Managing Colorado Potato Beetle Resistance

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$48 million spent in potatoes for insect control in 2010.

Key pests by expenditure in millions include:

<table>
<thead>
<tr>
<th>Pest</th>
<th>Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado potato beetle</td>
<td>$25.3</td>
</tr>
<tr>
<td>Green peach aphid</td>
<td>$12.4</td>
</tr>
<tr>
<td>Lepidoptera (BAW, looper, ECB)</td>
<td>$4.1</td>
</tr>
<tr>
<td>Potato aphid</td>
<td>$3.5</td>
</tr>
<tr>
<td>Potato leafhopper</td>
<td>$2.3</td>
</tr>
<tr>
<td>Potato psyllid</td>
<td>$1.5</td>
</tr>
</tbody>
</table>
Almost half of the insecticide expenditure ($23.6MM) is on two active ingredients, imidacloprid (Admire, Gaucho) and thiamethoxam (Cruiser, Platinum).

Both are in the same class of chemistry.

Length of control is getting shorter.

Resistance is growing to this class of chemistry (neonicotinoids – ‘neonics’).
# 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 + synergist</td>
</tr>
<tr>
<td>Esfenvalerate + PBO</td>
<td>1983</td>
<td>1984</td>
<td>Pyrethroid + synergist</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>1995</td>
<td>2000</td>
<td>Nicotinyl</td>
</tr>
<tr>
<td>Rynaxypyr</td>
<td>2008</td>
<td>2010</td>
<td>Anthranillic diamide</td>
</tr>
</tbody>
</table>
Insecticide Resistance Management (IRM): Neonicotinoid Insecticides

*The Challenge!*

Maintaining the effectiveness of nicotinyl insecticides:

- Admire, Provado, Gaucho, Genesis, Leverage, Platinum, Actara, Cruiser, Belay, Assail, Alias

- All are in same MoA class = 4

- Represent the backbone of CPB management

- Resistance already reported in several Midwest and Eastern U.S. production areas
Systemic Neonicotinoid Insecticides

**Beneficial Attributes**
- **Effective on** pyrethroid resistant CPB’s
- **Broad spectrum**
  - CPB, leafhoppers, aphids
- **Flexible**
  - Row mark, furrow, seed, layby
- **Long residual**
  - Rate dependant
- **Low toxicity**
  - “Healthy Grown”

**Disadvantages**
- **Same chemical class**
- **Resistance developing**
Neonicotinoid Resistance: CPB Survivorship

Seasonal, in-plant [imidacloprid]

Days (post-application)
Insecticide Resistance Management (IRM): Principles

I. **Problem Identification**: If you suspect resistance, first eliminate other possible causes.

Lack of control can be attributed to application error, equipment failure, or less-than-optimal environmental conditions.

II. **Product Rotation**: Avoid the consecutive use of a single product, or multiple products with similar modes of action. Insecticide Resistance Action Committee (IRAC) has developed and updates a Mode of Action (MoA) classification system.

http://www.irac-online.org/


- rotate different modes of action across generations
- successive foliar applications
Mode of Action Classification

IRAC
Insecticide Resistance Action Committee

The Key to Resistance Management

More information on IRAC and the Mode of Action Classification is available from:
www.irac-online.org or enquire@irac-online.org

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# General Positioning Guidelines

IRAC guidelines below show least to best product rotation recommendations.

Maintaining insect susceptibility greatly depends on rotation of Diamide insecticides with effective products with a different MOA that eliminate Diamide-resistant individuals. Rotation with products that provide poor control of the target pest increases the risk of developing Diamide resistance.

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Gen</td>
<td>2nd Gen</td>
<td>1st Gen</td>
<td>2nd Gen</td>
</tr>
<tr>
<td>1st Gen</td>
<td>2nd Gen</td>
<td>1st Gen</td>
<td>2nd Gen</td>
</tr>
<tr>
<td>1st Gen</td>
<td>2nd Gen</td>
<td>1st Gen</td>
<td>2nd Gen</td>
</tr>
</tbody>
</table>

**No alternation/rotation**
- High selection pressure
- No recovery of sensitive population

**Rotation within generation**
- Consecutive generations exposed to same MoA. Selection pressure doesn’t change between generations. Risk of resistance development for both ai’s

**Rotation among generations**
- Following generations are not exposed to same MoA. Selection pressure doesn’t increase within the generation. Recovery of susceptible population.

**Rotation within and between**
- Ideal situation (very low risk) Not alway applicable with good efficacy.

Guidance for Diamide Country Groups, August 2010

© IRAC-Online.org
Insecticide Resistance Management (IRM): Principles

III. *Rates and Spray Intervals*: Use insecticides at labeled rates and follow prescribed spray intervals. Do not reduce or increase rates from labeled recommendations as this can hasten resistance development. Use products at their full, recommended doses. Reduced (sub-lethal) doses quickly select populations with average levels of tolerance.

IV. *Cultural Control(s)*: Where possible, consider adopting all non-chemical techniques to suppress pest populations, including crop rotation. Rotations > 400 m (¼ mile) away from previous potato crop.

V. *Pest Surveillance and Scouting*: Monitor the pest population and track stages of development. Reduced-risk foliar insecticides generally require accurate timing of applications against susceptible life stages.
Insecticide Resistance Management (IRM): Principles

VIII. Tank Mixes: Mixtures may offer a short-term solution to resistance problems, but it is essential to ensure that each component of a mixture belongs to a different insecticide mode of action class, and that each component is used at its full rate.

- Compounds should persist on the crop or surface for similar periods in order to avoid sub-lethal exposure.

- Acute toxicity of each compound should be equal at full labeled rates.

- bifenthrin / imidacloprid

- lambda-cyhalothrin / thiamethoxam

- chlorantraniliprole / thiamethoxam
Wisconsin, 2007 - 11 Imidacloprid Bioassays

Survey Sites:
- Adams County (11)
- Dane County (2)
- Iowa County (1)
- Langlade County (8)
- Oconto County (1)
- Portage County (15)
- Waushara County (13)
Total: (51)

CPB Populations:
- Over-wintered adult
- 2nd generation adult

Adult Topical Bioassays:
Results

Assessment

- Beetle response assessed 7 days post treatment.
  - walking = able to walk forward normally
  - poisoned = legs extended and shaking, unable to walk forward in coordinated manner
  - dead = abdomen shrunken, elytra dark
Michigan, 2005 Imidacloprid Bioassays

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

LD$_{50}$ (µg/beetle)

10x susceptible LD$_{50}$

20x susceptible LD$_{50}$

Reported field control

- Good
- Fair
- Poor

Note: * = significantly greater than LD$_{50}$ for susceptible population

Farm / State

Michigan, 2005 Imidacloprid Bioassays

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LD$_{50}$ (µg/beetle)

10x susceptible LD$_{50}$

20x susceptible LD$_{50}$

Reported field control

- Good
- Fair
- Poor

Note: * = significantly greater than LD$_{50}$ for susceptible population

Farm / State
Preliminary Assays (2007): 35 populations, LC$_{50}$ range (0.021 – 1.355)

Wisconsin, 2008
Imidacloprid Bioassays

Reported field control

- Good
- Fair
- Poor

10X Susceptible LD$_{50}$
Preliminary Assays (2008): 31 populations, LC$_{50}$ range (0.018 – 1.33)

Wisconsin, 2009
Imidacloprid Bioassays

Reported field control
- Good
- Fair
- Poor

LD$_{50}$ (µg/beetle)

Location
Wisconsin, 2011 Imidacloprid Bioassays

- Topical Assays (2007-2011)
- 6 populations
  \( \text{LC}_{50} \) range (0.02 – 4.46)
Colorado Potato Beetle Management Development and Defoliation Thresholds

- 20% Defoliation (pre-flower) and < 10-15% (post-flower)

- Population Development Thresholds (eggs, larvae)
Factors Influencing Insect Pest Management

‘Food Safety’

– Major food retailers are setting acceptable residue levels below those set by government regulatory agencies.

“No detectable residues” will be a competitive advantage for food retailers.

– Older insecticides that do not meet these requirements are not being re-registered, resulting in increased use of novel insecticides (reduced-risk & bio-pesticides).
Reduced Risk Foliar Options

- **Radiant™ (spinetoram)**
  - MoA group 5
    - Use rate 4.5 – 8 fl oz / ac
    - Control of nymphal psyllids and CPB

- **Rimon 0.83 EC (novaluron):**
  - Chitin biosynthesis inhibitors (MoA Group 15)
    - Use rate 9 – 12 fl oz / ac (foliar) – control of CPB eggs and larvae
    - **Currently not registered for psyllids**

- **Agri-Mek 0.15EC (abamectin):**
  - Chloride channel activator (MoA Group 6)
    - Use rate 8 – 16 fl oz / ac (foliar)
    - Control of adult & nymphal psyllids, CPB larvae
    - Temprano, Abba, Epi-Mek
Reduced Risk Foliar Options - New Registrations

- **Voliam Flexi® (chlorantraniliprole + thiamethoxam)**
  - MoA groups 28 + 4A
  - Use rate 4 oz / ac (CPB)
  - Control of CPB adults and larvae, PLH, aphids, and Leps

- **Voliam Xpress® (lambda-cyhalothrin + chlorantraniliprole)**
  - MoA groups 3 + 28
  - Use rate 6 – 9 fl oz / ac (CPB)
  - Control of CPB adults and larvae, PLH, aphids, and Leps

- **Endigo® ZC (lambda-cyhalothrin + thiamethoxam)**
  - MoA groups 3 + 4A
  - Use rate 2.5 – 4.5 fl oz / ac (CPB)
  - Control of CPB, adults and larvae, PLH, aphids, and Leps
Reduced Risk Foliar and In-Furrow Options - New Registrations

- **Coragen™ (rynaxypyr)***
  - Anthranillic diamide (MoA group 28)
  - Use rate 3.5 - 5 oz / ac (CPB)
  - Control of CPB adults and larvae – no effect on psyllids

- **Benevia™ / Verimark™ (cyazypyr)****
  - Anthranillic diamide (MoA group 28)
  - Use rate 3.5 - 5 oz / ac (CPB)
  - Control of CPB adults and larvae, leafhoppers, Leps, and psyllids

* Water soluble, systemically mobile insecticides
** Not currently registered
Colorado Potato Beetle Management Hypothetical Program (No systemic)

- No neonicotinoid – 1\textsuperscript{st} generation RR-foliar (Radiant SC)
- 2\textsuperscript{nd} generation foliar (neonicotinoid)

Colorado Potato Beetle Management Hypothetical Program (No systemic)

- No neonicotinoid – 1\textsuperscript{st} generation RR-foliar (Radiant SC)
- 2\textsuperscript{nd} generation foliar (neonicotinoid)

- Need to protect potato crop from CPB for 6–8 weeks
- Development threshold = 1\textsuperscript{st} and 2\textsuperscript{nd} instar stadia

- Radiant (@ 8.0 & 6.0 oz)
- Actara (@ 3.0 & 1.5 oz)

- 2\textsuperscript{nd} Gen CPB
- 1\textsuperscript{st} Gen CPB

Potato Crop

Colorado Potato Beetle Management Hypothetical Program (At-Plant)

- At-plant neonicotinoid plus RR-foliar (Agri-Mek 0.7SC)
- 2nd generation foliar (Coragen 1.67SC)
Colorado Potato Beetle Management Hypothetical Program (Not Advised!!)

- At-plant neonicotinoid plus RR-foliar (Coragen 1.67SC)

- 2nd generation foliar (Voliam Xpress)

Vine Kill

1st Gen CPB

Potato Crop

Coragen (@ 50. & 3.5 oz)

Voliam Xpress (@ 9.0 & 6.5 oz)

Platinum (@ 2.67 oz)

1st Gen CPB

2nd Gen CPB


Need to protect potato crop from CPB for 6-8 weeks

Development threshold = 1st and 2nd instar stadia
Factors Influencing Insect Pest Management
‘Water Quantity and Quality’

- Decreasing availability of water for agriculture
  - Agriculture is the overwhelming user of fresh water
  - Increasing urban demand will drive irrigation efficiency.
### Wisconsin groundwater quality: Thiamethoxam detections 2008-09

<table>
<thead>
<tr>
<th>Well</th>
<th>Date(s)</th>
<th>Thiamethoxam Concentration Range (parts per billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private well near Lone Rock</td>
<td>6/23/09 &amp; 6/9/09</td>
<td>0.693-1.26</td>
</tr>
<tr>
<td>Private Well near Arena</td>
<td>6/23/08</td>
<td>0.656</td>
</tr>
<tr>
<td>Private well near Edgerton</td>
<td>11/2/09</td>
<td>1.61</td>
</tr>
<tr>
<td>Monitoring well Adams County</td>
<td>2008 and 2009*</td>
<td>0.82-8.93</td>
</tr>
<tr>
<td>Monitoring well Grant County</td>
<td>4/7/08</td>
<td>1.25</td>
</tr>
<tr>
<td>Monitoring well Iowa County</td>
<td>2008 and 2009*</td>
<td>0.784-2.04</td>
</tr>
<tr>
<td>Monitoring well Iowa County</td>
<td>2008 and 2009*</td>
<td>0.671-2.85</td>
</tr>
<tr>
<td>Monitoring well Sauk County</td>
<td>2008 and 2009*</td>
<td>1.47-3.66</td>
</tr>
<tr>
<td>Monitoring well Waushara County</td>
<td>8/19/08 &amp; 12/1/08</td>
<td>0.638-0.704</td>
</tr>
</tbody>
</table>

- All monitoring wells in the results table are in areas with sandy soil and shallow depth to groundwater.
- The monitoring well sites in Grant, Iowa, and Sauk Counties are located in the Lower Wisconsin River Valley.
- The monitoring wells listed in the table are screened at or near the water table and adjacent to agric. fields.
- The level of detection for thiamethoxam at the DATCP lab is 0.50 ug/l (parts per billion).
- There is no groundwater enforcement standard for thiamethoxam in Wisconsin.
# Products Included in this Study

<table>
<thead>
<tr>
<th>Product</th>
<th>Active Ingredient</th>
<th>Class</th>
<th>Rate</th>
<th>Application</th>
<th>Application Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Control</td>
<td>N/A</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Platinum 75SG</td>
<td>thiamethoxam</td>
<td>neonicotinoid</td>
<td>2.67 oz / acre</td>
<td>POLY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>thiamethoxam</td>
<td>neonicotinoid</td>
<td>2.67 oz / acre</td>
<td>IF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>thiamethoxam</td>
<td>neonicotinoid</td>
<td>2.67 oz / acre</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Cruiser 5FS</td>
<td>thiamethoxam</td>
<td>neonicotinoid</td>
<td>0.16 fl oz/cwt</td>
<td>ST</td>
<td></td>
</tr>
</tbody>
</table>

* Application type = POLY (polymer impregnated), IF (in-furrow), SD (side dress), ST (seed treatment)
Neonicotinoid - Polyacrylate Impregnation Trials: 2011

Insecticide Impregnated Polyacrylate (vacuum-dried)

Vacuum Oven
In-Plant Thiamethoxam Concentrations (ppb/mg) – Untreated Control

Date: $P = 0.0024$
Year: $P = 0.6458$
In-Plant Thiamethoxam Concentrations (ppb/mg) – Polyacrylamide (2.67 oz/acre)

Date: $P = 0.0249$ •
Year: $P = 0.2240$

Leaf: $P = 0.0074$ (2010)
$P < 0.0001$ (2011)
In-Plant Thiamethoxam Concentrations (ppb/mg) – In-Furrow (2.67 oz/acre)

Date: P = 0.0249
Year: P = 0.0164
In-Plant Thiamethoxam Concentrations (ppb/mg) – Side Dress (2.67 oz/acre)

Date: P = 0.0230

Concentration (ppb/mg)
Julian Day
In-Plant Thiamethoxam Concentrations (ppb/mg) – Seed Treatment (0.16 fl oz/cwt)

Date: P = 0.0535
In-Plant Thiamethoxam Concentrations
Delivery: $P = 0.0488$
Summary: Neonicotinoid Fate

• All treatments were effective in controlling 1st generation CPB populations

• Significant in-plant variability present within all delivery system treatments – spatial refugia for CPB’s and aphids.

• Highest initial peak concentrations (ppb/mg) of thiamethoxam in seed and in-furrow treatments

• Polyacrylate impregnation resulted in greatest overall concentrations throughout the experiment
Increase proportion of down-grades and rejections resulting from PVY
Modeling Aphid Phenology

- Acrithosiphon pisum
- Aphids glycines
- Macrosiphum euphorbiae
- Myzus persicae
- Rhopalosiphum maidis
- Rhopalosiphum padi
- Schizaphis graminum
- Sitobion avenae
- Theroaphis trifolii

Calendar Day/BLUPS

Calendar Day

150 200 250 300

3 2 1 0

-3 -2 -1
Generalized Additive Model
Wisconsin 2005-2011

Mean soybean aphids / trap

95% CI (Year)

Mean capture

Julian Date
Generalized Additive Model
Aphid Thresholds

Mean soybean aphids / trap

Julian Date
Proportion Soybean Aphid Counts

P = 0.3916

Proportion soybean aphids / trap

Julian Date

39 days

Relative A. glycines Risk
Seasonal Dispersal of PVY Aphid-Vectors: 2005 - 2011

Pea aphid
Soybean aphid
Cotton - melon aphid
Potato aphid
Peach potato aphid
Corn leaf aphid
Bird cherry-oat aphid
English grain aphid
Spotted Alfalfa aphid
## Insecticides for Managing Aphids / PVY

### In the Pipeline or under review:

- **NNI - 0101** (pyrfluquinizzon) – foliar (2009-10) (Nichino America)
- **Aza-Direct** (azadirachtin) – foliar (2010-11) (Gowan Co)
- **Benevia** (cyantraniliprole) – foliar (2011) (DuPont)
- **Sulfoxaflor** – foliar (2011) (Dow AgroSciences)
- **Oils** – foliar

### Table: Insecticides for Managing Aphids

<table>
<thead>
<tr>
<th>Mode of Action Class</th>
<th>Group</th>
<th>Active Ingredient</th>
<th>Trade Names</th>
<th>Application Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicotinic acetylcholine receptor (nAChR) agonists</td>
<td>4A</td>
<td>Imidacloprid</td>
<td>Admire Pro*, Gaucho*, Provado*</td>
<td>In-furrow, seed treatment, Foliar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thiamethoxam</td>
<td>Platinum*, Cruiser*, Actara*</td>
<td>In-furrow, seed treatment, Foliar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clothianadin</td>
<td>Belay*</td>
<td>In furrow, seed treatment, Foliar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dinotefuran</td>
<td>Scorpian™</td>
<td>Foliar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acetamiprid</td>
<td>Assail*</td>
<td>Foliar</td>
</tr>
<tr>
<td>Selective Homopteran Feeding Blockers</td>
<td>9B</td>
<td>Pymetrozine</td>
<td>Fulfill*</td>
<td>Foliar</td>
</tr>
<tr>
<td></td>
<td>9C</td>
<td>Flonicamid</td>
<td>Beleaf™</td>
<td>Foliar</td>
</tr>
<tr>
<td>Narrow-range mineral oil</td>
<td>NA</td>
<td>Petroleum oil</td>
<td>Aphoil*, Stylet Oil*</td>
<td>Foliar</td>
</tr>
<tr>
<td>Plant extract (C. ambrosoides)</td>
<td>NA</td>
<td>Plant oil</td>
<td>Requiem*</td>
<td>Foliar</td>
</tr>
<tr>
<td>Treatment</td>
<td>Rate</td>
<td>Start Date</td>
<td>Application Frequency</td>
<td>Proportion US</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------</td>
<td>------------</td>
<td>-----------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>UTC</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.96</td>
</tr>
<tr>
<td>Aphoil</td>
<td>2 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.97</td>
</tr>
<tr>
<td>Stylet Oil</td>
<td>0.75 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.95</td>
</tr>
<tr>
<td>Aphoil</td>
<td>4 %</td>
<td>22-Jul</td>
<td>2x weekly</td>
<td>0.97</td>
</tr>
<tr>
<td>Stylet Oil</td>
<td>1.5 %</td>
<td>22-Jul</td>
<td>2x weekly</td>
<td>0.94</td>
</tr>
<tr>
<td>Requiem 25 EC</td>
<td>1.7 fl oz/a</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.96</td>
</tr>
<tr>
<td>Aphoil + Benevia 10 OD</td>
<td>2 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>10.1 fl oz/a</td>
<td>15-Jul</td>
<td>3x apl</td>
<td></td>
</tr>
<tr>
<td>Aphoil + Benevia 10 OD</td>
<td>2 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>13.5 fl oz/a</td>
<td>22-Jul</td>
<td>3x appl</td>
<td></td>
</tr>
<tr>
<td>Aphoil + Sulfoxaflor 50 WG</td>
<td>2 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>0.714 oz/a</td>
<td>22-Jul</td>
<td>3x appl</td>
<td></td>
</tr>
<tr>
<td>Aphoil + Beleaf 50 SG</td>
<td>2 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>2.8 oz/a</td>
<td>20-Jul</td>
<td>3x appl</td>
<td></td>
</tr>
<tr>
<td>Aphoil + Fulfill 50 WDG</td>
<td>2 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>3.67 fl oz/a</td>
<td>20-Jul</td>
<td>3x appl</td>
<td></td>
</tr>
<tr>
<td>Aphoil + Fulfill 50 WDG</td>
<td>2 %</td>
<td>6-Jun</td>
<td>1x weekly</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>5.5 fl oz/a</td>
<td>20-Jul</td>
<td>2x appl</td>
<td></td>
</tr>
</tbody>
</table>

LSD: 0.22
PVY Foliar Protectant Trial, 2011-12
Winter Grow-Out Results

Mean Proportion of PVY-Infected Plants

<table>
<thead>
<tr>
<th>Oil Compound (Concentration)</th>
<th>Applied 1X / week (June 5)</th>
<th>Applied 2X / week (July 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTC</td>
<td></td>
<td>P &lt; 0.0001</td>
</tr>
<tr>
<td>Aphoil (2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stylet (0.75%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stylet (1.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requiem (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphoil (2%) + Benevia 100D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphoil (2%) + Benevia 100D +</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfoxaflor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphoil (2%) + Beleaf 50WG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphoil (2%) + Fulfill 50WG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphoil (2%) + Releaf 50WG</td>
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</tr>
</tbody>
</table>

5% mosaic ‘Certified’
Minimizing Current Season Infection: Foliar Protectant Summary

- In all experiments, 2X weekly oil applications of Aphoil and Stylet Oil significantly reduced PVY in daughter tubers.

- Again in 2009, Aphoil weekly (June 15) and twice weekly (July 15), resulted in lowest overall PVY in winter test.

  - Suggests that the bulk of infection / transmission occurs in late season
  - Additive effects of (1) selective feeding blockers (2) insecticides as behavioral modifiers warrants further investigation

- Level (degree) of foliar protection required varied by cultivar

  - Mature plant resistance (e.g. Snowden vs. Goldrush)

- Improved understanding of disease dynamics and relationship to primary insect vectors – *A. glycines*
http://www.entomology.wisc.edu/vegento/