Insecticide Resistance Management: Emphasis on the Control of Colorado Potato Beetle

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Potato IPM Workshop
Integrated Pest Management of Key Pests in Potato

- Colorado potato beetle
- Potato leafhopper
- Aphid spp.
### IPM of Colorado Potato Beetle

#### Seasonal History of CPB in WI

<table>
<thead>
<tr>
<th>Month</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>Plant emergence</td>
</tr>
<tr>
<td>Jun</td>
<td>OW Adults emerge</td>
</tr>
<tr>
<td>Jun</td>
<td>Eggs laid</td>
</tr>
<tr>
<td>Jul</td>
<td>Larvae</td>
</tr>
<tr>
<td>Jul</td>
<td>Economic Defoliation</td>
</tr>
<tr>
<td>Aug</td>
<td>Pupae</td>
</tr>
<tr>
<td>Aug</td>
<td>1st Generation adults</td>
</tr>
<tr>
<td>Aug</td>
<td>Eggs laid</td>
</tr>
<tr>
<td>Jul</td>
<td>Larvae</td>
</tr>
<tr>
<td>Jul</td>
<td>Economic Defoliation</td>
</tr>
<tr>
<td>Sep</td>
<td>Pupae</td>
</tr>
<tr>
<td>Sep</td>
<td>2nd Generation adults</td>
</tr>
<tr>
<td>Oct</td>
<td>Harvest</td>
</tr>
</tbody>
</table>

**Key Events:**
- **CPB Dispersal / Crop Colonization**
- **Crop Infestation**
- **Adult Diapause**
Resistance

• A genetically controlled decrease in susceptibility of a population to a control measure
  – resistance to insecticides (IRAC 2006)
    • 500+ insect species resistant to 1 or more insecticides
    • 1800+ species/insecticide resistance combinations
  – adaptation to pest resistant crop varieties
  – adaptation to crop rotation
Resistance Development

- Resistance genes occur naturally at low frequencies
  - $10^{-3}$ to $10^{-6}$
- Proportionately more insects with R-genes survive and leave offspring when exposed to toxin than insects with only S-genes

```
RR  RS  SS
```
Resistance Development

Time 1

Time 2

Time 3

Time 4
Rate of Resistance Determined by:

- **Genetic Factors (initial rate, fitness, inheritance)**
- **Biological and Environmental Factors**
  - Population biology of insect pest
    - reproductive and mortality rate(s)
    - number of generations per year
    - dispersal rates and distances
    - host range
- **Operational Factors**
  - Pesticide use and crop production practices
Measuring Resistance

- $\text{LD}_{50}$ (or $\text{LC}_{50}$) = dose (or concentration) that is lethal to 50% of the test population under defined conditions

- $\text{LD}_{90}$ = dose that is lethal to 90% of the test population
Resistance Ratio

- Ratio of LC$_{50}$ of test population to LC$_{50}$ of reference population
  - $\frac{\text{LC}_{50}\text{(test)}}{\text{LC}_{50}\text{(reference)}}$

- Resistance ratios of susceptible (controllable) populations can vary as much as 20-fold
### Chronology of Insecticide Resistance in Colorado Potato Beetle: Long Island, NY

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Introduced</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Failed</th>
<th>Chemical Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbaryl</td>
<td>1957</td>
<td>1958</td>
<td>Carbamate</td>
</tr>
<tr>
<td>Azinphosmethyl</td>
<td>1959</td>
<td>1964</td>
<td>OP</td>
</tr>
<tr>
<td>Phosmet</td>
<td>1973</td>
<td>1973</td>
<td>OP</td>
</tr>
<tr>
<td>Phorate</td>
<td>1973</td>
<td>1974</td>
<td>OP</td>
</tr>
<tr>
<td>Carbofuran</td>
<td>1974</td>
<td>1976</td>
<td>Carbamate</td>
</tr>
<tr>
<td>Oxamyl</td>
<td>1978</td>
<td>1978</td>
<td>Carbamate`</td>
</tr>
<tr>
<td>Fenvalerate</td>
<td>1979</td>
<td>1981</td>
<td>Pyrethroid</td>
</tr>
<tr>
<td>Permethrin</td>
<td>1979</td>
<td>1981</td>
<td>Pyrethroid</td>
</tr>
<tr>
<td>Fenvalerate + PBO</td>
<td>1982</td>
<td>1983</td>
<td>Pyrethroid +</td>
</tr>
<tr>
<td>Esfenvalerate + PBO</td>
<td>1983</td>
<td>1984</td>
<td>Pyrethroid +</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>1995</td>
<td>2000</td>
<td>Nicotinyl</td>
</tr>
</tbody>
</table>
Severity & Impact of Resistance Varied Among Areas

<table>
<thead>
<tr>
<th>Location</th>
<th>Cost of controlling CPB ($/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Island</td>
<td>$988</td>
</tr>
<tr>
<td>New Jersey</td>
<td>$368</td>
</tr>
<tr>
<td>S. Maine</td>
<td>$348</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>$254 - $512</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>$200 - $300</td>
</tr>
</tbody>
</table>
Resistance Crisis Ended

- Nicotinyl insecticides: (imidacloprid, thiamethoxam)
  - Admire / Platinum
    - applied in seed furrow at plant
    - controls CPB, aphids, & leafhoppers for c.a. 80 days
  - Provado / Actara
    - applied to foliage
    - rescue control of CPB (all stages), aphids, leafhoppers

- Provided time for additional effective insecticides to become registered
Beneficial Attributes

- Effective on resistant CPB’s
- Broad spectrum
  - CPB, leafhoppers, aphids
- Flexible
  - Row mark, furrow, seed, layby
- Long residual
  - Rate dependant
  - Excessive rain may impact
- Low toxicity
  - “Healthy Grown”

Disadvantages

- Same chemical class (Group 4 MoA)
- Resistance likely
Reported Neo-nicotinoid Use

2003 = 13,330 acres (84% of total potato acres)
2004 = 12,786 acres (70% of total potato acres)
2005 = 12,238 acres (73% of total potato acres)
Mean 12,785 76%

Application(s):
One application = 13,727 acres
Two applications = 3992 acres
Three applications = 1102 acres (??)

Area-wide reliance on nicotinoid insecticide use: need to conserve the effectiveness!!
Maryland, 2005 Imidacloprid Bioassays

Dively et al. (2006): 32 populations, LC$_{50}$ range (0.28 – 16.6 ppm)

Reported field control
- Good
- Fair
- Poor
- Not used

20X Susceptible LD$_{50}$

10X Susceptible LD$_{50}$

Farm / State
Michigan, 2005 Imidacloprid Bioassays

Byrne and Grafius (2006): 15 populations, LC$_{50}$ range (0.03 – 4.06)

**Reported field control**
- Good
- Fair
- Poor

**10x susceptible LD$_{50}$**

**20x susceptible LD$_{50}$**

Note: * = significantly greater than LD$_{50}$ for susceptible population
Wisconsin, 2006 Imidacloprid Bioassays

Byrne and Grafius (2006): 15 populations, LC$_{50}$ range (0.05 – 2.31)

Resistance Ratio(s): (LD$_{50}$ test pop / LD$_{50}$ susceptible NJ)

<table>
<thead>
<tr>
<th>Location / Farm</th>
<th>Loc A</th>
<th>Loc B</th>
<th>Loc C</th>
<th>Loc D</th>
<th>Loc E</th>
<th>Loc F</th>
</tr>
</thead>
<tbody>
<tr>
<td>NJ</td>
<td>0.017/0.039</td>
<td>0.051/0.039</td>
<td>0.068/0.039</td>
<td>0.158/0.039</td>
<td>0.297/0.039</td>
<td>2.31/0.039</td>
</tr>
<tr>
<td>WI A</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WI B</td>
<td></td>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WI C</td>
<td></td>
<td></td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WI D</td>
<td></td>
<td></td>
<td></td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WI E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>WI F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59.2</td>
</tr>
</tbody>
</table>
Insecticide Resistance Management (IRM): Nicotinyl Insecticides

**The Challenge!**

Maintaining the effectiveness of nicotinyl insecticides:

- Admire, Provado, Gaucho, Genesis, Leverage, Platinum, Actara, Cruiser, Venom, Poncho, Belay
- All are in same MoA class = 4
- Represent the backbone of CPB management
- Resistance already reported in eastern production areas

*Note:* Under evaluation / unregistered
IRM: Nicotinyl Insecticides

1. **DON’T FOLLOW SOIL APPLICATION WITH SIMILAR FOLIAR**

When systemic group 4 is used in the soil (Admire, Gaucho, Genesis, Platinum, Cruiser), **DO NOT USE** foliar group 4 in same season (Provado, Actara, Leverage), even as an edge spray.
2. **ROTATE SOIL APPLICATIONS**

When systemic group 4 is used in the soil, group 4 systemics **SHOULD NOT BE USED** on the next years potato crop at the same or adjacent site, but should be rotated at least ¼ mile from the previous crop.
IRM: Nicotinyl Insecticides

3. **AVOID REPEAT FOLIAR APPLICATIONS:**

   When a foliar group 4 is used, (Provado, Leverage, Actara), **DO NOT USE** in consecutive sprays and do not treat successive generations.
IRM: Foliar Sprays

- Used as alternatives to systemics in resistance management programs
- Used on shorter season crops
- Used to augment systemic programs
- New registrations!

**Keys to foliar success**
- Scout crops for good timing
- Treat at thresholds
- Good coverage
- Beware of resistance
IRM & Crop Rotation; avoid planting adjacent to previous potato

- Rotate > 400 m (¼ mile)
- Delays infestation
- Reduces infestation size
  - effect increased if small grain separates field from source of overwintered beetles
- Causes infestation to proceed from field edge
  - facilitates scouting
  - allows spot or perimeter applications of insecticide
Establish Colorado Potato Beetle Resistance Monitoring Scheme

- **Primary**
  - provide decision aid for insecticide selection to avoid control failure

- **Secondary**
  - detect increases in resistance before they become fixed in the population
Insecticide Mixtures Strategy

• Apply tank mixture of insecticides A & B
  – individuals resistant to one compound in the mixture will be killed by the other

• Basic principle
  – if resistance to each compound is independent (no cross resistance) and initially rare, individuals resistant to both compounds will be extremely rare

• Equal persistence of both compounds
  – If A loses activity before B, all individuals resistant to B will not be killed by A
    • a 5% difference in persistence of A & B can completely negate advantages of mixture
Rule Out Common Causes of Control Failures Other Than Resistance

• Calibration error
• Mixing error
• Use of inappropriate product
• Use of out-dated product
• Re-infestation following application
Impediments to Resistance Management

• Must be implemented before resistance problem exists
• Involves added costs and/or complexity
• Pesticide dealers may not always stock inventory for required rotations
• Sales incentives favor maximizing pesticide sales in short-term
• No positive feedback
QUESTIONS??