Entomological Research at the USDA-ARS

Yakima Agricultural Research Laboratory
USDA-ARS

Garczynski, Horton, Knight, Lacey, Landolt, Neven, Unruh, Yee
Codling Moth
Explosive Reproductive Potential in the arid Western U.S.

PROFITS

Cull bin
**OP To Be Phase Out in the U.S.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount ai /HA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>10 lb ai/HA</td>
</tr>
<tr>
<td>2008-2009</td>
<td>7 lb ai/HA</td>
</tr>
<tr>
<td>2010</td>
<td>5 lb ai/HA</td>
</tr>
<tr>
<td>2011-2012</td>
<td>4 lb ai /HA</td>
</tr>
<tr>
<td>2013</td>
<td>Gone</td>
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</tbody>
</table>

Phosmet, chlorpyrifos, diazinon, and malathion face further regulatory action.
So what, OP insecticide use is down 50% since FQPA in 1996

AND,

There are **NOW** more insecticides and miticides registered in tree fruits **than ever before**

### Issues with New Materials

- Low human toxicity, safer to the environment.
- More selective materials.
- More active than OP’s against resistant targets
  - Good for pests
  - Bad for natural enemies
  - Most require ingestion to be effective
  - Bad for CM control
  - Requires better timing
- Generally more expensive.
- Organic production.
## OP-alternatives

<table>
<thead>
<tr>
<th>Insecticides</th>
<th>Class</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assail</td>
<td>Neonicotinyl</td>
<td>Disrupt nerve transmission</td>
</tr>
<tr>
<td>Calypso</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rimon</td>
<td>Insect growth regulator</td>
<td>Chitin inhibitor</td>
</tr>
<tr>
<td>Intrepid</td>
<td></td>
<td>Molt accelerator</td>
</tr>
<tr>
<td>Esteem</td>
<td></td>
<td>JH mimic</td>
</tr>
<tr>
<td>Delegate</td>
<td>Spinosyn</td>
<td>Disrupt nerve transmission</td>
</tr>
<tr>
<td>Success</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proclaim</td>
<td>Avermectin</td>
<td>Disrupt nerve transmission</td>
</tr>
<tr>
<td>Altacor</td>
<td>Anthranilamide</td>
<td>Disrupt muscle action</td>
</tr>
<tr>
<td>HMO</td>
<td></td>
<td>Asphyxiant</td>
</tr>
<tr>
<td>Virus</td>
<td>Biologicals</td>
<td>Viral infection</td>
</tr>
<tr>
<td>BT</td>
<td></td>
<td>Bacterial infection</td>
</tr>
</tbody>
</table>
4.4% of Apple Industry has gone Organic with 54% growth expected in next 2 years

Organic growers use:

MD, CM-GV, Spinosid

Finally, Can Achieve Good CM Control!
Strategic IPM Plan

• **Creating sustainable pest management**
  - Targeting multiple pests
    • **Optimize application timing** and tank-mixing modes of action
  - Minimize insecticide resistance development
    • Use materials with different modes of action
Attack the Entire Life Cycle

MD, adulticides

Ovicides

Larvicides

Cultural, biological
Strategic IPM Plans

- Pheromones are used on 75% of apple acreage.
- Horticultural oil, neonicotinyls, IGRs can kill eggs when timed after petal fall.
  - Use of IGR’s at ‘petal fall’ timing is also good for leafrollers.
- If using an ovicide early then delay 1st application of larvicide and tank-mix an ovicide and larvicide
- If needed, a second larvicide is applied 14 d later.
- 2nd Gen.: Use an IGR for leafrollers and a new class of larvicides for CM

But, the key is always proper timing
Has CM's Phenology Changed?

Phenology model was developed in Michigan

![Graph showing mean number of moths per trap over time in April - September with data from Washington 2003 and Michigan 1974]

Michigan model was validated in WA with prediction of 1st egg hatch
Broad Flight Periods in Unsprayed Sites in WA
Broad Periods of Egg Hatch in WA

B.

Mean no. new injuries

May - June - July - August - Sept

Developed A New Model

A broader fit of the data
Impact of New Model:

- Timing of control tactics for CM, especially in the 1st generation, needs to be reconsidered and optimized.

- Importance of each cover spray interval
- Timing of ovicides
- Covering the gap between overlapping generations
CM Resistance - Important Factor

- Does resistance affect timing?
- Is there any evidence of cross resistance in CM to other insecticides?
Insecticide Resistance in CM is Diverse

Classes

- Avermectins
- Benzoylureas
- Benzoylhydrazines
- Neonicotinoids
- Organophosphates
- Synthetic pyrethroids

Mechanisms

- MFO
- GST
- kdr
- AchE
- EST+
- EST-

Is resistance management going to be possible?
Selected Populations - 2003

Does the OP resistance level impact the timing of the generations?
Shift in Emergence Curve

Cumulative DD

% population emerging

SS  SS/RS
Shift in Emergence Curve

% population emerging

Cumulative DD

SS/RS  RS

0 100 200 300 400 500 600 700
Shift in Emergence Curve

% population emerging

Cumulative DD

RS
RS/RR

0 100 200 300 400 500 600 700
OP Resistant Populations Have Broader Periods of Flight
Resistance Reduces # of Eggs

GOOD NEWS!
**Guthion’s Effectiveness Drops**

- **LAB**
- **SS/RS**
- **RS**
- **RS/RR**
- **RR**

**Proportion clean fruit**

- **BAD NEWS!**

- **Resistant population:** 
  - < 3 wks of control

**Days post spray**

- 7
- 14
- 21
- 28
MORE BAD NEWS!

Cross Resistance

<table>
<thead>
<tr>
<th>Population</th>
<th>Guthion</th>
<th>Asana</th>
<th>Intrepid</th>
<th>Assail</th>
<th>Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>AB</td>
</tr>
<tr>
<td>SS/RS</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>RS</td>
<td>A</td>
<td>A</td>
<td>AB</td>
<td>AB</td>
<td>B</td>
</tr>
<tr>
<td>RS/RR</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

Neonate bioassay conducted at two rates per chemical. Three larvae per fruit. Means separated in sig. ANOVA's with LSD.
OP-Neonicotinyls
Positive Cross Resistance

Enhanced GST and EST activity

RR-ratio to Assail of 3.5-fold
Another Example of Resistance

Novaluron / Rimon

Benzoyl urea insect growth regulator

Mode of action:
Inhibition of chitin synthesis, causing abnormal endocuticular deposition and abortive moulting
## Significant Differences

<table>
<thead>
<tr>
<th>Populations</th>
<th>Mean fecundity</th>
<th>% egg hatch</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAB</td>
<td>B</td>
<td>Highest</td>
</tr>
<tr>
<td>YARL Farm</td>
<td>Highest</td>
<td>A</td>
</tr>
<tr>
<td>Organic (3 yrs sprayed)</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>CONV (5 yrs unsprayed)</td>
<td>CD</td>
<td>B</td>
</tr>
<tr>
<td>CONV (1 yr unsprayed)</td>
<td>D</td>
<td>B</td>
</tr>
<tr>
<td>CONV</td>
<td>Lowest</td>
<td>Lowest</td>
</tr>
</tbody>
</table>
2007 Results

Proportion of females with successful egg hatch

LC50 Assail

YARL selected 1 year
Abandoned
Lab
Conv
Novaluron
Negative Cross Resistance Can Occur

- Dunley and Welter (2000)
  - 2 – 10-fold levels between azinphosmethyl and chlorpyrifos and methyl parathion

![Graph showing LC50 values for different populations and pesticides](image-url)
Grower’s Actions Impact Everything

And, the complex evolution of insecticide resistance marches on

THANK YOU!