Notes:

Measuring insecticide impact on natural enemies

Green lacewing: *Chrysoperla spp.*

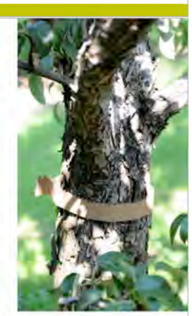




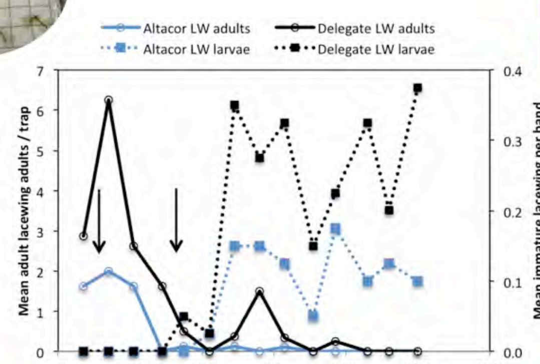


Notes:

Measuring insecticide impact on natural enemies



Green lacewing: *Chrysoperla spp.*

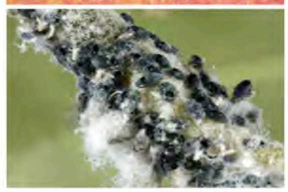


Tropic effects: enemies of natural enemies

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:

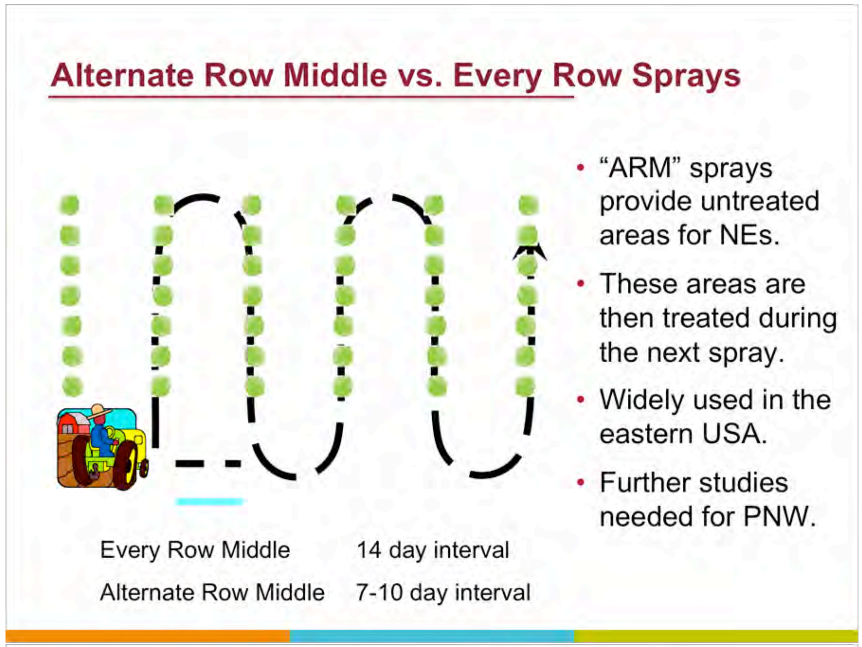
Mitigating risks to natural enemies

Promoting conservation biological control

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

Notes:

Notes:



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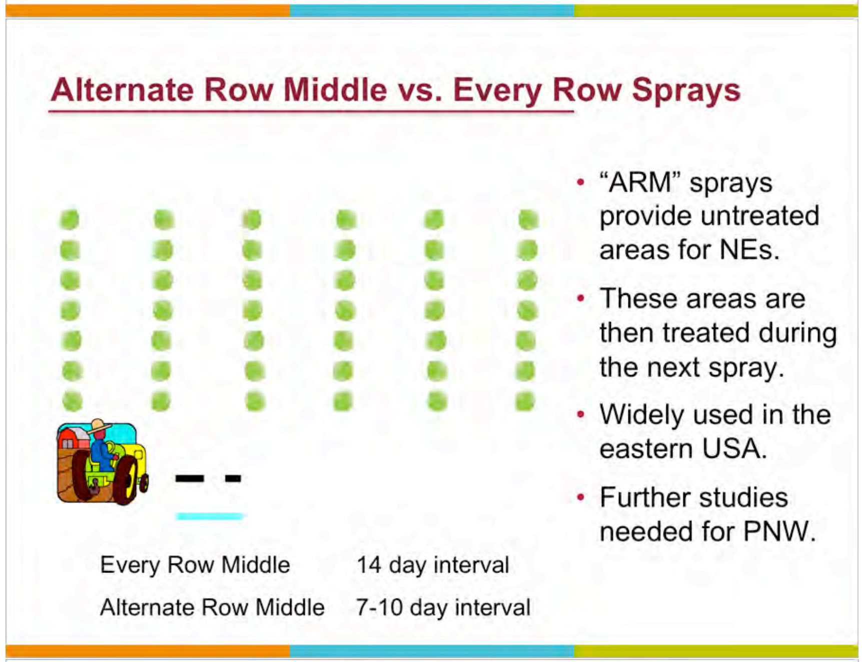

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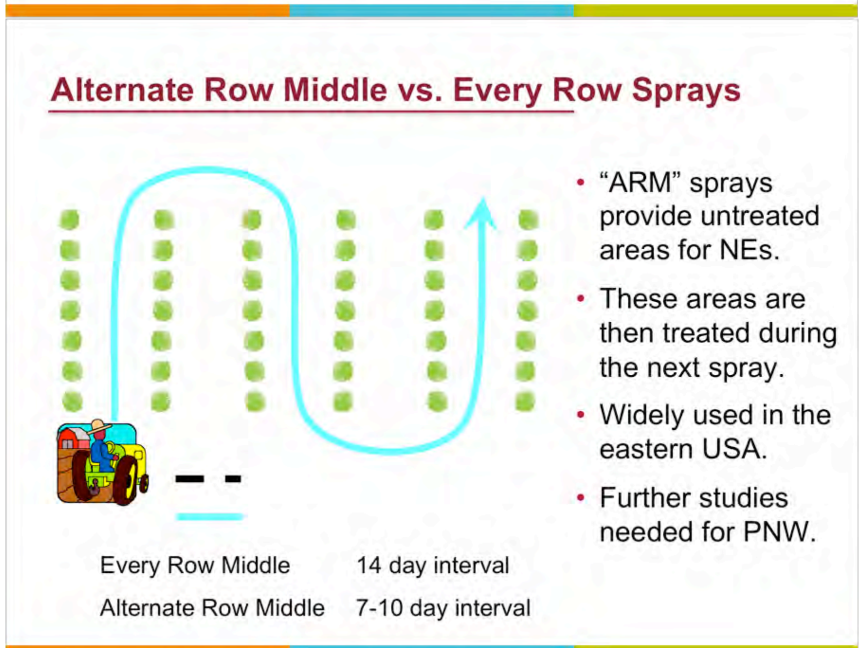
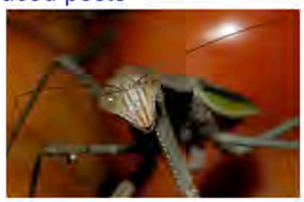


Summary

- 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

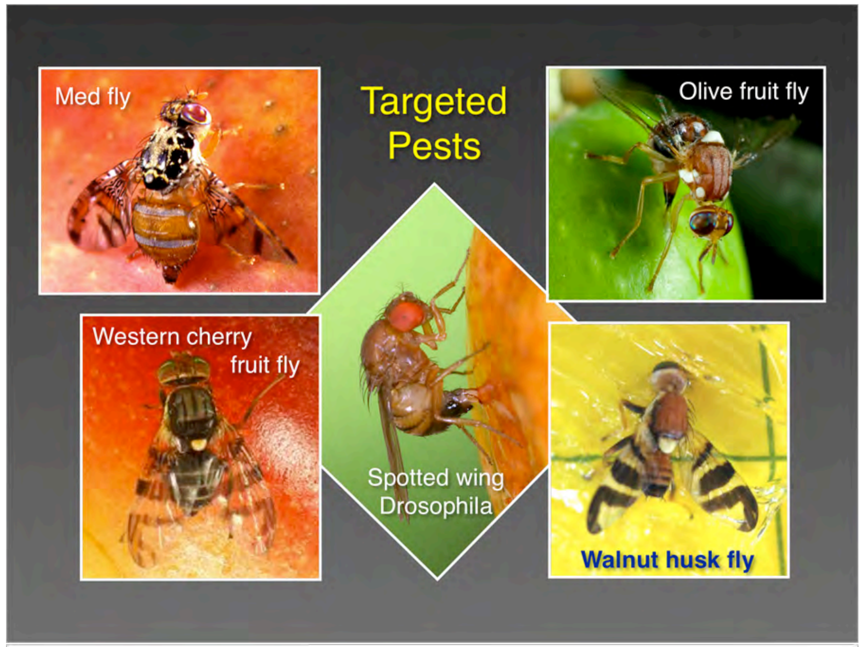
Parlier, California

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:

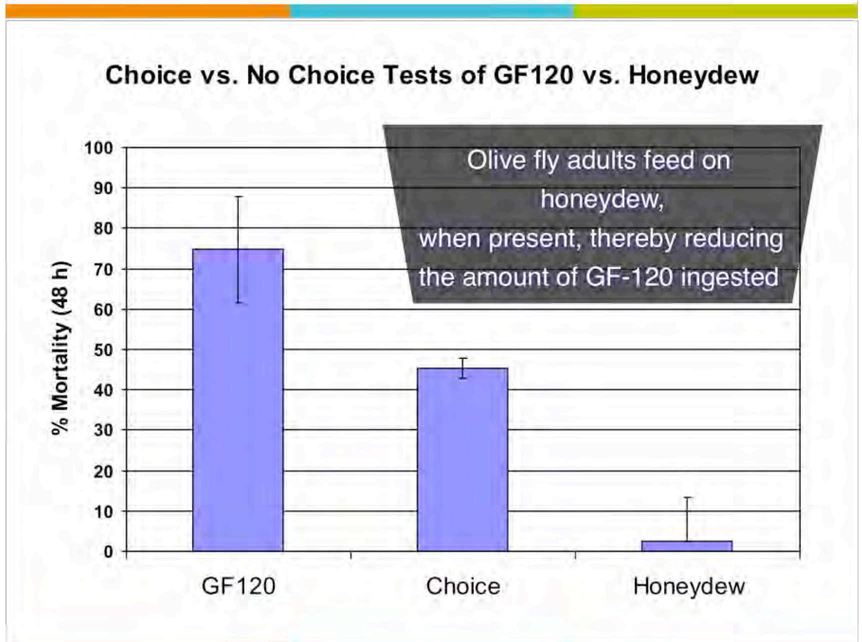
Notes:

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:



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

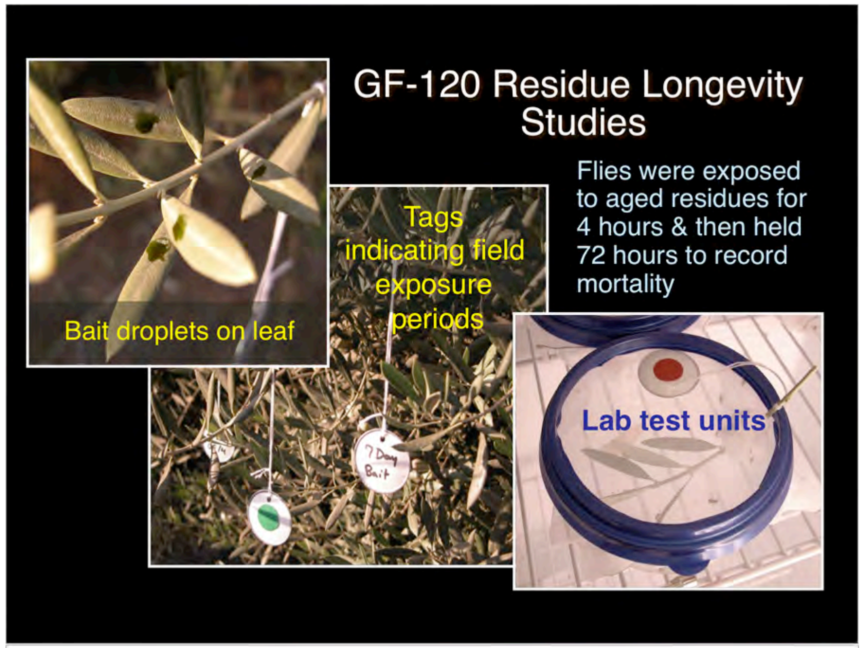
Notes:

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:

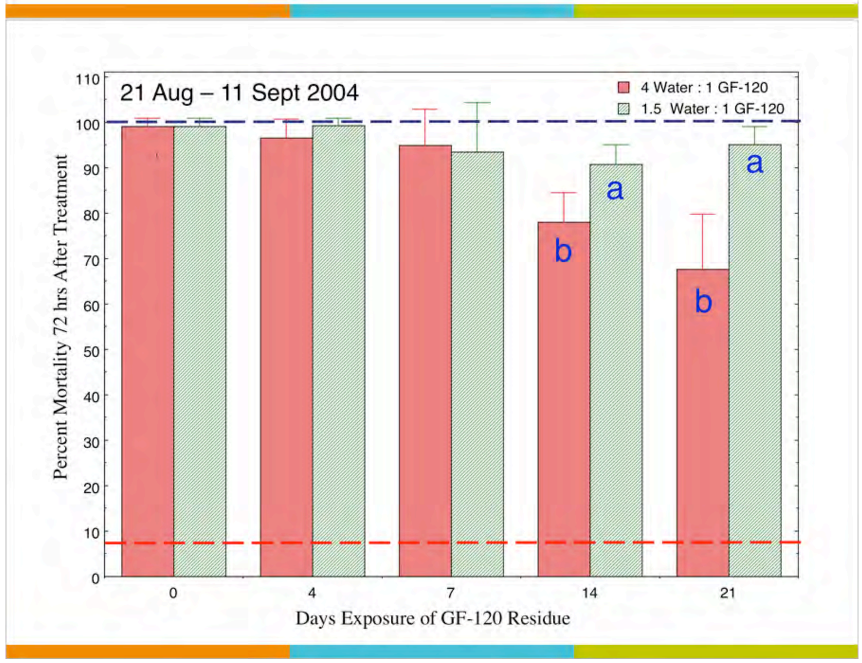


Notes:

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:

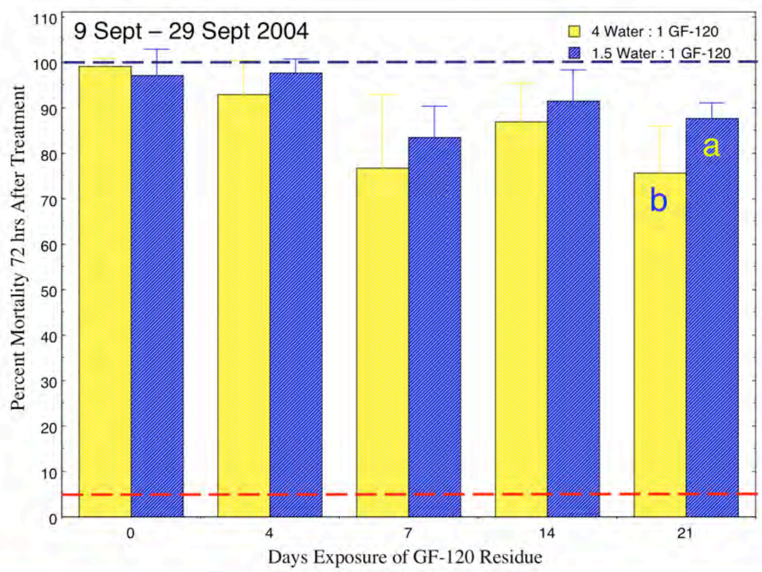


Dilution and post treatment time research results

- *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:

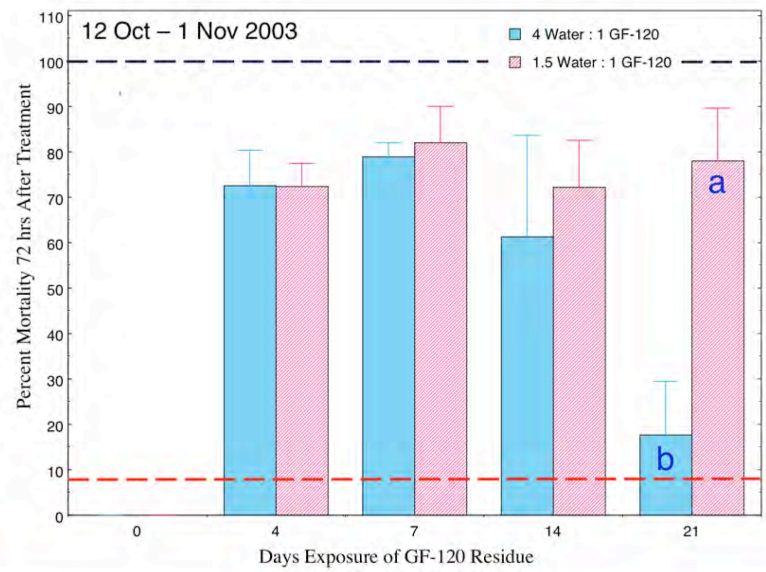
Dilution and post treatment time research results

- *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).

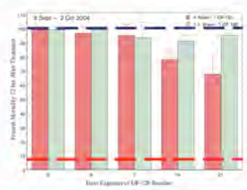
- *October 2003 test*: 21 days after treatment (DAT), mortality in the 1.5:1 solution residue held at 77.9%, but flies exposed to the 4:1 solution exhibited a mortality of only 17.7% ($P = 0.0022$) not significantly different from the control ($P = 0.18$).

Notes:

Notes:



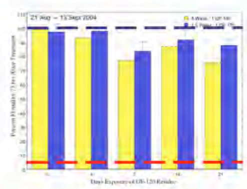
Notes:



Mean daily maximum temp = 94.4 ± 5.9°F

Mean maximum RH = 84.1 ± 3.7%

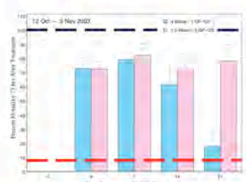
Days when dew formed = 0.0%



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.

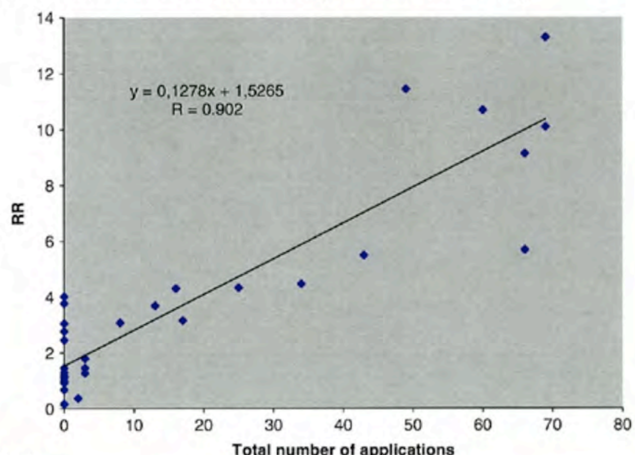
RESULTS: Populations from California, Greece and Cyprus, plus a laboratory population, were tested. Bioassays were performed by oral or topical application of different concentrations of the insecticide. Cypriot populations demonstrated no resistance as compared with that of the laboratory population. 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.

Presentation 3: Microbial Control in Orchard Systems

Microbial Control in Orchard Systems: Prospects and Problems

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

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

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?

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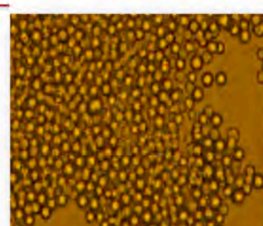
Notes:

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:

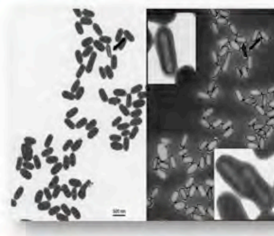
How are microbial control products applied?

- 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

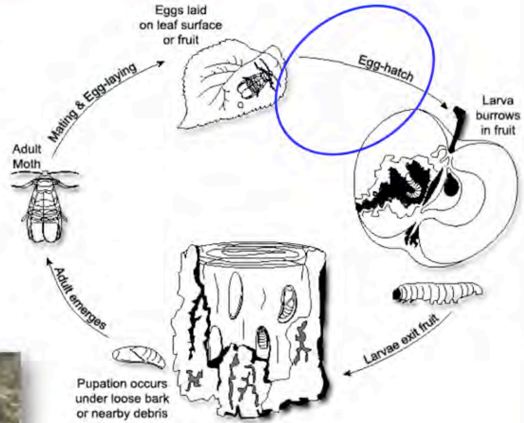
Notes:

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

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.

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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:

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:

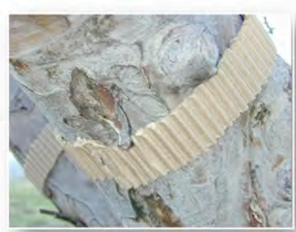
Fruit Injury

Brunner 2010

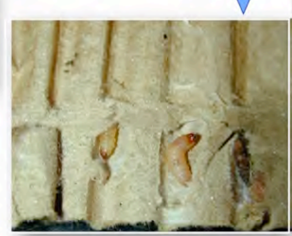
Notes:

Collecting Emerging Larvae

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



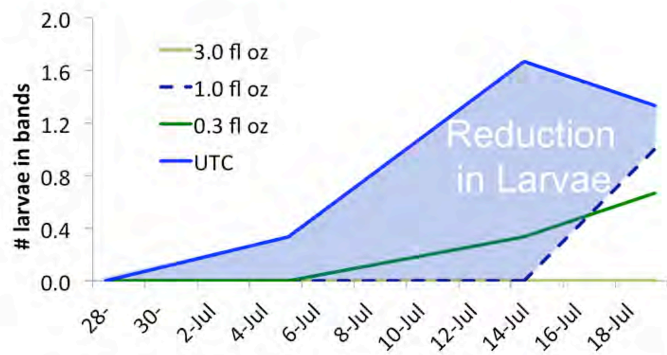
Mature larvae exit fruit and enter bands



Bands are collected and replaced for four weeks

Notes:

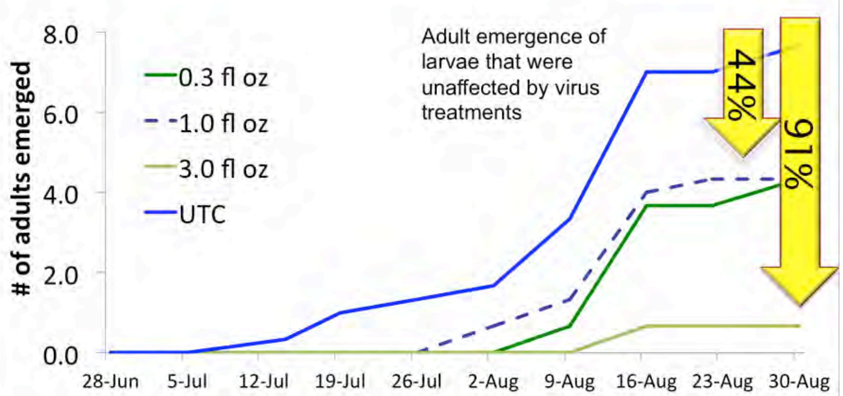
CM reduction from virus in 1st generation



Brunner 2010

Notes:

Cumulative Adult Emergence



Brunner 2010

Notes:

CM virus summary

Pros

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

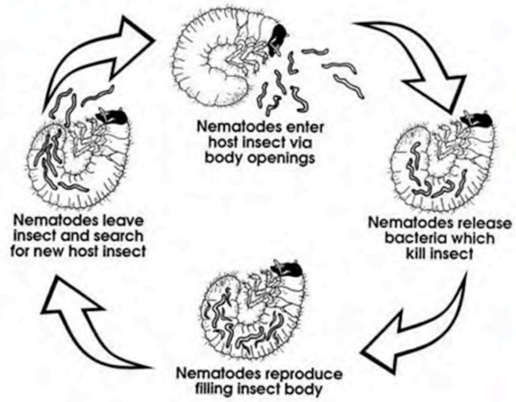
Cons

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

Notes:

Insect Parasitic Nematodes

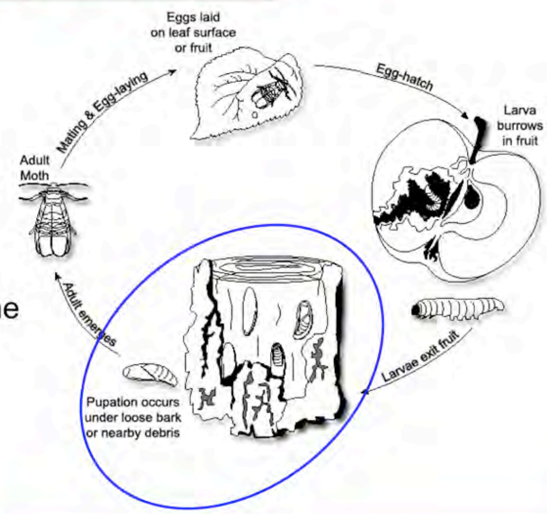
- Round worms



Notes:

Control of codling moth in orchards

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

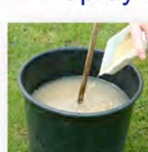


Notes:

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

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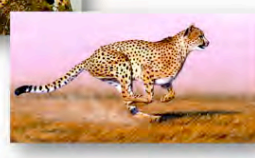
Notes:

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

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Notes:

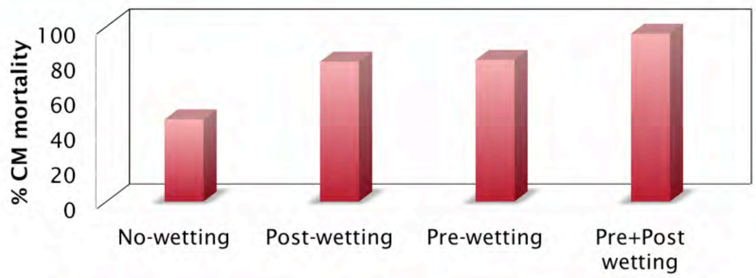
Notes:

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:

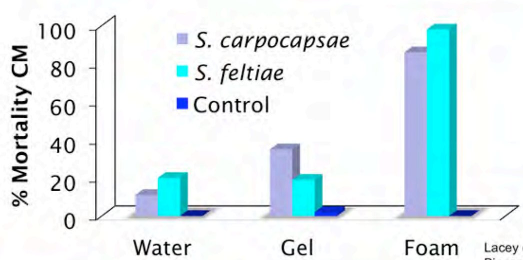
Adding moisture to enhance nematode activity (*S. carpocapsae*)



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

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Notes:

Bacillus thuringiensis kurstaki (Bt): Control of leafroller

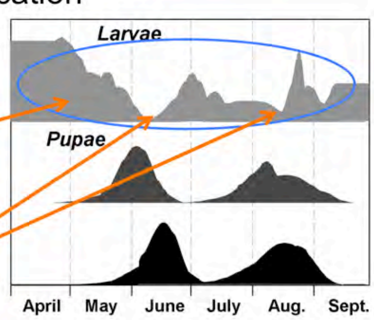
- Toxins produced by bacteria function as stomach poisons and kill larvae once digested

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

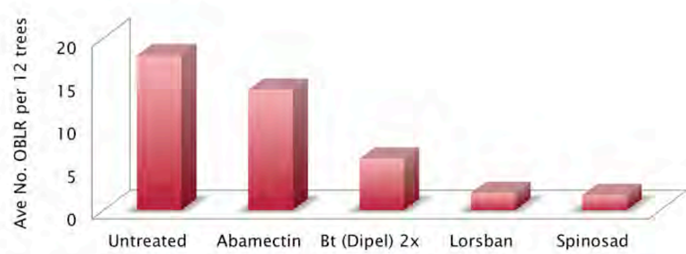
- Leafroller has to ingest Bt sprayed leaf material to obtain a lethal dose
- UV degradation
- Possible interactions with leafroller parasitoids


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

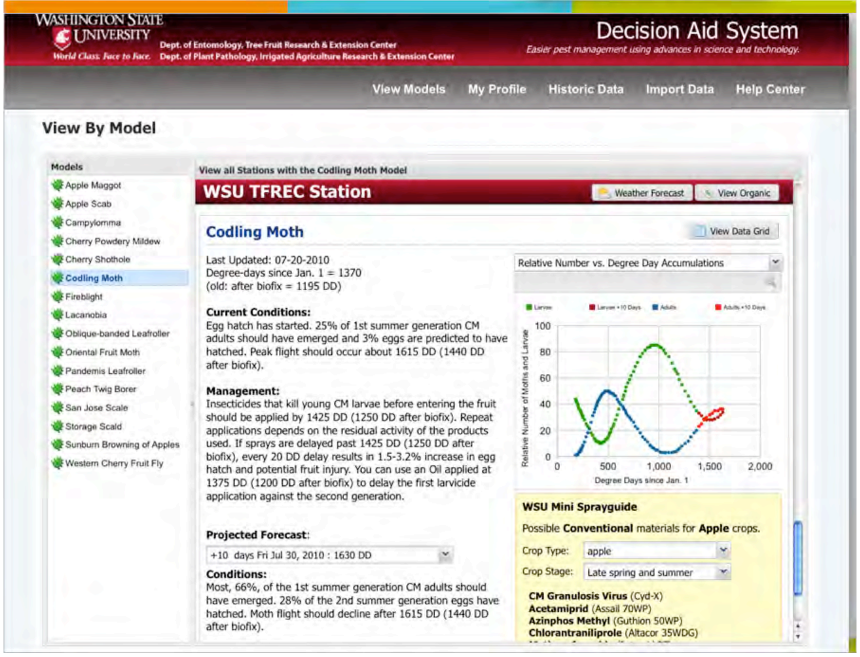
- Leafroller has to ingest Bt sprayed leaf material to obtain a lethal dose
- UV degradation
- Multiple applications

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:

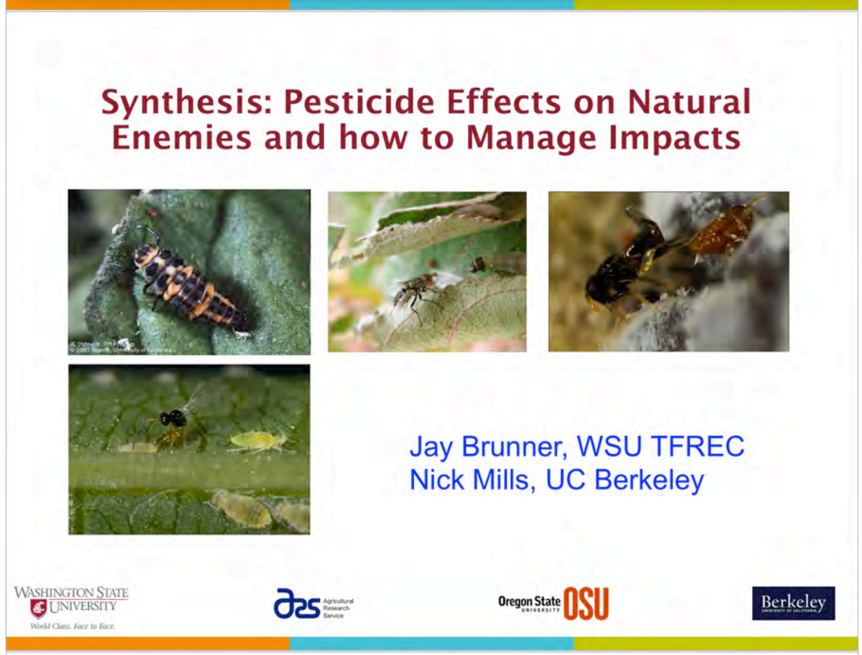


Notes:

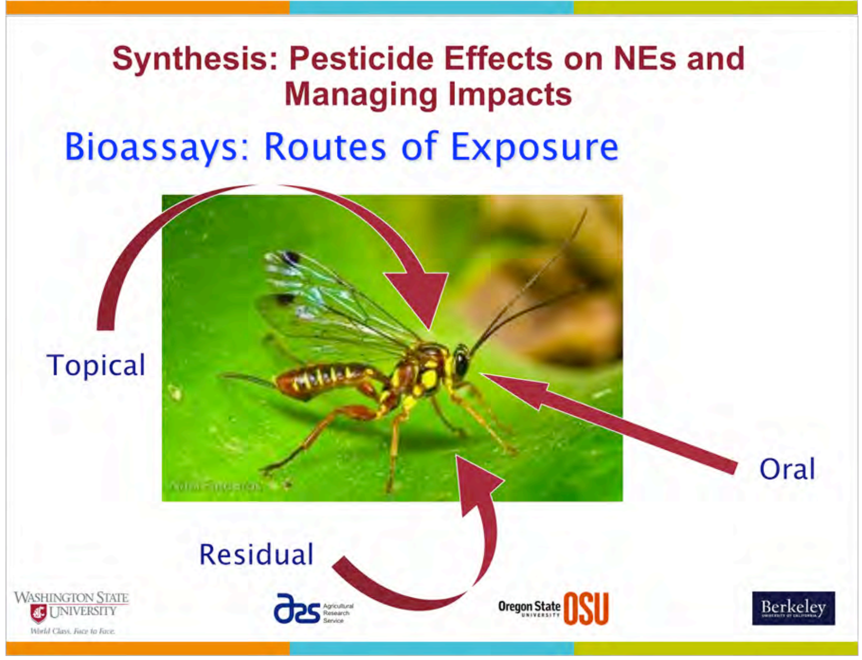
Notes:

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

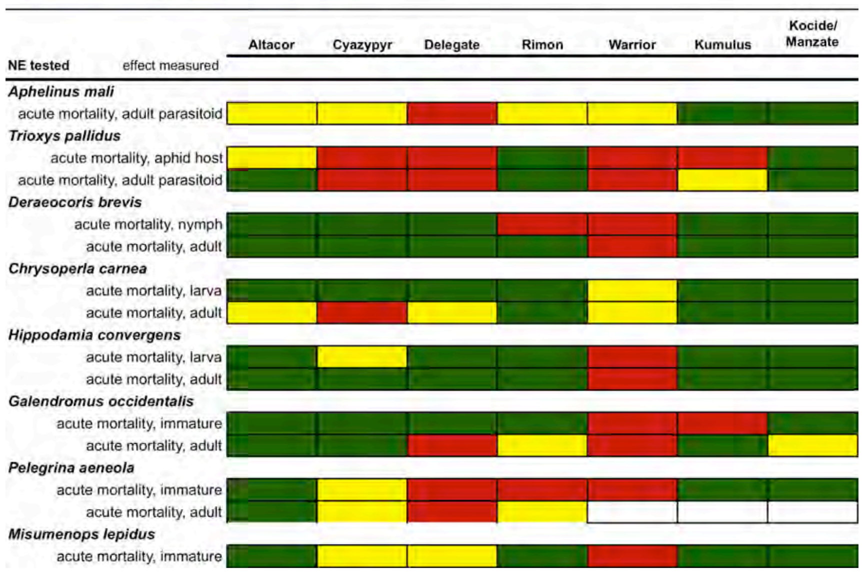
These data will be updated as data become available

0	< 25% acute mortaility or reduction in r
1	25 - 75% acute mortaility or reduction in r
2	> 75% acute mortaility or reduction in r

This color key applied to all tables

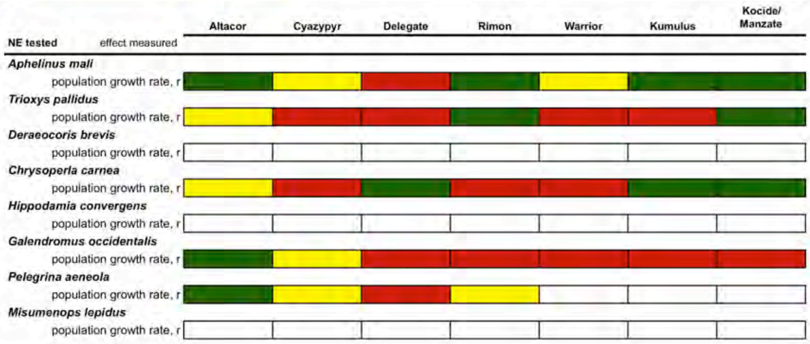
Notes:

Acute toxicity information



Synthesis: Pesticide Effects on NEs and Managing Impacts

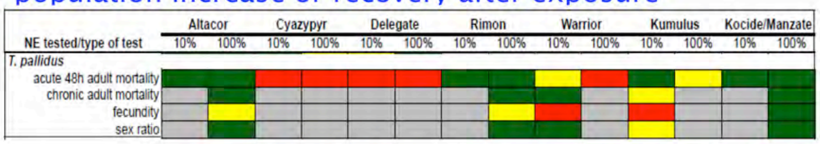
Population growth rate

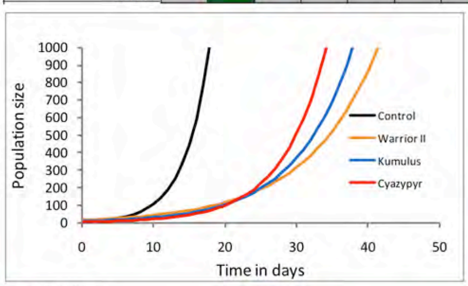


Notes:

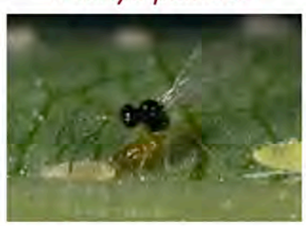
Synthesis: Pesticide Effects on NEs and Managing Impacts

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





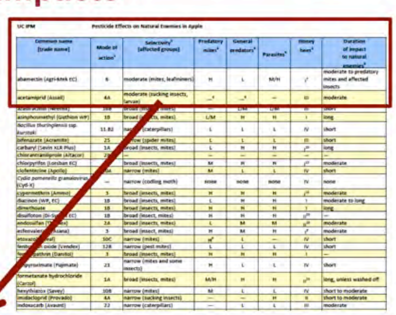
Trioxys pallidus



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[6]
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

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	Relative impact rating[1] WPM[2]	ARM[3]	*Colpoclypeus florus*[4]	*Pnigalio flavipes*[4]	*Aphelinus mali*	Coccinellids[4]	Lacewing
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

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

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 OSU — Berkeley

Notes:

NE tested	effect measured	Altacor	Cyazypyr	Delegate	Rimon	Warrior	Kumulus	Kocide/ Manzate
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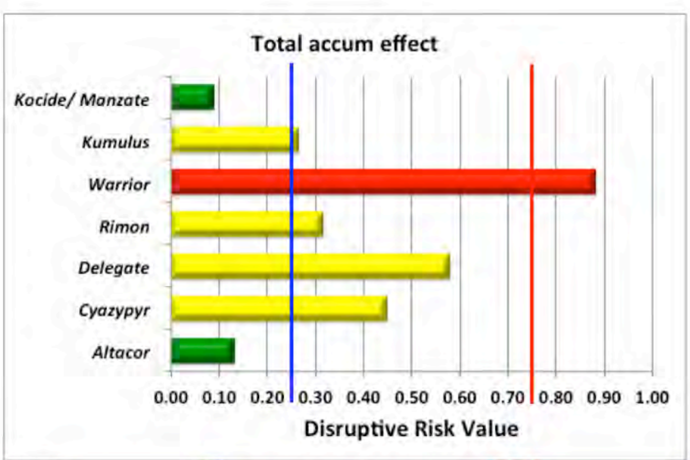

Washington State University — ars Agricultural Research Service — Oregon State OSU — Berkeley

Notes:

Notes:

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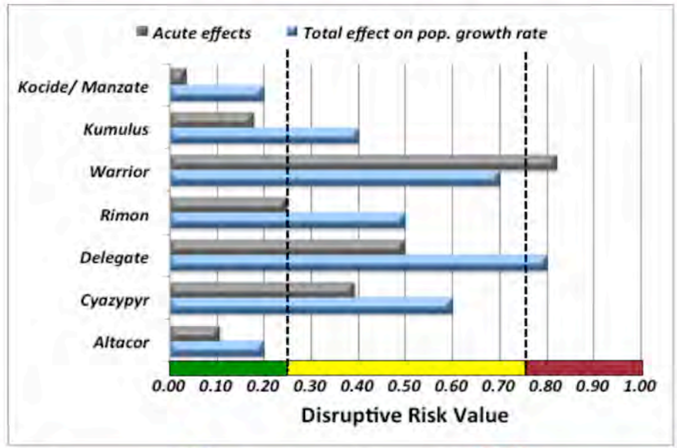
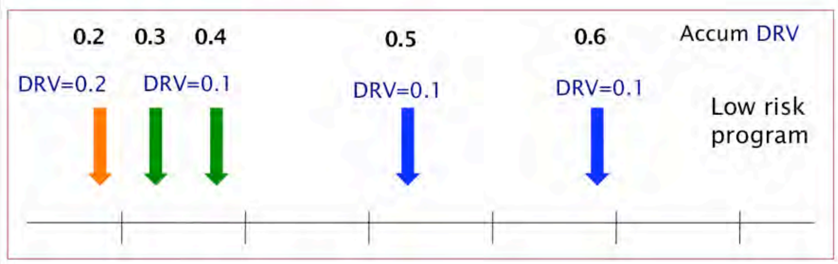


Notes:

Synthesis: Pesticide Effects on NEs and Managing Impacts

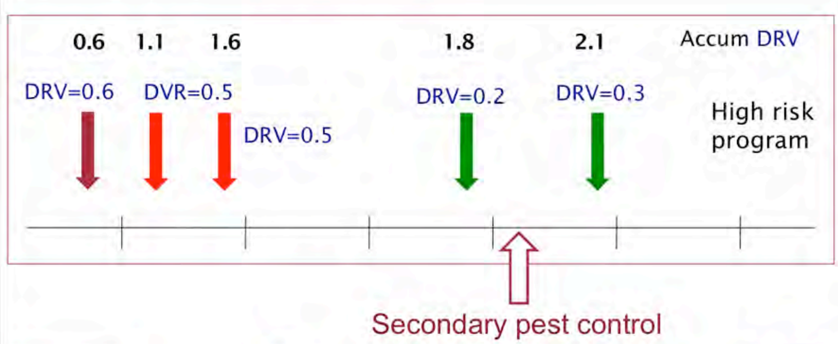
A hypothetical example of how the DRV concept could work for growers/consultants.



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:

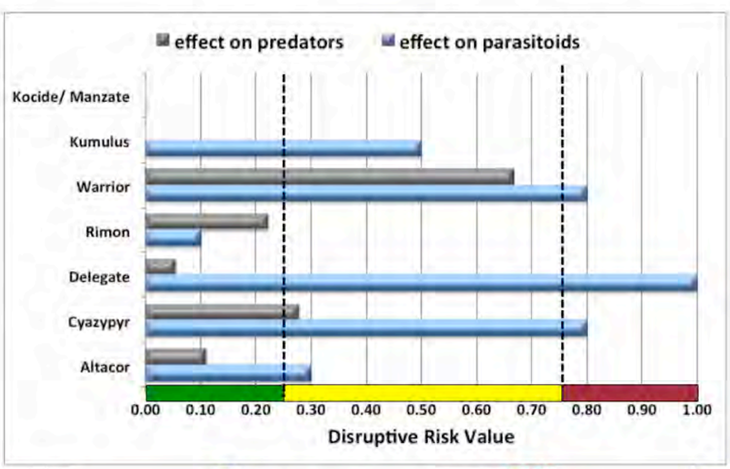
Synthesis: Pesticide Effects on NEs and Managing Impacts

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:

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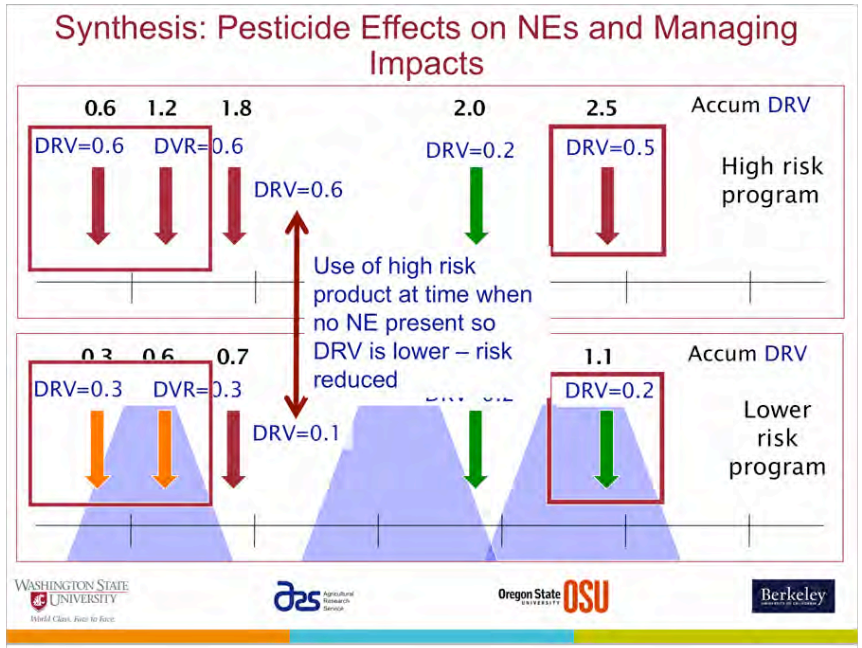
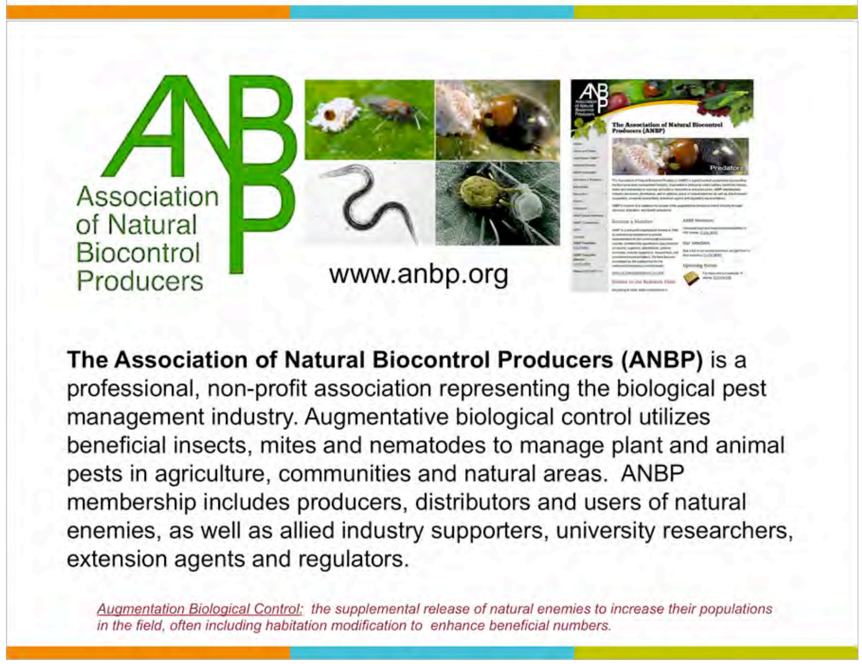


Presentation 5: Using Commercially Available Natural Enemies for Biological Control

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?

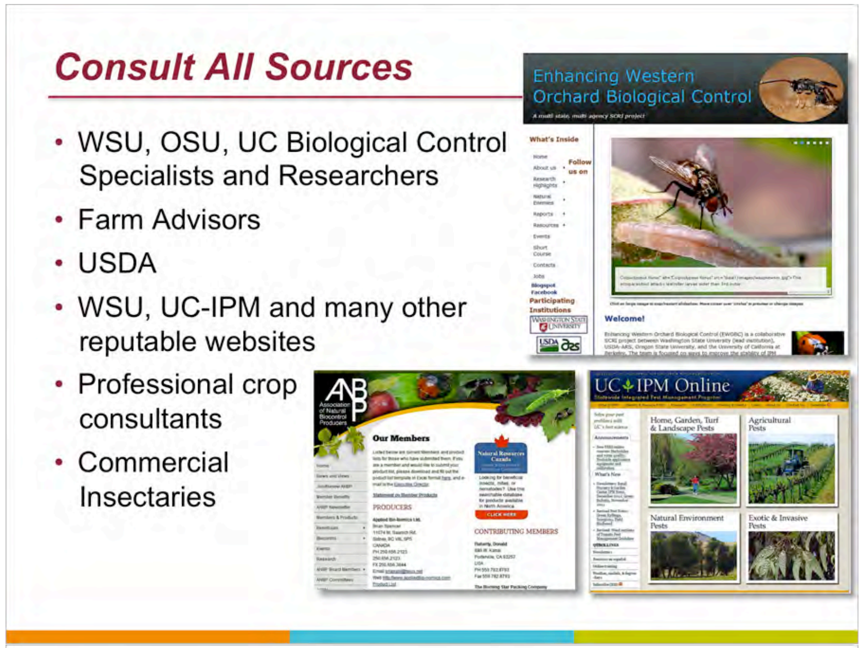
Notes:

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:



Notes:

Notes:

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:

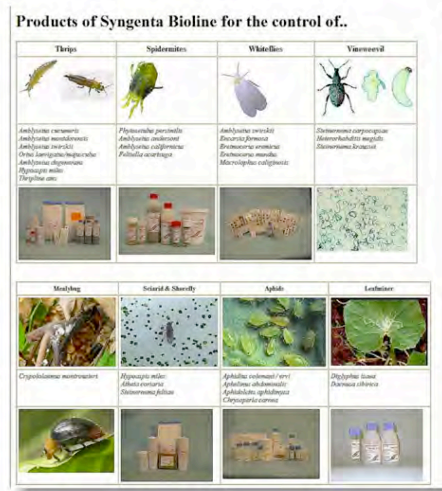
Notes:

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.

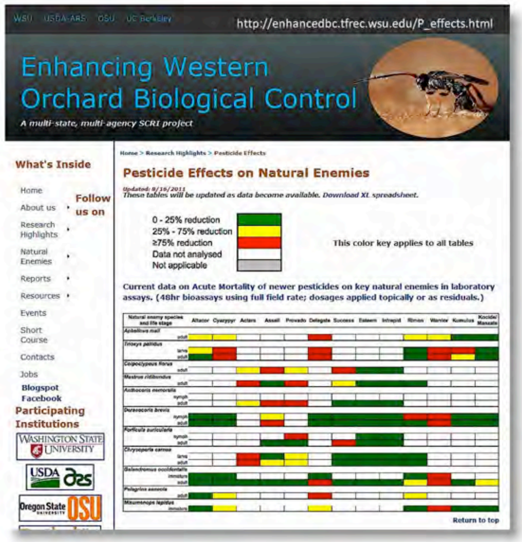
Galendromus occidentalis **are sent direct from the Insectary Next Day Air. ALL ORDERS MUST BE RECEIVED BY NOON (MT. TIME) THURSDAY TO SHIP THE FOLLOWING WEEK**

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.



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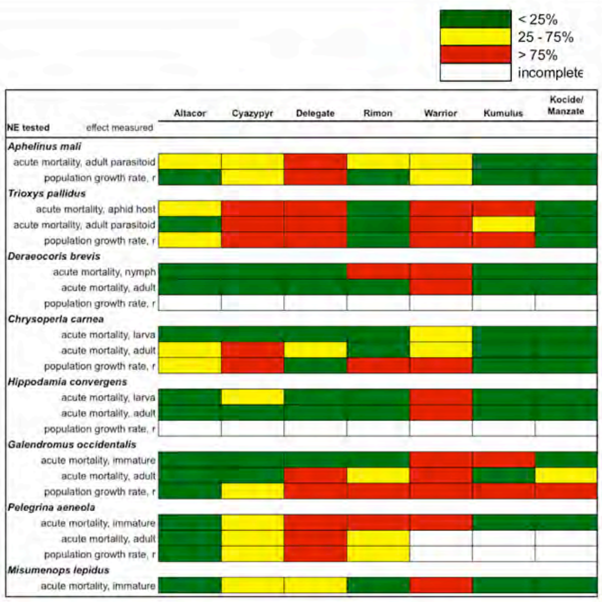
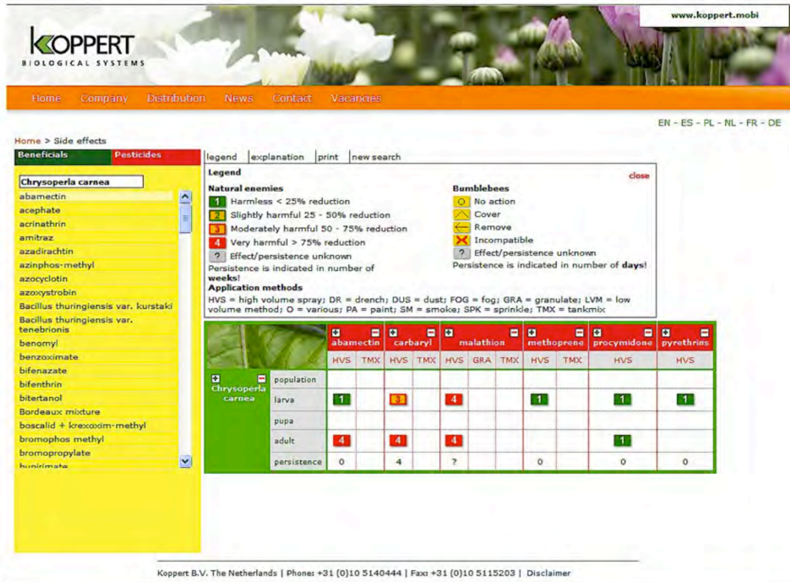


Notes:

Some insectaries will have pesticide compatibility information on their websites

Notes:

Notes:



Notes:

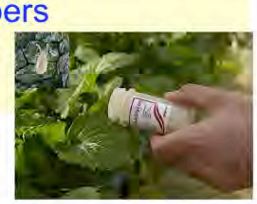
What about Quality Control?

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



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- Ensure packaging is effective
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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?

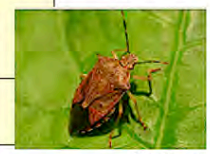
Notes:

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 Predatory midge	Spider mites
Aphidoletes aphidimiza Predatory midge	Aphids, pysllids
Stethorus punctillum Coccinellid beetle	Spider mites
Orius insidiosus Minute pirate bug	Spider mites, aphids, thrips, scale crawlers, psyllids
Podisus maculiventris 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

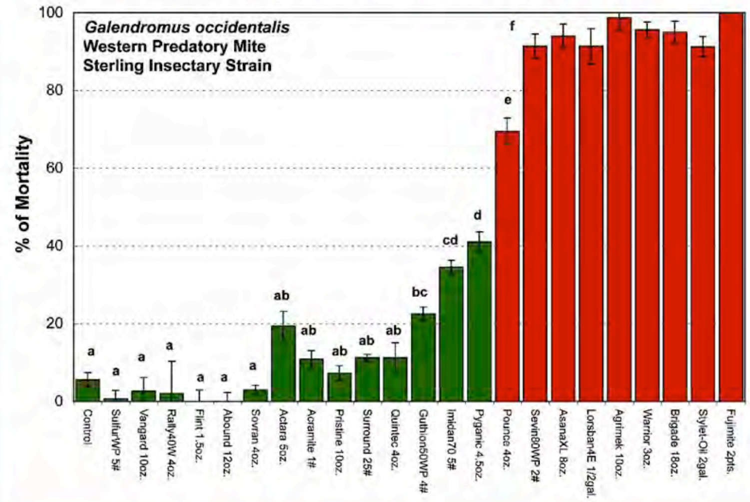
- Bean leaf releases may be preferable in some crops where carriers (corn grit or vermiculite) might easily fall to the ground.
- Biobest (example): one flat or bouquet of cut bean plants = 10,000 predators on 250 plants. Spread bean plants throughout crop at desired rate. To release from bottles, gently 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:

Chemical Resistance for Western Predatory Mites

Pesticide resistance of the Sterling strain of predatory mites



Notes:

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

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

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

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 modern 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.

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.

Figure 1

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.

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Introduction

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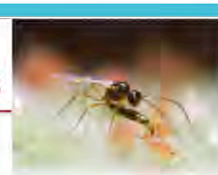
Chrysoperla rufilabris A green lacewing.

Figure 1

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	$25.75 each
1 bottle contains 1,000 crawlers plus food source	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

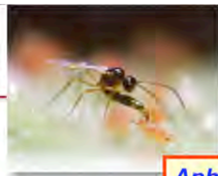
Shipping

- 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.

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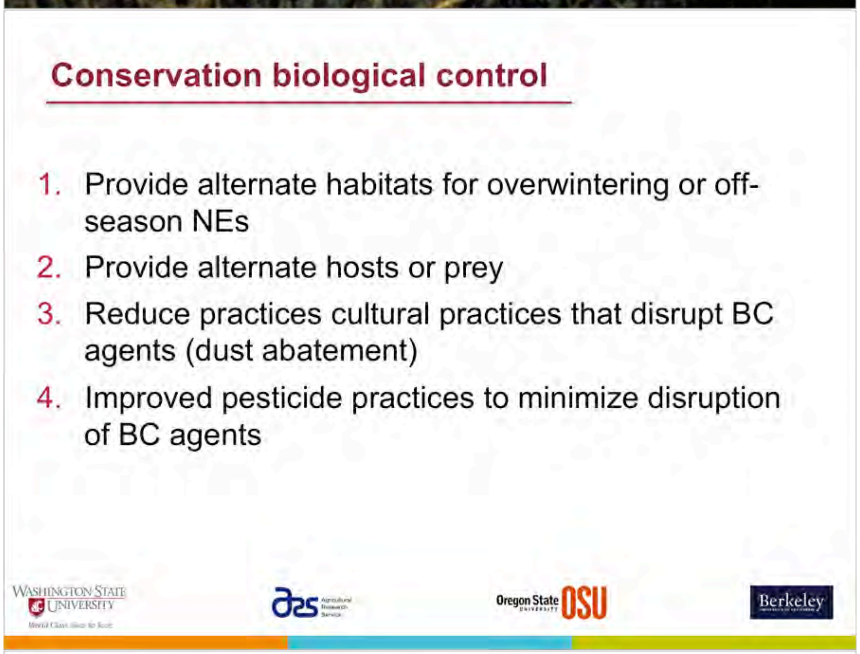
Presentation 6: Conservation Biological Control through Habitat Modifications

Notes:

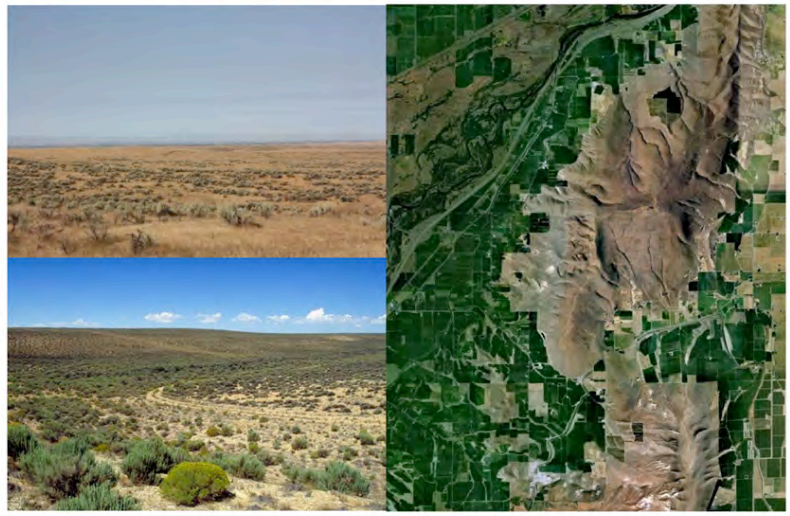


Notes:

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

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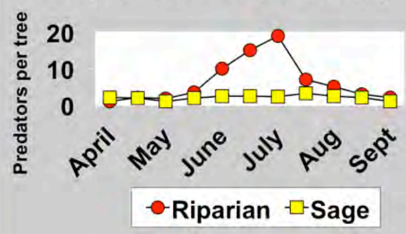
Colonization of potted trees

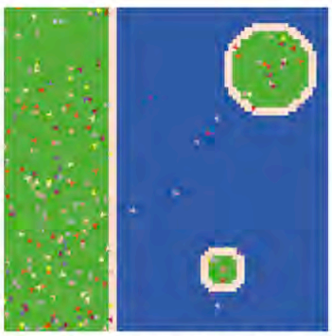
Riparian	Sage
Rose	Lupine
Cottonwood	Sage
Willow	Bitterbrush

(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.



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

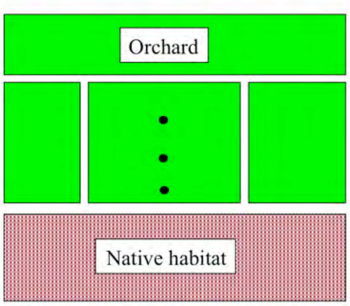
Intuitive:
- *Larger (and richer) surrounding habitats provide more natural enemies*
- *Closer surrounding habitats provide more natural enemies*

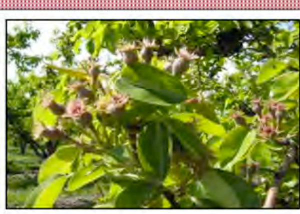
Counter intuitive:
- *Smaller orchards collect more natural enemies per area than large orchards because perimeter/area gets smaller with increasing size* ($2\pi r / \pi r^2$)

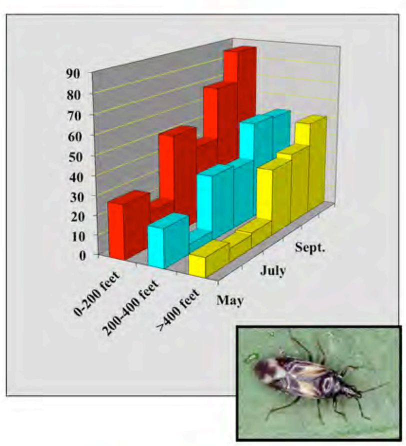
Reality
- *These concepts are largely untested in field studies*

Notes:

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







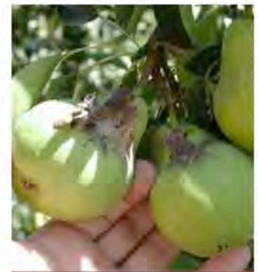
Notes:

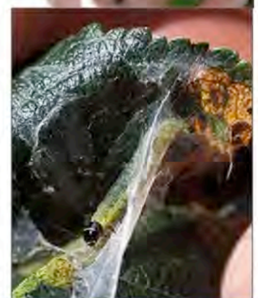
Notes:

General principles may not be enough

The leafroller problem

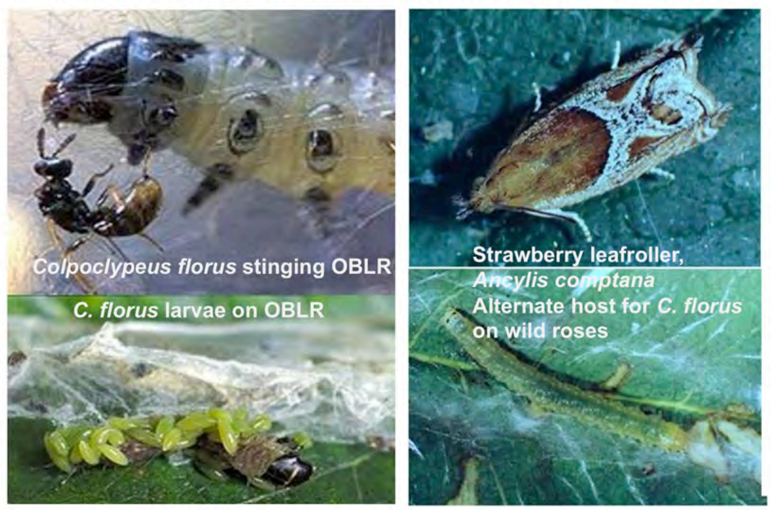
- *Choristoneura rosaceana,* OBLR, and *Pandemis limitata,* PLR, can damage more than 25% of a pear or apple crop
- LRs are often responsible for as much damage as codling moth
- One or two pesticide applications are often used
- There are many parasitoids that attack LRs but they arrive to orchards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

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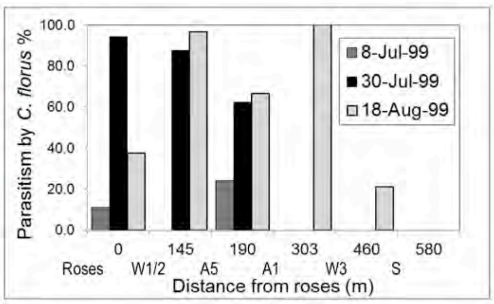
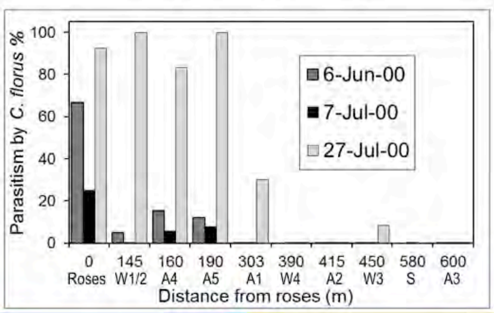
Notes:

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.

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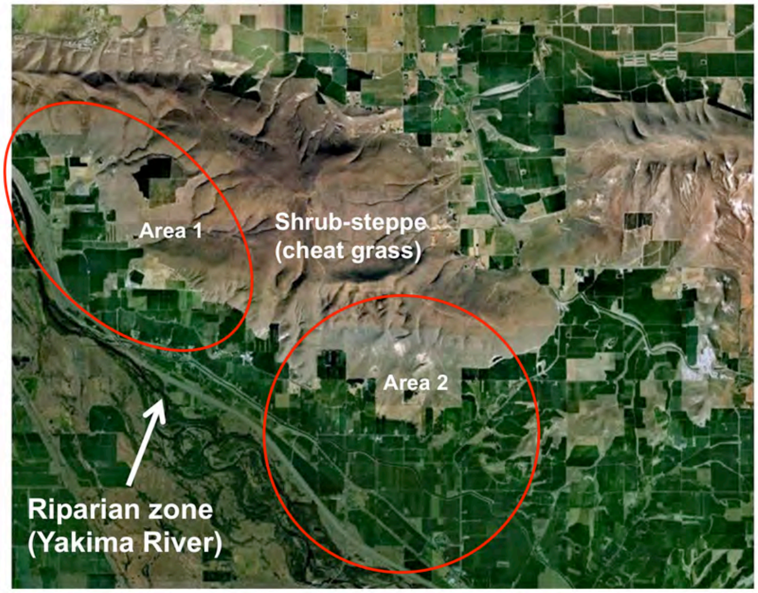
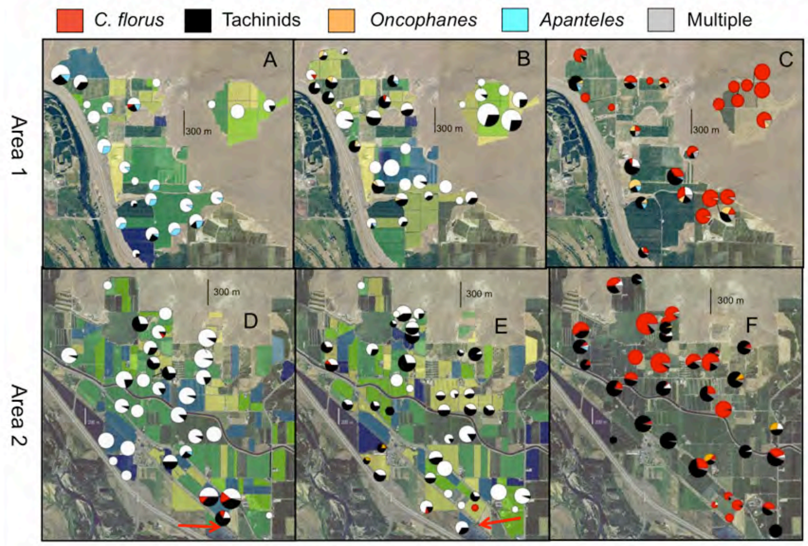
Notes:

Notes:



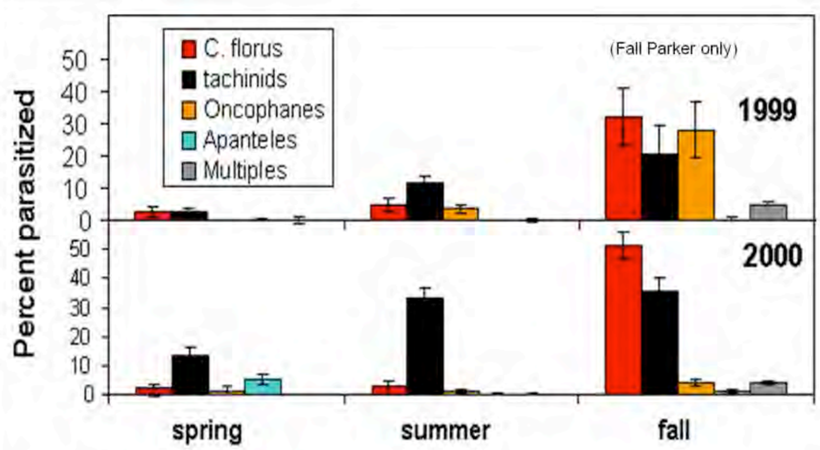
Notes:

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*

Notes:

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

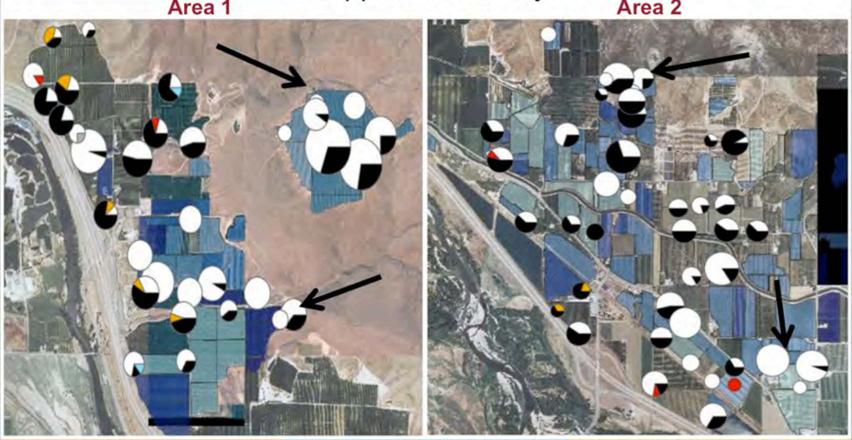
We tried to choose sites where no parasitism was observed.

Notes:

The Gardens (summer 2000)

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

Area 1 Area 2



Notes:

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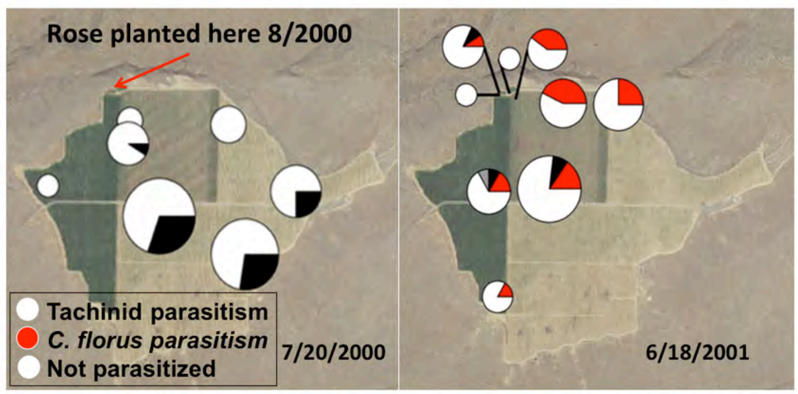
Notes:

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



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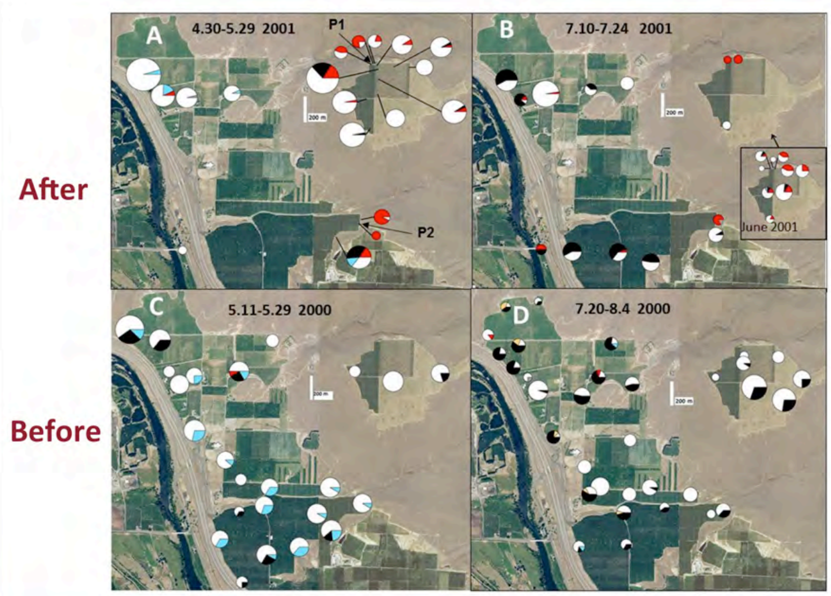
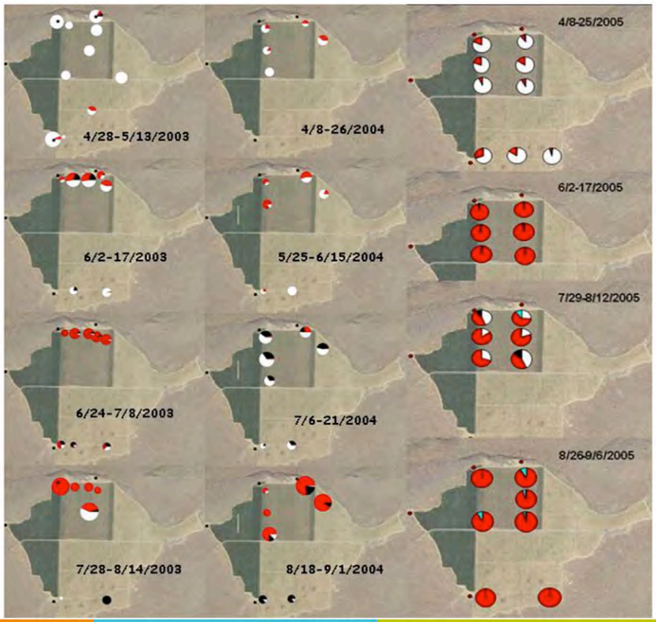


Three year pattern in 100 acre block



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.

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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:

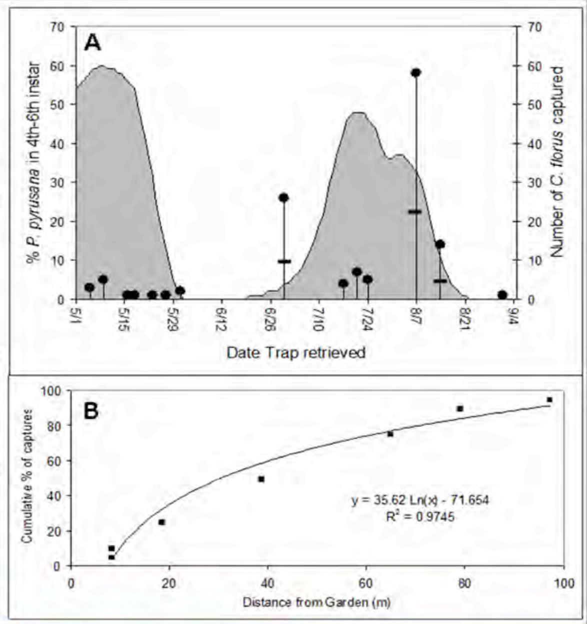
Notes:

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

Notes:

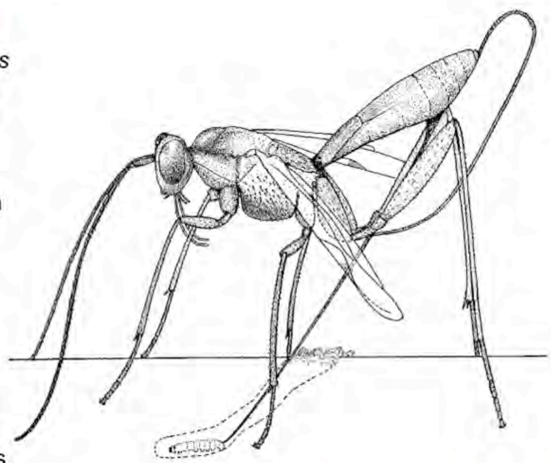
Rose study conclusions

- 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:

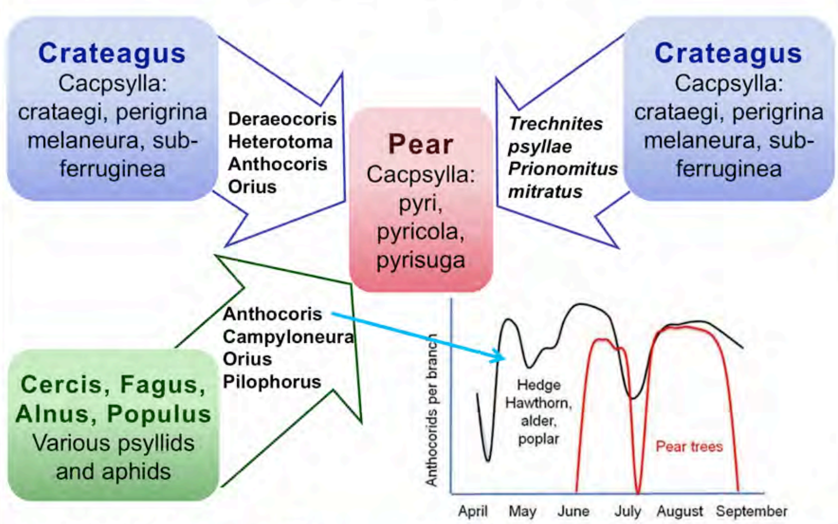
A related system

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:

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)

Case Studies

Case Study #1 Scenario 1

Secondary Pest Problems - Why did they get out of control?

Crop = Apple - Focus on spider mites

Situation:

- This is a large (100 acre) apple orchard with a modern high-density planting.
- Insect damage in cullage assessment for the last three years is show below.
- Total packout is high, 21 boxes per bin (84%).

	Percent of Injury - Cullage Assessment								
Crop year	*CM*	San Jose scale	LR	Campy *	Thrips	Sunburn	Bruises	Other non-insect	Total %
2009	*1*	0	5	1	5	15	32	41	100
2010	*2*	0	0	0	0	21	25	52	100
2011	*0*	0	1	0	0	23	27	49	100

** Campy = Campylomma*

Management Program - Monitoring:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***. Pheromones have been a part of the IPM program.

Pest	CM	Campy / thrips	LR	Mites	Aphids	Other pests
Methods used 2009-2011	1 trap with combo lure per 5 acres	Beat tray	None	Visually observe	Visually observe	Visually observe
Results	Ave. Moths/trap 2.3	Campy/tray =0.3 thrips/tray= 3	Did not monitor	Easy to see, brown leaves	Some on shoots, WAA present	none

Management Program - Pest Control:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***.

Pest control program - products used	CM generation	Timing	Target(s)	$ per acre ***with appl.***	% area treated
Oil, Lorsban Application		Delayed dormant	Scale, mites, aphids	$20 $30 $25	100%
Pheromone Application Delegate Application	1^{st} & 2^{nd}	Bloom	Codling moth, thrips	$110 $15 $59 $25	100%
Rimon Application	1st	Petal Fall	Codling moth, leafrollers	$55 $25	100%
Delegate Application	1st	1st spray – *delayed egg hatch*	Codling moth	$59 $25	100%
Delegate Application	1st	2nd spray *14 day interval*	Codling moth	$59 $25	100%
Nexter Application		3rd spray – late July	Spider mites	$21 $25	100%
			Total	***$578***	

Class Exercise I: Secondary Pest Problems

GOAL: Propose a new management program restoring biological control of spider mite while maintaining or increasing fruit quality (packout).

1. Identify the issues that are likely causing a problem with spider mites.

 ____

 ____

 ____

2. Mark the pesticides in the pest control table above that are harmful to predatory mites (*Galendromus occidentalis*, Western predatory mite – WPM). Use the pesticide effect tables 1 & 2 (on pages 206-207) to help you make these decisions.

3. With the goal of keeping fruit quality high, at least from pest injury, similar to the past three years, what changes would you make in your monitoring and pest control program to enhance biological control of spider mites? Fill out the monitoring and pest control program tables out below. Use the pesticide effect tables 1 &2 (on pages 206-207) to choose pesticides that are least harmful to natural enemies.

Monitoring program changes

Pest	Codling moth	Campylomma /thrips	Leafroller	Mites	Aphids	Other pests
Method used (traps, visual, beat tray, other)						
Number (traps, samples, trees)						
Unit area sampled (acre, tree, etc.)						

Propose changes in products that you would recommend for pest control.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

4. In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement to reduce problems with secondary pests?

   1. ______________________________

   2. ______________________________

   3. ______________________________

   4. ______________________________

5. ***Optional***: If you have time, compare the costs of your new pesticide program with the original pest control program. (Use the pesticide cost table on page 209.)

Case Study #1 Scenario 2

Secondary Pest Problems - Why did they get out of control?

Crop = Apple - Focus on Leafroller

Situation:

- This is a large (100 acre) apple orchard with a modern high-density planting.
- Insect damage in cullage assessment for the last three years is show below.
- Total packout is high, 22 boxes per bin (84%).

	Percent of Injury - Cullage Assessment								
Crop year	*CM*	San Jose scale	LR	Campy *	Thrips	Sunburn	Bruises	Other non-insect	Total %
2009	*3*	0	0	1	0	20	22	54	100
2010	*5*	3	0	0	5	22	21	44	100
2011	*0*	0	0	0	0	34	27	39	100

** Campy = Campylomma*

Management Program - Monitoring:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***. Pheromones have been a part of the IPM program.

Pest	Codling moth	Campylomma/ thrips	Leafroller	Mites	Aphids	Other pests
Methods used 2009-2011	1 trap with combo lure per 10 acres	Beat tray	None	None	Visually observe	Visually observe
Results	Moths/trap 3.5 max = 12	Campy/tray = 0.1 thrips/tray=7	Did not monitor	Did not monitor	few on shoots, no WAA present	none

Management Program - Pest Control:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the last three years.

Pest control program - products used	CM generation	Timing	Target(s)	$ per acre with appl.	% area treated
Oil, Esteem Application		Delayed dormant	Scale, mites, aphids	$20 $48 $25	100%
Carzol Application		Bloom	thrips	$56 $25	100%
Proclaim Application	1st	Petal Fall	leafroller	$40 $25	100%
Altacor Application	1st	1st spray *delayed egg hatch*	Codling moth	$40 $25	100%
Altacor Application	1st	2nd spray *14 day interval*	Codling moth	$40 $25	100%
Intrepid Application		3rd spray – early July	leafroller	$30 $25	100%
			Total	***$424***	

Proposed New Management Program:

GOAL: Propose adjustments in the pest control program that would enhance biological control of leafrollers while maintaining or increasing fruit quality (packout).

1. Identify the issues limit the biological control of leafrollers.

____

____

____

____

2. Mark the pesticides in the pest control table above that could be harmful to leafroller parasitoids (*Colpoclypeus florus*). Use the pesticide effect tables 1 & 2 (on pages 206-207).

3. With the goal of keeping fruit quality high, at least from pest injury, what changes would you make in your monitoring and pest control program to enhance biological control of leafrollers? Fill out the monitoring and pest control program tables out below. Use the pesticide effect tables 1 & 2 (on pages 206-207) to choose pesticides and timings that would be least harmful to or avoid periods when natural enemies are most active.

Monitoring program changes

Pest	Codling moth	Campylomma/ thrips	Leafroller	Mites	Aphids	Other pests
Method used (traps, visual, beat tray, other)						
Number (traps, samples, trees)						
Unit area sampled (acre, tree, etc.)						

Propose changes in products that you would recommend for pest control.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

4. In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement to reduce problems with secondary pests?

   1. ______________________________

   2. ______________________________

   3. ______________________________

   4. ______________________________

5. ***Optional***: Compare the costs of your new pesticide program with the original pest control program. (Use the pesticide cost table on page 209.)

Case Study #2 Scenario 1

Designing BC Friendly IPM Programs

Crop = Apple

Situation:

- You have taken over an apple orchard with the history outlined below.
- This is a moderate size (40 acre) apple orchard with a modern high-density planting.
- The variety is a mix of Gala (15 acres) and Fuji (25 acres).
- Insect damage in cullage assessment for the last three years is below.
- Total packout is modest, 19 boxes per bin.

	Percent of Injury – Cullage Assessment								
Crop year	*CM*	San Jose scale	LR	Campy *	Thrips	Sunburn	Bruises	Other non-insect	Total %
2009	*5*	0	1	1	5	15	32	41	100
2010	*12*	2	0	0	1	14	21	50	100
2011	*20*	15	0	0	0	7	13	45	100

Management Program - Monitoring:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***. Pheromones have **not** been a part of the IPM program.

Pest	CM	Campylomma/ thrips	LR	Mites	Aphids	Other pests
Methods used	1 trap with 1X lure per 10 acres	Beat tray	None	None	Visually observe	None
2009	Ave. Moths/trap 8	Campy/tray= 0.3 thrips/tray=3	NA	NA	Present on shoots, WAA present	NA
2010	Ave. Moths/trap 12	Campy/tray= 0.1 thrips/tray=7	NA	NA	Present on shoots, high WAA	NA
2011	Ave. Moths/trap 23	Campy/tray= 0.0 thrips/tray=6	NA	NA	Present on shoots, high WAA	NA

- The cost of the monitoring program outline above is estimated to be ***$12 per acre***.
- When you design your new monitoring program below consider what if any would be the change in cost of monitoring and if this increase would be justified and how.

Management Program - Pest Control

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***.

Pest control program - products applied	CM generation	Timing	Target(s)	$ per acre with appl.	% area treated
Oil Lorsban Application		Delayed dormant	Scale, mites, aphids	$20 $30 $25	100%
Carzol Application		Bloom	Campy*, thrips	$57 $25	100%
Esteem Application	1st	Petal Fall	Codling moth, leafrollers	$48 $25	100%
Assail+oil Application	1st	1st spray - egg hatch	Codling moth	$60 $25	100%
Assail+oil Application	1st	2nd spray 14 day interval	Codling moth	$60 $25	100%
Delegate Application	2nd	3rd spray – mid July	Codling moth	$59 $25	100%
Delegate + Provado+ Acramite Application	2nd	4th spray – early August	Codling moth, aphids, leafroller	$59 $15 $38 $25	100%
Diazinon Application		5th spray – late July	Spider mites	$32 $25	100%
			Total cost	$ 610	

** Campy = Campylomma*

Class Exercise II: Designing a BC Friendly Management Program

GOAL: Design a BC friendly pest management program that over the next five years maintains or increases fruit quality.

Resources: As you design your BC friendly IPM program take advantages of the resources in your workbook. These would include:

- *Tables of pesticides effects on NEs (pages 206-207)*
- *Lists of NEs most common in apple and pear orchards (Day 1 presentations on NE ID)*
- *Information given in different presentations*

1. What are your key and secondary pests and their natural enemies? Make a list in the table below.

Key pests:	**Natural enemies:**
Secondary pests:	

2. Mark in your list above which of the natural enemies can likely be enhanced?

3. In the table below outline a monitoring program you would implement to enhance biological control and maintain or increase fruit quality.

4. Include the method use, when monitoring would occur, frequency of monitoring, and number of samples taken per area (traps placed or trees sampled).

   - What new tools/practices you have learned about would you employ to enhance biological control (e.g. natural enemy monitoring)?
   - When and how would you change your monitoring strategy between years?
   - ***Optional***: compare the cost between your new and the old monitoring program.

Proposed monitoring program

Pest	Codling moth	Campy/ thrips	Leaf-roller	Mites	Aphids	Other ( )	Other ( )
Method used (traps, visual, beat tray, other)							
Number (traps, samples, trees)							
Unit area sampled (acre, tree, etc.)							

5. In the two tables below outline a pest management program you would implement that enhances biological control and maintains or increases fruit quality.

   - Which pesticides would you change from the current program?
   - How would you change application timing to protect natural enemies and effectively control the pests?
   - How would your management program change from year 1 to year 5, assuming your control practices are effective?
   - Use the tables showing effects of pesticides on natural enemies to help you choose pesticides (pages 206-207) and the chart (page 208) for application timing.
   - **Optional:** if you have time calculate the cost of the new pest control program by using the table on pesticide costs (page 209).

Propose products that you would recommend for pest control - year ONE.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

Propose products that you would recommend for pest control - year FIVE.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement?

1. ____________________

2. ____________________

3. ____________________

4. ____________________

Case Study #2 Scenario 2

Designing BC Friendly IPM Programs

Crop = Pear

Situation:

- You have taken over an pear orchard with a history outlined below.
- This is a moderate size (30 acre) pear orchard with a standard planting.
- The variety is a mix of Bartlett (30%), and Anjou (70%).
- Insect damage in cullage assessment for the last three years is below.
- Total packout is modest, 18 boxes per bin.

	Percent of Injury - Cullage Assessment								
Crop year	*CM*	San Jose scale	LR	Psylla russet	Mealybug	Pear russet	Limb rub	Other non-insect	Total %
2009	*3*	0	0	10	1	20	22	44	100
2010	*2*	3	0	24	5	5	26	35	100
2011	*4*	1	0	15	0	25	23	32	100

Management Program - Monitoring:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***. Pheromones have **not** been a part of the IPM program.

Pest	Codling moth	Pear psylla	Leafroller	Mites	Mealybug	Other pests
Method used	1 trap with 1X lure per 10 acres	Beat tray / leaf samples	None	None	Visually observe	Visually observe
2009	Moths/trap 2.4 max = 17	psylla/tray = 6 nymphs/leaf = 2.3	Did not monitor	Did not monitor	Low numbers present	None
2010	Moths/trap 1.9 max = 12	psylla/tray = 15 nymphs/leaf = 1.3	Did not monitor	Did not monitor	Low numbers present	None
2011	Moths/trap 3.2 max = 17	psylla/tray = 12 nymphs/leaf = 3.3	Did not monitor	Did not monitor	Low numbers present	None

- The cost of the monitoring program outline above is estimated to be ***$12 per acre***.
- When you design your new monitoring program below consider what if any would be the change in cost of monitoring and if this increase would be justified and how.

Management Program - Pest Control

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***.

Pest control program - products used	CM gen	Timing	Target(s)	$ per acre with appl.	% area treated
Sulfur 80W +		Dormant	Pear psylla + pear rust mite	25	100%
Oil				20	
Application				20	
Oil +		Delayed dormant	Pear psylla	20	100%
Warrior II +				10	
Lorsban				30	
Application				20	
Mancozeb 75DF +		Cluster bud	Pear psylla + mites	35	100%
Nexter 75WP				78	
Application				20	
Ultor 1.25SC		Petal fall	Pear psylla	53	100%
Mancozeb 75DF				35	
Application				20	
Oil +		Post petal fall	Mites + pear psylla	5	100%
Agrimek 0.15EC +				87	
Ultor 1.25SC				53	
Application				20	
Delegate 25WG +	1st gen	1st cover codling moth spray	Pear psylla + codling moth	59	100%
oil				3	
Application				20	
Delegate 25WG +	1st gen	2nd cover codling moth spray	Pear psylla + codling moth	59	100%
oil				3	
Application				20	
Acramite		Summer	Spider mites + Pear psylla	58	100%
Clutch				50	
oil				3	
Application				20	
Sulfur 80W +		Post harvest	Pear psylla + pear rust mite	25	100%
oil				10	
Application				20	
			Total cost	901	

Exercise: Designing a BC Friendly IPM Program

GOAL: Design a BC friendly pest management program that over the next five years maintains or increases fruit quality.

Resources: As you design your BC friendly IPM program take advantages of the resources in your workbook. These would include:

- *Tables of pesticides effects on NEs (pages 206-207)*
- *Lists of NEs most common in apple and pear orchards (Day 1 presentations on NE ID)*
- *Information given in different presentations*

1. What are your key and secondary pests and their natural enemies? Make a list in the table below.

Key pests:	**Natural enemies:**
Secondary pests:	

2. Mark in your list above which of the natural enemies can likely be enhanced?

3. In the table below outline a monitoring program you would implement to enhance biological control and maintain or increase fruit quality.

4. Include the method use, when monitoring would occur, frequency of monitoring, and number of samples taken per area (traps placed or trees sampled).

   - What new tools/practices you have learned about would you employ to enhance biological control (e.g. natural enemy monitoring)?
   - When and how would you change your monitoring strategy between years?
   - ***Optional***: compare the cost between your new and the old monitoring program.

Proposed monitoring program

Pest	Codling moth	Pear psylla	Leaf-roller	Mites	Aphids	Mealybug	Other ( )
Method used (traps, visual, beat tray, other)							
Number (traps, samples, trees)							
Unit area sampled (acre, tree, etc.)							

5. In the two tables below outline a pest management program you would implement that enhances biological control and maintains or increases fruit quality.

   - Which pesticides would you change from the current program?
   - How would you change application timing to protect natural enemies and effectively control the pests?
   - How would your management program change from year 1 to year 5, assuming your control practices are effective?
   - Use the tables showing effects of pesticides on natural enemies to help you choose pesticides (pages 206-207) and the chart (page 208) for application timing.
   - **Optional:** if you have time calculate the cost of the new pest control program by using the table on insecticide costs (page 209).

Propose products that you would recommend for pest control – year ONE.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

Propose products that you would recommend for pest control - year FIVE.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement?

1. ____

2. ____

3. ____

4. ____

Case Study #3 Scenario 1

Dealing with Crisis and Restoring BC

Resistance in the key pest

Situation:

- This is a moderate size (30 acre) apple orchard with a modern high-density planting.
- The variety is Fuji with crab pollinizers.
- Insect damage in cullage assessment for the last three years is below.
- Total packout has declined from 22 packs per bin to 17 packs per bin.
- The orchard has had increased problems controlling codling moth over the last three years.
- Bioassay of codling moth from this orchard shows a high degree of resistance to Altacor.
- You have been asked to manage the orchard with a history outlined below and to produce a crop without codling moth damage.

	Percent of Injury - Cullage Assessment								
Crop year	*CM*	San Jose scale	LR	Campy *	Thrips	Sunburn	Bruises	Other non-insect	Total %
2009	*15*	0	1	0	2	15	29	38	100
2010	*36*	2	0	0	1	8	15	38	100
2011	*48*	1	0	0	0	4	12	35	100

** Campy = Campylomma*

Management Program - Monitoring:

The pest monitoring program used in this orchard is outlined below. The methods have remained essentially the same for the ***last three years***.

Pest	CM	Campylomma/ thrips	LR	Mites	Aphids	Other pests
Methods used	1 trap per 5 acres with combo lure	Beat tray	None	Visually observe	Visually observe	None
2009	Ave. Moths/trap 5	Campy/tray= 0.3 thrips/tray=3	NA	Low levels	Present on shoots	NA
2010	Ave. Moths/trap 22	Campy/tray= 0.1 thrips/tray=7	NA	Low levels	Present on shoots	NA
2011	Ave. Moths/trap 44	Campy/tray= 0.0 thrips/tray=2	NA	Moderate levels	Present on shoots, high WAA	NA

Management Program - Pest Control

The pest control program used in 2011 in this orchard is outlined below. It has remained essentially the same for the ***last five years***.

Pest control program - products used	CM generation	Timing	Target(s)	$ per acre with appl.	% area treated
Oil Application		Delayed dormant	Scale, mites	$20 $25	100%
Pheromone Application		Pink	Codling moth	$50 $15	100%
Carzol Application		Bloom	Campy*, thrips	$57 $25	100%
Altacor Application	1st	Petal Fall	Codling moth, leafrollers	$48 $25	100%
Altacor Application	1st	1st spray @ egg hatch	Codling moth	$60 $25	100%
Altacor Application	1st	2nd spray 17 day interval	Codling moth	$60 $25	100%
Intrepid + Provado Application	2nd	3rd spray – mid July	Codling moth	$59 $15 $25	100%
Altacor + Acramite Application	2nd	4th spray – early August	Codling moth, leafroller	$59 $38 $25	100%
Diazinon Application		5th spray – late July	Woolly apple aphid	$32 $25	100%
			Total cost	***$ 654***	

* Campy = *Campylomma*

Class Exercise III - Dealing with Crisis and Restoring Biological Control

GOALS:

- Manage a crisis with a key pest that has developed resistance to a pesticide.
- Consider option of how to restore BC into an IPM program.

Scenario #1 - Dealing with CM resistance to Altacor

- Your assignment is to bring CM back under control – reduce cullage to acceptable levels (2-4% of all culls), as inexpensively as possible in year one.
- Outline a pest control program you would implement to achieve the assigned task (use blank program below) for year one.

Propose products that you would recommend for pest control - year ONE.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

- What will be the impact of the program outlined above on biological control in the orchard?

- If the program you used in year one will disrupt biological control, what kind of a program will you implement in the following years to restore biological control in the orchard? Fill in the table below with your choice of products.
- How long do you think it will take to restore biological control to previous levels, that is, no need for application of controls for secondary pests?

Propose products that you would recommend for pest control – year TWO +.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.

In addition to the changes in pest control practices outlined above, what other activities might you propose to change or implement?

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

What kinds of research solutions would be needed to deal with future problems such as this?

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

Case Study #3 Scenario 2

Dealing with Crisis and Restoring BC

A new pest invades the region and your orchard

Situation:

- This is a large sized (100 acre) apple orchard with a modern high-density planting.
- The varieties are a mix of Gala (60%) and Fuji (40%) with crab pollinizers.
- Insect damage in cullage assessment for the last three years is below.
- Total packout has declined from 22 packs per bin to 15 packs per bin in the last year alone.
- Injury from ***stink bugs*** has dramatically increased in last two years.
- The injury from stink bug has been identified as coming from the *brown marmorated stink bug (BMSB)*, a new invasive species (see fact sheet on this bug on page 210).

	Percent of Injury - Cullage Assessment								
Crop year	*CM*	San Jose scale	LR	Campy *	Thrips	Stink bugs	Bruises	Other non-insect	Total %
2009	*4*	1	1	1	2	0	32	59	100
2010	*2*	2	0	1	1	12	24	58	100
2011	*1*	0	0	0	0	67	9	23	100

** Campy = Campylomma*

Management Program - Monitoring:

The pest monitoring program used in this orchard is outlined below. The methods have remained essentially the same for the ***last three years***.

Pest	CM	Campylomma/ thrips	LR	Mites	Aphids	Other pests
Methods used	1 trap per 5 acres with combo lure	Beat tray	None	Visually observe	Visually observe	None
2009	Ave. Moths/trap 5	Campy/tray= 0.3 thrips/tray=3	NA	Low levels	Present on shoots	NA
2010	Ave. Moths/trap 3	Campy/tray= 0.1 thrips/tray=1	NA	Low levels	Present on shoots	NA
2011	Ave. Moths/trap 2	Campy/tray= 0.0 thrips/tray=2	NA	Moderate levels	Present on shoots, high WAA	NA

Management Program – Pest Control

The pest control program used in 2011 in this orchard is outlined below. It has remained essentially the same for the ***last five years***. There have been no applications for control of secondary pests over the last five years.

Pest control program – products used	CM gen	Timing	Target(s)	$ per acre with appl.	% area treated
Oil Application		Delayed dormant	Scale, mites	$20 $25	100%
Pheromone Application		Bloom	Codling moth	$100 $15	100%
Intrepid Application	1st	Petal Fall	Codling moth, leafrollers	$30 $25	100%
Altacor Application	1st	1st spray delayed egg hatch	Codling moth	$40 $25	100%
Altacor Application	1st	2nd spray 17 day interval	Codling moth	$40 $25	100%
			Total cost	***$345***	

Class Exercise III - Dealing with Crisis and Restoring Biological Control

GOAL: Manage the crisis associated with the appearance of a new invasive pest, BMSB

Scenario #2 - dealing with presence of a new invasive pest, BMSB

- ***In this scenario we are just asking you to address the questions below.***

What are the most likely pest control options for controlling BMSB?

What will be the likely impact on biological control when implementing the above controls for BMSB?

What barriers will exist to restoring biological control into an IPM program that must deal with this new pest?

What information or tools for managing BMSB would be needed to help restore biological control to an orchard dealing with this new pest?

Resources

List of Web Resources

Biological Control Resources on the Web

Enhanced BC Project http://www.enhancedbiocontrol.org/

Pest Management Transition Project http://pmtp.wsu.edu/

UC IPM http://www.ipm.ucdavis.edu/

- Natural enemies - galleries http://www.ipm.ucdavis.edu/PMG/NE/index.html

Orchard Pest Management Guide http://jenny.tfrec.wsu.edu/opm/

Cornell University – Guide to Natural Enemies in North America
http://www.biocontrol.entomology.cornell.edu/

IPM Resources Michigan State University – Identifying natural enemies
http://www.ipm.msu.edu/natural-enemies.htm

OSU Integrated Plant Protection Center http://www.ipmnet.org/

- Natural enemy pocket ID guide: http://www.ipmnet.org/Pocket_Guide_of_Natural_Enemies.pdf

Pacific Northwest Insect Management Handbook http://uspest.org/pnw/insects

DAS Home Page http://das.wsu.edu

Association of Natural Biocontrol Producers http://www.anbp.org

Koppert Biological Systems http://www.kopert.mobi

DAS Screen Shot 1

Leafroller Overwintering Generation Management Recommendations

View all Stations with the Oblique-banded Leafroller Model

WSU Sunrise Station

Weather Forecast | View Organic

Oblique-banded Leafroller

View Data Grid

Last Updated: 05/11/2009
Degree days since January 1st. = 256

Current Conditions:
About 33% of the overwintering generation is in the 4th instar and 22% are in the 5th instar.

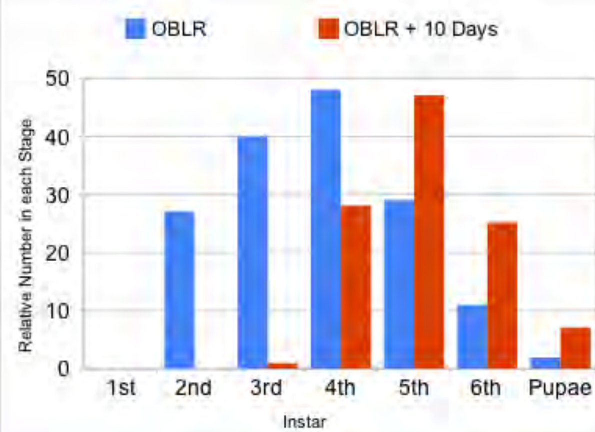
Management:
Sample to determine population levels between 180-280 DD. If treatments are needed, apply before 370 DD so that less than 10% of the overwintering generation is in the pupal stage (pupae are insensitive to the pesticide); if using Esteem the first spray must be on between 250-300 DD. For every 20 DD delay in the application, the portion of the population controlled decreases by 3-5%.

Projected Forecast:
+10 days Thu May 21, 2009 : 342

Conditions:
69% of the overwintering generation is in the 5th and 6th instars. 8% of the population is in the pupal stage, and first adults should appear at roughly 550 DD.

Management:
If treatments are needed, apply before 370 DD so that less than 10% of the population is in the pupal stage (pupae are insensitive to the pesticide); if using Esteem the first spray must be on between 250-300 DD. For every 20 DD delay in the application, the portion of the population controlled by Esteem decreases by 3-5%. If sprays are not required for the first generation, sampling can be continued during this period to help determine if the summer generation larvae need to be treated.

Graph of Relative Number in each Stage



WSU Mini Spray guide

Possible **Conventional** materials for **Apple** crops.

Crop Type: apple
Crop Stage: Bloom

Bacillus Thuringiensis Subsp. Kurstaki (DiPel DF)
Methoxyfenozide (Intrepid 2F)

View Full WSU Spray guide

DAS Screen Shot 2

Leafroller Summer Generation Management Recommendations

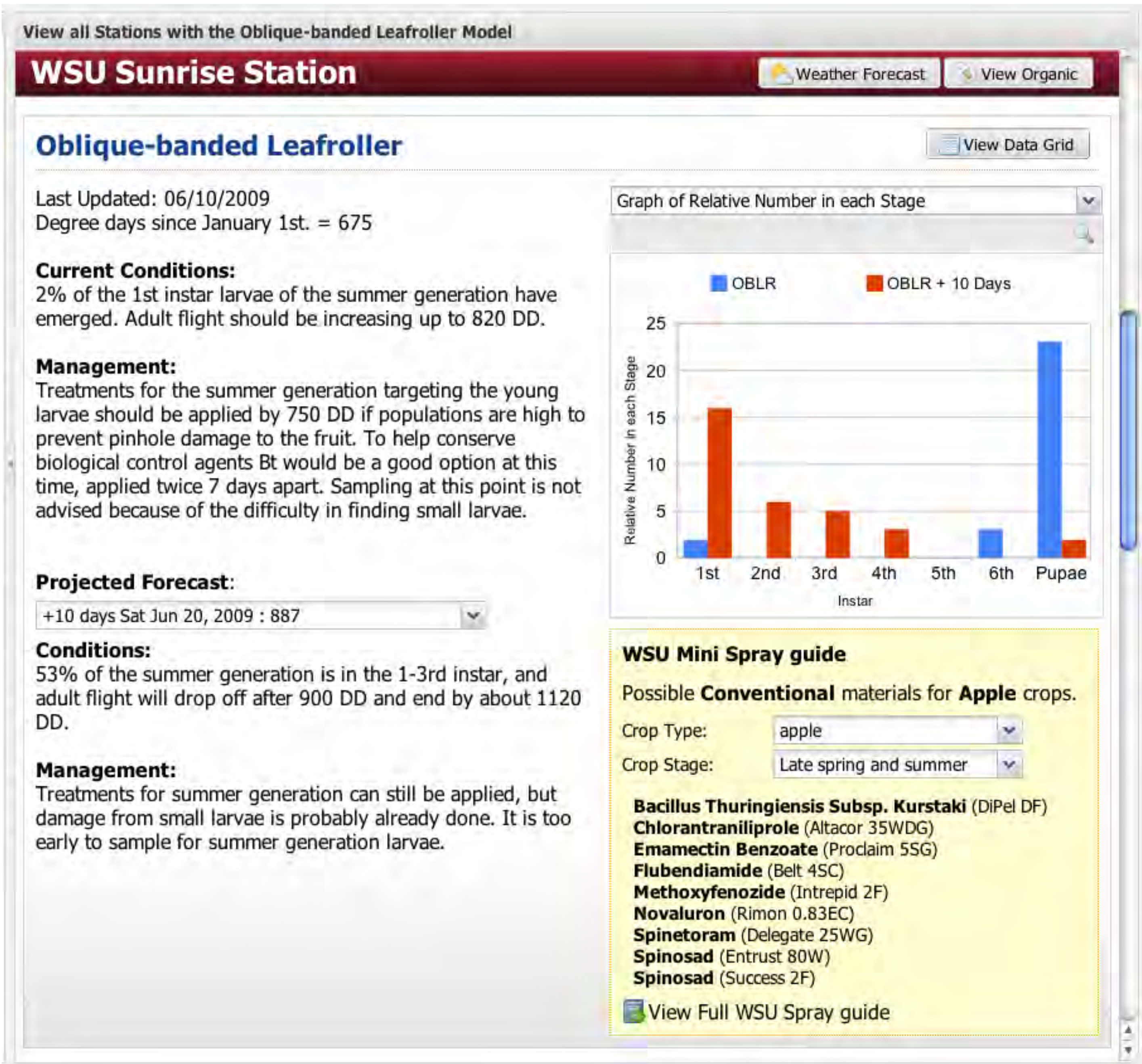


Table 1: Pesticide Effects

Pesticide Effects on Natural Enemies (based on current research)

Laboratory bioassays
(full field rate)

green	< 25% acute mortaility or reduction in r
yellow	25 - 75% acute mortality or reduction in r
red	> 75% acute mortality or reduction in r
white	not yet completed

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
population growth rate, r	green	yellow	red	green	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
population growth rate, r	yellow	red	red	green	red	red	green
Deraeocoris brevis							
acute mortality, nymph	green	green	green	red	red	green	green
acute mortality, adult	green	green	green	green	red	green	green
population growth rate, r	not yet completed	not yet completed	not yet completed	not yet completed	not yet completed	not yet completed	not yet completed
Chrysoperla carnea							
acute mortality, larva	green	green	green	green	yellow	green	green
acute mortality, adult	yellow	red	yellow	green	yellow	green	green
population growth rate, r	yellow	red	green	red	red	green	green
Hippodamia convergens							
acute mortality, larva	green	yellow	green	green	red	green	green
acute mortality, adult	green	green	green	green	red	green	green
population growth rate, r	not yet completed	not yet completed	not yet completed	not yet completed	not yet completed	not yet completed	not yet completed
Galendromus occidentalis							
acute mortality, immature	green	green	green	green	red	red	green
acute mortality, adult	green	green	red	yellow	red	green	yellow
population growth rate, r	green	yellow	red	red	red	red	red
Pelegrina aeneola							
acute mortality, immature	green	yellow	red	red	red	green	green
acute mortality, adult	green	yellow	red	yellow	not yet completed	not yet completed	not yet completed
population growth rate, r	green	yellow	red	yellow	not yet completed	not yet completed	not yet completed
Misumenops lepidus							
acute mortality, immature	green	yellow	yellow	green	red	green	green

r - red (negative values or <25% of range from 0 to control value)
- yellow (25 - 75% of range from 0 to control value)
- green (>75% of range from 0 to control value)

Table 2: Pesticide Effects

Pesticide Effects on Natural Enemies (from WSU spray guide)

Natural Enemy Relative Impact Guide

This table is intended as a guide to the relative impact of commonly applied pesticides to natural enemies that are important components of an integrated pest management program on tree fruits. Use it in conjunction with the Pest Control Program for each fruit crop. These give recommended rates and timing of sprays. The impact of some insecticides may vary considerably with the history of use in a given orchard. This is especially true relative to their effect on the western predatory mite (WPM) and the apple rust mite (ARM).

Trade Name	Compound	Relative impact rating[1]						
		WPM[2]	ARM[3]	*Colpoclypeus florus*[4]	*Pnigallo flavipes*[4]	*Aphelinus mali*	Coccinellids[4]	Lacewing
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

[1]Rating system: L = low impact, M = moderate impact, H = high impact, – no data available.

[2]WPM = western predatory mite, *Typhlodromus occidentalis*.

[3]ARM = apple rust mite, *Aculus schlechtendali*. Although ARM is a plant feeding species, its presence is very useful in maintaining populations of *Typhlodromus occidentalis*.

[4]*C. florus* is a wasp parasitoid of leafrollers; *P. flavipes* is a wasp parasitoid of western tentiform leafminer. See Orchard Pest Management for more information.

[5]Coccinellid data based on bioassays of late instar larvae of *Harmonia axyridis, Hippodamia convergens*, and *Coccinella transversoguttata*. Kaolin data based on bioassays using *Stethorus punctum*.

[6]Overall negative impact is reduced due to short residual activity.

[7]Spray volume may be important in determining toxicity.

[8]Preliminary data; based on field trials of 4 cover sprays.

[9]Preliminary data; based on field trials with a single application.

[10]The use of this material has been associated with mite problems, although the effect is inconsistent; there appears to be moderate acute toxicity, but more severe reproductive effects on WPM.

[11]100% mortality/sterility was caused by exposure to novaluron

[12]Novaluron has little or no acute toxicity to lacewing eggs, larvae, or adults; however, this material caused a near-complete shutdown of egg hatch from exposed adults.

[13]While this material is toxic to WPM, it is also somewhat miticidal, and thus may not cause flare-ups of mites.

[14]Preliminary data, based on laboratory acute toxicity tests.

Chart 1: CM & LR Spray Timing

LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Petal fall **225-275 DD** (50-100 DD pbf)	**375 DD** (200 DD pbf)	**1st cover** **425 DD** (250 DD pbf)	**Delayed 1st cover** **525 DD** (350 DD pbf)	**2nd cover** **625-675 DD** (450-500 DD pbf)	**Delayed 2nd cover** **725-825 DD** (550-650 DD pbf)	**3rd cover** **875-925 DD** (700-750 DD pbf)
Proclaim Success Delegate Belt Bt	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus
Proclaim Success Delegate Belt Bt →	**Oil**	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	
Altacor Intrepid Rimon Esteem	→	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	
Altacor Intrepid Rimon Esteem	*Tank mix* →	→	Delegate Entrust Assail Calypso virus **+** Altacor Intrepid Rimon Esteem		**May not need 2nd cover**	

pbf = post biofix

Source: Pest Management Transition Project Handbook (*http://pmtp.wsu.edu/handbook.html*)

Table 3: Pesticide Costs

Average Cost of Pesticides Use per Acre

Pesticide name	*$ per acre (full rate)*
Acramite	$38
Actara	$24
Agrimek	$87
Altacor	$40
Assail	$55
Avaunt	$37
Bt	$25
Calypso	$54
Carzol	$56
Centaur	$48
Clutch	$65
CM virus	$30
Danitol	$32
Delegate	$59
Diazinon	$32
Dithane	$35
Envidor	$36
Esteem	$48
FujiMite	$28
Application	$25

Pesticide name	*$ per acre (full rate)*
Guthion	$28
Intrepid	$30
Imidan	$30
Lorsban	$30
Manzate	$35
Nexter	$21
Oil	$5/gal.
Pheromone	$100
Proclaim	$40
Provado	$15
Rimon	$55
Sevin	$34
Success	$54
Sulfur 80W	$28
Surround WP	$40
Thionex	$40
Ultor	$46
Warrior	$25
Zeal	$64

Fact Sheet: BMSB

Brown Marmorated Stink Bug (BMSB), *Halyomorpha halys*

BMSB is native to China, Japan, Korea and Taiwan. It may have been introduced to the US by way of cargo shipments from Asia. It is considered a major economic pest in Asia attacking a variety of high value crops, including tree fruit. The first discovery of BMSB was in Allentown, PA where it quickly spread to other Mid-Atlantic states. It is now found in 29 states across the US, including confirmed detections in northwest OR (Portland south to Corvallis and east just past Hood River) and in southwestern WA.

In the Mid-Atlantic states devastating crop loss has already occurred in commercial orchards with some growers losing entire blocks of stone fruit. Severe injury was also detected in apples and pears. Besides tree fruit it feeds on over 300 host plants, including corn, soy beans, and grapes.

Adults and nymphs feed on fruit beginning in the Spring and continuing through harvest. The images to the left show the effect of stink bug feeding on apple. Dimples and even cat-facing if severe enough, are exterior signs of feeding. When cut, internal damage appears as corkiness similar to bitterpit. There is one generation per year in OR and WA, though it can have more than one generation in warmer areas.

Traps can be used to monitor BMSB, however, the true pheromone for this insect has yet to be identified.

Control of stink bugs has always been a challenge. Native stink bug species spend most of their life cycle outside pome fruit orchards and migrate in as adults in late season to feed on fruit. The BMSB is different in that it can live inside the orchard and complete its life cycle without leaving. Of course it also invades orchards from other crops or wild habitats.

The list of insecticides that are effective against BMSB and other stink bugs is shown in the table below. All of these insecticides either have severe limitations on their use and/or will disrupt biological control.

Insecticide	Negative characteristics	48 h mortality
Carzol	Limited to early season use	88
Lannate	High toxicity risk to humans	100
Thiodan	Closed cab and long PHI	94
Danitol	Problems with secondary pests	94
Warrior	Problems with secondary pests	100

Case Study Solutions

Case Study #1 Scenario 1

Secondary Pest Problems - Why did they get out of control?

Crop = Apple - Focus on spider mites
Proposed New Management Program:

GOAL: Propose a new management program restoring biological control of spider mite while maintaining or increasing fruit quality (packout).

1. Identify the issues that are likely causing a problem with spider mites.

Over spraying for control of codling moth based on cullage levels in packout and on monitoring results.
Use of insecticides that are highly toxic to predatory mites.

2. Mark the pesticides in the pest control table above that are harmful to predatory mites (*Galendromus occidentalis*, Western predatory mite – WPM). Use the pesticide effect tables 1 & 2 to help you make these decisions.

Pest control program - products used	CM generation	Timing	Target(s)	$ per acre ***with appl.***	% area treated
Oil, Lorsban Application		Delayed dormant	Scale, mites, aphids	$20 $30 $25	100%
Pheromone Application ***Delegate*** Application	1^{st} & 2^{nd}	Bloom	Codling moth, thrips	$110 $15 $59 $25	100%
Rimon Application	1st	Petal Fall	Codling moth, leafrollers	$55 $25	100%
Delegate Application	1st	1st spray – *delayed egg hatch*	Codling moth	$59 $25	100%
Delegate Application	1st	2nd spray *14 day interval*	Codling moth	$59 $25	100%
Nexter Application		3rd spray – late July	Spider mites	$21 $25	100%
			Total	***$578***	

Delegate has a large impact on predatory mites.
Rimon has more subtle secondary but negative effects on predatory mite reproduction.
The combination of Delegate and Rimon would increase the risk of spider mite problems.

3. With the goal of keeping fruit quality high, at least from pest injury, similar to the past three years, ***what changes would you make in your monitoring and pest control program*** to enhance biological control of spider mites?

Fill out the monitoring and pest control program tables out below. Use the pesticide effect tables 1 & 2 to choose pesticides that are least harmful to natural enemies.

Below are possible monitoring activities that could have used to assess the level of different pests.

Some kind of monitoring program for pests and NE is foundational to a good IPM program.

Monitoring program changes

Pest	Codling moth	Campylomma/ thrips	Leafroller	Mites	Aphids	Other pests
Method used (traps, visual, beat tray, other)	***Combo lures***	***Beat tray***	***Visual 2-minute sample***	***Visual exam of leaves***	***Visual exam of shoots***	
Number (traps, samples, trees)	***One delta trap***	***3 beats 25 trees***	***30 trees***	***5 leaves 10 trees***	***20 trees***	
Unit area sampled (acre, tree, etc.)	***2.5 acres***	***20 acres***	***20 acres***	***20 acres***	***20 acres***	

See program suggestions on next page.

Retain use of Lorsban as it provides some suppression of Campylomma.

Use Intrepid at petal fall to set up delayed spray for CM.

Delay first spray of Altacor - monitoring results will determine the need and what areas should be treated.

Plan 2nd generation CM sprays based on a survey of 1st generation damage.

If fruit injury is very low then good options would be to use CM virus at peak hatch of second generation OR a targeted treatment of Calypso where there is most pressure.

$200 saved in program can be put towards monitoring or additional soft products and applications.

Propose changes in products that you would recommend for pest control.

Pest control program - products used	CM gen	Timing	Target(s)	$ per acre ***with appl.***	% area treated
Oil, Lorsban Application		Delayed dormant	Scale, mites, aphids	\$20 \$30 \$25	100%
Pheromone Application	1st & 2nd	Bloom	Codling moth	\$110 \$15	100%
Intrepid Application	1st	Petal Fall *275 CMDD*	Codling moth, leafrollers	\$30 \$25	100%
Altacor Application	1st	1st spray – *525 CMDD*	Codling moth	\$40 \$25	***100% all area need treating?***
CM virus OR ***Calypso*** where needed Application		3rd spray – late July (use model for timing)	Codling moth	\$30 OR \$54 \$25	***Area to treat? 20 to 100%***
			Total	***\$375 versus \$578***	

4. In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement to reduce problems with spider mites?

Collect shoots from orchards with stable biological control of spider mites to introduce populations of predatory mites. This should be done early in the spring to allow for establishment and buildup of the predatory mites.

5. ***Optional***: If you have time, compare the costs of your new pesticide program with the original pest control program. ***See program cost comparisons above.***

Case Study #1 Scenario 2

Secondary Pest Problems - Why did they get out of control?

Crop = Apple - Focus on Leafroller

	Percent of injury – Cullage assessment								
Crop year	*CM*	San Jose scale	LR	Campy *	Thrips	Sunburn	Bruises	Other non-insect	Total %
2009	*3*	0	0	1	0	20	22	54	100
2010	*5*	3	0	0	5	22	21	44	100
2011	*0*	0	0	0	0	34	27	39	100

** Campy =Campylomma*

Management Program - Monitoring:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the ***last three years***. Pheromones have been a part of the IPM program

Pest	Codling moth	Campylomma /thrips	Leafroller	Mites	Aphids	Other pests
Methods used 2009-2011	1 trap with combo lure per 10 acres	Beat tray	None	None	Visually observe	Visually observe
Results	Moths/trap 3.5 max = 12	Camp/tray = 0.1 thrips/tray=7	Did not monitor	Did not monitor	few on shoots, no WAA present	none

Monitoring of codling moth with too few traps.

Low captures suggest a low CM population, which is supported by packout data.

No Campylomma pressure and very low thrips pressure.

No leafroller damage and low scale infestation.

Management Program – Pest Control:

The pest control program used in this orchard is outlined below. It has remained essentially the same for the last three years.

Pest control program - products used	CM generation	Timing	Target(s)	$ per acre with appl.	% area treated
Oil, Esteem Application		Delayed dormant	Scale, mites, aphids	$20 $48 $25	100%
Carzol Application		Bloom	thrips	$56 $25	100%
Proclaim Application	1st	Petal Fall	leafroller	$40 $25	100%
Altacor Application	1st	1st spray *delayed egg hatch*	Codling moth	$40 $25	100%
Altacor Application	1st	2nd spray *14 day interval*	Codling moth	$40 $25	100%
Intrepid Application		3rd spray – early July	leafroller	$30 $25	100%
			Total	***$424***	

Proposed New Management Program:

GOAL: Propose adjustments in the pest control program that would enhance biological control of leafrollers while maintaining or increasing fruit quality (packout).

4. Identify the issues limit the biological control of leafrollers.

   Carzol is used for thrips control and not justified by monitoring results. Carzol is likely toxic to parasitoids of LR.

   Proclaim is highly effective against LR. Proclaim at petal fall will eliminate all or most leafrollers so no opportunity for LR parasitoids to establish a population.

   There is a low threat of crop injury from LR at petal fall or in the period following.

5. Mark the pesticides in the pest control table above that could be harmful to leafroller parasitoids (*Colpoclypeus florus*). Use the pesticide effect tables 1 & 2.

   Use of Carzol and Proclaim – see comments above.

3. With the goal of keeping fruit quality high, at least from pest injury, what changes would you make in your monitoring and pest control program to enhance biological control of leafrollers? Fill out the monitoring and pest control program tables out below. Use the pesticide effect tables 1 & 2 to choose pesticides and timings that would be least harmful to or avoid periods when natural enemies are most active.

Monitoring program changes

Pest	Codling moth	Campy /thrips	Leafroller	Mites	Aphids	Other pests
Method used (traps, visual, beat tray, other)	***Combo lures***	***Beat tray***	***Visual 2-minute sample***	***Visual exam of leaves***	***Visual exam of shoots***	
Number (traps, samples, trees)	***One delta trap***	***3 beats on 25 trees***	***30 trees***	***5 leaves 10 trees***	***20 trees***	
Unit area sampled (acre, tree, etc.)	***2.5 acres***	***20 acres***	***20 acres***	***20 acres***	***20 acres***	

Propose changes in products that you would recommend for pest control.

Delay LR control until summer.

(Optional) If not confident in monitoring for LR then apply Bt or lower rates of Intrepid timed using LR model, which would allow survival of some LR to sustain NEs.

This approach will shift pesticide intervention away from periods when LR parasitoids are most active and when later instars are present (late spring and late summer).

Refer to LR models for the periods in degree days when NE are present.

Pest control program – products used	CM gen	Timing	Target(s)	% Area treated	Cost est.
Oil Application		Delayed dormant	Scale, mites, aphids	\$20 \$25	100%
Pheromone Application		Bloom	Codling moth	\$110 \$15	100%
Oil Application	1st	375 CMDD	Codling moth	\$10 \$25	100%
Altacor Application	1st	1st spray *delayed egg hatch*	Codling moth	\$40 \$25	100%
Altacor Application	1st	2nd spray ***optional***	Codling moth	\$40 \$25	100%
Bt OR Intrepid Application		3rd spray – early July	leafroller	\$30 \$25	100%
			Total	***\$390 versus \$424***	

4. In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement to reduce problems with secondary pests?

   Based on injury in packout and monitoring it does not appear that thrips OR scale are a serious problems. Put more effort into monitoring and base the need to control thrips on these data.

   Consider a more aggressive scale control program every second or third year and use targeted treatments where scale is present in orchard.

   Plant rose-strawberry gardens to enhance biological control of LR by parasitoids.

5. ***Optional***: Compare the costs of your new pesticide program with the original pest control program. ***See program cost comparisons above.***

Case Study #2 Scenario 1

Designing BC Friendly IPM Programs

Crop = Apple

Class Exercise II: Designing a BC Friendly Management Program

GOAL: Design a BC friendly pest management program that over the next five years maintains or increases fruit quality.

Resources: As you design your BC friendly IPM program take advantages of the resources in your workbook. These would include:

- *Tables of pesticides effects on NEs*
- *Lists of NEs most common in apple and pear orchards*
- *Information given in different presentations*

1. What are your key and secondary pests and their natural enemies? Make a list in the table below.

Key pests:	**Natural enemies:**
Codling moth	None or few
Leafroller	Parasitoids – *C. florus*
Scale	Parasitoids, general predators
Secondary pests:	
Woolly apple aphid	General predators, *A. mali*
Green apple aphid	General predators
Spider mites	Predatory mites
While apple leafhopper	Egg parasitoid
Leafminer	Parasitoids – *Pnigalio flavipes*

2. Mark in your list above which of the natural enemies can likely be enhanced?

All NE can be enhanced using the right approach

Easiest to enhance are predatory mites and general predators

3. In the table below outline a monitoring program you would implement to enhance biological control and maintain or increase fruit quality.
4. Include the method use, when monitoring would occur, frequency of monitoring, and number of samples taken per area (traps placed or trees sampled).
   - What new tools/practices you have learned about would you employ to enhance biological control (e.g. natural enemy monitoring)?
   - When and how would you change your monitoring strategy between years?
   - ***Optional***: compare the cost between your new and the old monitoring program.

Proposed monitoring program

Pest	Codling moth	Campy/ thrips	Leaf-roller	Mites	Aphids	NE Green lacewing	NE WAA parasite
Method used (traps, visual, beat tray, other)	***Combo lures***	***Beat tray***	***Visual 2-minute sample***	***Visual exam of leaves***	***Visual exam of shoots***	***Traps and HIPV lures***	***Traps and lures***
Number (traps, samples, trees)	***One delta trap***	***3 beats 25 trees***	***30 trees***	***5 leaves 10 trees***	***20 trees***	***As advised by WSU***	***As advised by WSU***
Unit area sampled (acre, tree, etc.)	***2.5 acres***	***20 acres***	***20 acres***	***20 acres***	***20 acres***	***As advised by WSU***	***As advised by WSU***

5. In the two tables below outline a pest management program you would implement that enhances biological control and maintains or increases fruit quality.
   - Which pesticides would you change from the current program?

Recommend retaining use of Lorsban in year one. Identify where scale problem is coming from and target the area. Lorsban use in the first year would help suppress WAA.

In future years move towards an oil only program. If scale control is needed could include Esteem in some years but would delay application for optimum timing for LR.

No bloom treatments unless dictated by monitoring that shows Campylomma or thrips – if these pests are present could use Success for thrips or Carzol for Campy.

   - How would you change application timing to protect natural enemies and effectively control the pests?

Use oil to delay first CM spray

Tank mix Altacor and Calypso at 525 CMDD. Reasoning is to combine 1st generation control into one application for CM at a time when many NE are not present. Minimize effects on predatory mites by using Calypso.

To ensure good control of CM, add CM virus at end of egg hatch period

Implement a soft but aggressive CM control 2nd generation to set up orchard for a reduced pest control program in years 2-5.

Treatments in 2nd generation should be based on need due to number and distribution of moth capture in traps and on level and location of 1st generation fruit injury.

   - How would your management program change from year 1 to year 5, assuming your control practices are effective? **SEE PROGRAM FOR YEAR FIVE**

- Use the tables showing effects of pesticides on natural enemies to help you choose pesticides and the chart for application timing.
- **Optional:** if you have time calculate the cost of the new pest control program by using the table on pesticide costs.

Propose products that you would recommend for pest control - year ONE.

Pest control program - products applied	CM generation	Timing	Target(s)	$ per acre with appl.	% area treated
Oil Lorsban Application		Delayed dormant	Scale, mites, aphids	$20 $30 $25	100%
Pheromone Application		Bloom	Codling moth	$110 $15	100%
	1st	Petal Fall			
Oil Application	1st	***375 CMDD topical ovicide***	Codling moth	$10 $25	100%
Altacor+ Calypso Application	1st	***1st spray delayed egg hatch***	Codling moth	$40 $54 $25	100%
CM virus Application	1st	2nd spray at end of egg hatch	Codling moth	$30 $25	100%
CM virus+oil Application	2nd	3rd spray – mid July	Codling moth	$30+ $10 $25	100%
Intrepid Application	2nd	4th spray – late July	Codling moth	$30 $25	100%
CM virus+oil Application	2nd	5th spray – late July	Codling moth	$30+ $10 $25	100%
CM virus+oil Application	2nd	6th spray – late July	Codling moth	$30+ $10 $25	100%
			Total cost	***$624*** versus ***$610***	

Propose products that you would recommend for pest control – year FIVE.

In delayed dormant use an oil only program or possibly include Esteem. If Esteems is used it should be applied at optimum timing for LR.

Pheromone at bloom but reduce rates to 75% as CM problem diminishes

Bloom/Petal Fall - No treatments unless dictated by monitoring that shows injury levels of Campylomma or thrips; if needed use Success for thrips or Carzol for Campy.

Use oil to delay first CM spray

Implement a soft CM control 1st generation if needed in years 2-5.

Altacor at 525 CMDD – if needed

Anticipate no need for 2nd generation CM treatments – monitor.

Optional treatment of Bt for LR if spring sampling indicates a need.

Propose products that you would recommend for pest control – year FIVE.

Pest control program - products applied	CM gen	Timing	Target(s)	$ per acre with appl.	% area treated
Oil Application		Delayed dormant	Scale, mites, aphids	$20 $25	100%
Pheromone Application		Bloom	Codling moth	$80 $10	75%
	1st	Petal Fall			
Oil Application	1st	375 CMDD topical ovicide	Codling moth	$10 $25	100%
Altacor Application	1st	1st spray delayed hatch 14-17 day residue	Codling moth	$40 $25	100%
CM virus+oil Application	1st	2nd spray 17 day residue	Codling moth	$10+ $10 $25	100%
CM virus+oil Application	1st	3rd spray 7day residue	Codling moth	$10+ $10 $25	100%
Bt Application	2nd	4th spray – early July	Leafroller	$30 $25	100%
			Total cost	***$380*** versus ***$ 610***	

In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement?

Plant and manage rose/strawberry gardens

Invest time into training on-farm labor to sample for secondary pest presence

Invest in trapping for general NE to understand presence and impact of program on abundance.

Cost of monitoring program would be offset by a reduction in the cost of pesticides and applications.

Case Study #2 Scenario 2

Designing BC Friendly IPM Programs

Crop = Pear

Exercise: Designing a BC Friendly IPM Program

GOAL: Design a BC friendly pest management program that over the next five years maintains or increases fruit quality.

Resources: As you design your BC friendly IPM program take advantages of the resources in your workbook. These would include:

- *Tables of pesticides effects on NEs (pages 206-207)*
- *Lists of NEs most common in apple and pear orchards (Day 1 presentations on NE ID)*
- *Information given in different presentations*

1. What are your key and secondary pests and their natural enemies? Make a list in the table below.

Key pests:	**Natural enemies:**
Codling moth	Few or none
Secondary pests:	
Pear psylla	*Deraeocoris brevis*, Campylomma, lacewings, *Trechnites psyllae*, minute pirate bug, yellow jackets
Pear rust mite	*Typhlodromus pyri* & *T. occidentalis* (predatory mites), lace wings
Spider mites, European red mite	*Typhlodromus pyri* & *T. occidentalis* (predatory mites), lace wings, Stethorus
OBLR	*Colpoclypeus florus*, tachinid flies
Scale	Parasitoids, general predators

2. Mark in your list above which of the natural enemies can likely be enhanced?

All NE can be enhanced using the right approach

3. In the table below outline a monitoring program you would implement to enhance biological control and maintain or increase fruit quality.

4. Include the method use, when monitoring would occur, frequency of monitoring, and number of samples taken per area (traps placed or trees sampled).

   - What new tools/practices you have learned about would you employ to enhance biological control (e.g. natural enemy monitoring)?
   - When and how would you change your monitoring strategy between years?
   - ***Optional***: compare the cost between your new and the old monitoring program.

Proposed monitoring program

Pest	Codling moth	Pear psylla	Leafroller	Mites	Aphids	NE Green lacewing	NE Deraeocoris
Method used (traps, visual, beat tray, other)	***pheromone trap***	***Beat trays*** ***leaves***	***pheromone traps*** ***visual observation***	***spurs*** ***leaves***	***visual observation***	***traps and HIPV lures***	***beat trays***
Number (traps, samples, trees)	***1***	***20 to 40*** ***40***	***1*** ***20***	***40***	***20***	***As advised by OSU/WSU***	***20 to 40*** ***40***
Unit area sampled (acre, tree, etc.)	***2.5 to 5 acres***	***20 acres***	***10 to 20 acres***	***20 acres***	***20 acres***	***As advised by OSU/WSU***	***20 acres***

5. In the two tables below outline a pest management program you would implement that enhances biological control and maintains or increases fruit quality.

   - Which pesticides would you change from the current program?

   Intrepid for early CM spray, Altacor for 1st generation covers
   Mating disruption for codling moth.
   No Delegate for 1st generation CM.
   Apply summer mite and psylla sprays based on monitoring.

   - How would you change application timing to protect natural enemies and effectively control the pests?

   Use Delegate for summer psylla spray in 2nd CM generation if needed based on monitoring.

   - How would your management program change from year 1 to year 5, assuming your control practices are effective?

   CM sprays may be eliminated as pressure is reduced. Need for sprays for secondary pests should be reduced.

- Use the tables showing effects of pesticides on natural enemies to help you choose pesticides and the chart for application timing.
- **Optional:** if you have time calculate the cost of the new pest control program by using the table on insecticide costs.

Propose products that you would recommend for pest control – year ONE.

Pest control program - products used	CM gen	Timing	Target(s)	$ per acre with appl.	% area treated
Sulfur 80W +		Dormant	Pear psylla + mites	25	100%
Oil				20	
Application				20	
Esteem +		Delayed dormant	Pear psylla, ***leafroller, San Jose scale***	48	100%
Oil				20	
Application				20	
Mancozeb 75DF +		Cluster bud	Pear psylla + mites	35	100%
Nexter 75WP				78	
Application				20	
Mating disruption	***all***	***Before full bloom***	***Codling moth***	125	100%
Mancozeb 75DF		Petal fall	Pear psylla	35	100%
Application				20	
Oil +	1st gen	Post petal fall	Mites + pear psylla ***San Jose Scale, Codling moth***	5	100%
Agrimek 0.15EC +				87	
Ultor 1.25SC				53	
Intrepid				30	
Application				20	
Altacor+	1st gen	1st cover codling moth spray	codling moth	40	100%
oil				3	
Application				20	
Altacor+	1st gen	2nd cover codling moth spray	codling moth	40	100%
oil				3	
Application				20	
Sulfur 80W +		Post harvest	Pear psylla + pear rust mite	25	100%
oil				10	
Application				20	
			Total cost	$842 versus $901	

Propose products that you would recommend for pest control - year FIVE.

Pest control program - products used	CM gen	Timing	Target(s)	$ per acre with appl.	% area treated
Sulfur 80W +		Dormant	Pear psylla + mites	25	100%
Oil				20	
Application				20	
Esteem +		Delayed dormant	Pear psylla, ***leafroller, San Jose scale***	48	100%
Oil				20	
Application				20	
Mancozeb 75DF +		Cluster bud	Pear psylla + mites	35	100%
Nexter 75WP				78	
Application				20	
Mating disruption	***all***	***Before full bloom***	***Codling moth***	125	100%
Mancozeb 75DF		Petal fall	Pear psylla	35	100%
Application				20	
Oil +	1st gen	Post petal fall	Pear psylla+ ***San Jose Scale***	5	100%
Ultor 1.25SC				53	
Application				20	
Sulfur 80W +		Post harvest	Pear psylla + pear rust mite	25	100%
oil				10	
Application				20	
			Total cost	$599 versus $901	

In addition to the changes in monitoring and pest control practices outlined above, what other activities might you implement?

1. ***Eliminate extra-orchard sources of codling moth***.
2. ***Work with neighbors to implement areawide mating disruption for codling moth and areawide psylla control with postharvest sulfur + HMO applications.***

Case Study #3 Scenario 1

Resistance in the key pest

GOALS:

- Manage a crisis with a key pest that has developed resistance to a pesticide.
- Consider option of how to restore BC into an IPM program.

Scenario #1 - Dealing with CM resistance to Altacor

- Your assignment is to bring CM back under control – reduce cullage to acceptable levels (2-4% of all culls), as inexpensively as possible in year one.
- Outline a pest control program you would implement to achieve the assigned task (use blank program below) for year one.

Propose products that you would recommend for pest control - year ONE.

Pest control program - products used	CM gen	Timing	Target(s)	$ per acre with appl.	% area treated
Oil Application		Delayed dormant	Scale, mites	$20 $25	100%
Pheromone Application	1st & 2nd	Pink	Codling moth	**$110** $15	100%
No treatment unless needed		Bloom	Campy*, thrips ???		
Esteem (Rimon or Intrepid) Application	1st	Petal Fall ***Timed at optimum for CM***	Codling moth, leafrollers	***$48*** $25	100%
Delgate+Rimon (NN+Intrepid (Pyreth+Ovicide) Application	1st	1st spray ***tank mix @ delayed egg hatch***	Codling moth	***$59+55*** $25	100%
Calypso (Assail, Delegate, pyrethroids) Application	1st	***2nd spray 17 day interval***	Codling moth	***$54*** $25	100%
CM virus+oil Application	2nd	***3rd spray Egg hatch timing***	Codling moth	***$40 $25***	100%
Intrepid Application	2nd	***4th spray 7 day interval***	Codling moth	***$30 $25***	100%
CM virus+oil Application	2nd	***5th spray 10 day interval***	Codling moth	***$40 $25***	100%
Intrepid Acramite Application	2nd	***6th spray 7 day interval***	Codling moth	***$30 $38 $25***	100%
CM virus+oil Application	2nd	***7th spray 10 day interval***	Codling moth	***$40 $25***	100%
			Total cost	***$804 versus $654***	

- What will be the impact of the program outlined above on biological control in the orchard?

The primary goal is to restore control of codling moth and produce a crop that has low fruit injury and might be eligible for export.

Avoiding the use of Altacor or any other insecticides in the same class is critical

An aggressive program of control in the first generation is the recommended approach, even at the expense of biological control, but every effort should be made to minimize impacts on NEs.

Increase pheromone to full rate – this will help improve CM control

Use ovicide at petal fall period – choice should be based on what product you might want to use late in the year

Apply delayed tank mix of ovicide+larvicide. There are several possible options, even use of a pyrethroids such as Warrior as a way to reduce cost

Apply a larvicide after the tank mix to obtain a high level of control of CM in 1st gen

Plan an aggressive but soft control program for CM in the 2nd gen – alternation of CM virus+oil and Intrepid would be a good example

Treatments in 2nd generation should be based on need – monitoring program results

A control treatment for spider mites is likely – use of a product or rate that would allow survival of predatory mites is recommended

Monitor for aphids and spider mites as the potential for disruption of BC is high and intervention may be necessary

- If the program you used in year one will disrupt biological control, what kind of a program will you implement in the following years to restore biological control in the orchard? Fill in the table below with your choice of products.

Implement controls for CM only if needed based on monitoring program

A good monitoring program would pay for itself from control treatments that are not applied or in crop protection actions that are justified – reduce potential injury

The program outlined on next page is expensive but less than in year one and it is not likely that it would all be required

- How long do you think it will take to restore biological control to previous levels, that is, no need for application of controls for secondary pests?

Most BC could be restored in year two but most likely a stable BC program would require more than one year following correction of year one actions

Propose products that you would recommend for pest control - year TWO +.

Pest control program - products used	CM gen	Timing	Target(s)	$ per acre with appl.	% area treated
Oil Application		Delayed dormant	Scale, mites	$20 $25	100%
Pheromone Application	1^{st} & 2^{nd}	Pink	Codling moth	**$110** $15	100%
No treatment unless needed		Bloom	Campy*, thrips ???		
Bt Application	1^{st}	Petal Fall	leafrollers	**$25** $25	100%
Oil Application	1^{st}	1^{st} spray ***375 CMDD***	Codling moth	***$10*** $25	100%
CM virus+oil Application	1^{st}	***2nd spray delayed hatch 525 CMDD***	Codling moth	***$40*** $25	100%
Calypso Application	1^{st}	***3rd spray 7 day interval***	Codling moth	***$54 $25***	100%
CM virus+oil Application	1^{st}	***4th spray 14 day interval***	Codling moth	***$40 $25***	100%
CM virus+oil Application	1^{st}	***5th spray 7 day interval***	Codling moth	***$40 $25***	100%
CM virus+oil Application	2^{nd}	***6th spray egg hatch***	Codling moth	***$40 $25***	100%
Intrepid Application	2^{nd}	***6th spray 7 day interval***	Codling moth	***$30 $25***	100%
CM virus+oil Application	2^{nd}	***7th spray 14 day interval***	Codling moth	***$40 $25***	100%
			Total cost	***$714 versus $ 804***	

In addition to the changes in pest control practices outlined above, what other activities might you propose to change or implement?

An aggressive monitoring program for CM should be implemented to determine if there is sufficient need to apply treatments in the 2nd gen

A monitoring program should also be implemented for spider mites

What kinds of research solutions would be needed to deal with future problems such as this?

Implement better monitoring programs for CM and other pests

Understand cross-resistance possibilities between different insecticide classes

Identify new controls for CM that rely less on pesticide applications, e.g. attract and kill

Case Study #3 Scenario 2

A new pest invades the region and your orchard

Scenario #2 – dealing with presence of a new invasive pest, BMSB

GOAL: Manage the crisis associated with the appearance of a new invasive pest, BMSB

In this scenario we are just asking you to address the questions below.

What are the most likely pest control options for controlling BMSB?

There are few available options and none are deemed compatible with biological control in orchards

Pyrethroids seem to be the best control option but even these have weaknesses

What will be the likely impact on biological control when implementing the above controls for BMSB?

Programs designed to conserve biological control in orchards would be sacrificed to protect the crop

What barriers will exist to restoring biological control into an IPM program that must deal with this new pest?

Lack of chemical controls for BMSB that are compatible with conservation of biological control agents is the obvious barrier

What information or tools for managing BMSB would be needed to help restore biological control to an orchard dealing with this new pest?

A good monitoring system to detect BMSB when in the orchard or moving into the orchard

Efficacy of orchard border sprays to reduce damage and minimize disruptive effects of pesticides on BC

New chemical controls or strategies that have lower negative impacts on BC - Possibly the development of attract and kill strategies to protect orchards

Biological controls for BMSB to reduce populations in non-agricultural areas

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