Insecticide Rotation Options for the Control of Resistant Colorado Potato Beetles

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## Wisconsin’s specialty crop industry

<table>
<thead>
<tr>
<th></th>
<th>Total Economic Activity (in $ millions per year)</th>
<th>Total Jobs</th>
<th>USDA-NASS 2011 National ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable &amp; Fruit Production</td>
<td>$1,092</td>
<td>9,900</td>
<td>-</td>
</tr>
<tr>
<td>Potatoes</td>
<td>$349</td>
<td>2,770</td>
<td>3</td>
</tr>
<tr>
<td>Cranberries</td>
<td>$300</td>
<td>3,400</td>
<td>1</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>$83</td>
<td>660</td>
<td>3</td>
</tr>
<tr>
<td>Green Beans</td>
<td>$63</td>
<td>490</td>
<td>1</td>
</tr>
<tr>
<td>Carrots, Cucumbers &amp; Onions</td>
<td>$28</td>
<td>220</td>
<td>2, 5, 10</td>
</tr>
<tr>
<td>Green Peas</td>
<td>$26</td>
<td>200</td>
<td>3</td>
</tr>
<tr>
<td>Ginseng</td>
<td>$16</td>
<td>130</td>
<td>1</td>
</tr>
<tr>
<td>Specialty Crop Processing</td>
<td>$5,268</td>
<td>24,800</td>
<td></td>
</tr>
<tr>
<td>Total Impact</td>
<td>$6,360</td>
<td>34,700</td>
<td></td>
</tr>
</tbody>
</table>

Production estimates based on 2006-2008 average farmgate values; processing estimates based on 2007 Economic census values. Note: sum of estimates may not equal total impact due to rounding.

(Keene and Mitchell, 2010; USDA NASS 2011)
Potato production in Wisconsin

- ca. 63,500 acres annually, estimated 267 million dollars
- fresh, processed (chips/frozen/dehydrated), or seed potatoes

Major commercial varieties

- Russet Burbank
- Yukon Gold
- Dark Red Norland
- Atlantic
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.
### Groundwater Well Detects and Relationship to Vegetable Production

<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
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 or bio-pesticides).
US Potato Insecticide Market

- $48 million spent in potatoes for insect control in 2010.
- Key pests by expenditure in $millions include:

<table>
<thead>
<tr>
<th>Pests</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>
US Potato Insecticide Market

• 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’)

Annual Changes in Crop Uses in the U.S.


Annual Changes in Crop Uses in the U.S.


Annual Changes in Crop Uses in the U.S.


Key pests of Wisconsin Potato

- Potato leafhopper (*Empoasca fabae*)
- Colonizing Aphids (*Myzus persicae* & *Macrosiphium euphorbiae*)
- Colorado potato beetle (*Leptinotarsa decemlineata*)
Dormancy & crop colonization

- Overwinter in non-crop habitats
- Dormancy habitats close to previous year potato
- Diapause 20-60cm in the soil
- Duff layers and snow cover lessens mortality
- Colonize crop by walking
Colonization and egg deposition

- Field edges colonized first
- Minimal adult feeding
- Yellow/orange egg masses
- 20-40 eggs/mass
- Adults lay eggs on underside of leaves
Larvae and Associated Damage

- Egg hatch in 1-2 weeks depending on temperature
- Small larvae move to leaf terminals
- 4 instars, 5-7 days per instar
- Large larvae (3 & 4) feed extensively
- 4th instars leave plant and pupate in soil for 2-3 weeks
Summer Generation Adults

- 2-3 generations per summer
- 1st summer generation emerges in July
- Very active and hungry
- Rapid defoliation
- Second generation adults leave to overwinter
- Can be partial 3rd generation

Potato defoliation
IPM and Methods of Control

Overwintering Emergence
spatial rotation
temporal rotation
dispersal disruption

Crop Infestation
- trap crops
- deterrents
- physical control

Growing Season
deterrants
physical control

Potato Growing Season

Colorado Potato Beetle Ecology

Dormancy

Adult Diapause
- habitat disruption
cold shock

Crop Departure
- trap crops
- physical control

May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
CPB Phenology

<table>
<thead>
<tr>
<th>Life stage</th>
<th>DD52</th>
<th>Accum DD</th>
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<tbody>
<tr>
<td>Egg</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; instar</td>
<td>65</td>
<td>185</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; instar</td>
<td>55</td>
<td>240</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; instar</td>
<td>60</td>
<td>300</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; instar</td>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>Pupa</td>
<td>275</td>
<td>675</td>
</tr>
</tbody>
</table>
Degree-Day Accumulations in 2012

- Ground Crack
- Overwintered Adults
- Overwintered Adults
- First Generation
- Second Generation
- Third Generation
- To Overwintering
- To Overwintering
Targeting Vulnerable Stages
Colorado Potato Beetle Management Development and Defoliation Thresholds

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

- Population Development Thresholds (eggs, larvae)

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**At-plant systemic**

**RR-Foliar**

**2nd Gen CPB**

**1st Gen CPB**

**Potato Crop**
Systemic Neonicotinyl Insecticides

**Beneficial Attributes**

- Broad spectrum
  - CPB, leafhoppers, aphids
- Flexible
  - Row mark, furrow, seed, layby
- Long residual
  - Rate dependent
- Low toxicity

**Disadvantages**

- Same chemical class
- Resistance likely
- Non-target impacts
Reduced Risk Foliar Options

- **Radiant® (spinetoram) & Blackhawk® (spinosad)**
  - 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 & 0.7SC (abamectin):**
  - Chloride channel activator (MoA Group 6)
    - Use rate 8 – 16 fl oz / ac (foliar)
    - Control of adult & nymphal psyllids, CPB larvae
    - Abba, Epi-Mek, Athena, Raptor, etc…
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

- **Besiege® (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, Leps, and psyllids

* Water soluble, systemically mobile insecticides
** Not currently registered
## 2013 CPB Foliar Control

<table>
<thead>
<tr>
<th>Product</th>
<th>Active Ingredient</th>
<th>Class</th>
<th>Rate</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Exirel 10SE</td>
<td>cyazypyr</td>
<td>MoA 28</td>
<td>5.1 &amp; 6.8 fl oz/ac</td>
<td>F</td>
</tr>
<tr>
<td>Endigo 2.7ZC</td>
<td>thiamethoxam + lambda-cyhalo</td>
<td>MoA 3 + 4A</td>
<td>4.0 and 4.5 fl oz/ac</td>
<td>F</td>
</tr>
<tr>
<td>Blackhawk 36WG</td>
<td>spinosyn</td>
<td>MoA 5</td>
<td>2.0, 2.5 &amp; 3.3 oz/ac</td>
<td>F</td>
</tr>
<tr>
<td>Besiege</td>
<td>CTPR + lambda-cyhalothrin</td>
<td>MoA 3 + 28</td>
<td>7.5 &amp; 9.0 fl oz/ac</td>
<td>F</td>
</tr>
<tr>
<td>Athena</td>
<td>abamectin + bifenthrin</td>
<td>MoA 3 + 6</td>
<td>13 &amp; 17 fl oz/ac</td>
<td>F</td>
</tr>
<tr>
<td>Agri-Mek 0.7SC</td>
<td>abamectin</td>
<td>MoA 6</td>
<td>3.0 &amp; 3.5 fl oz/ac</td>
<td>F</td>
</tr>
<tr>
<td>Coragen 1.67SC</td>
<td>CTPR</td>
<td>MoA 28</td>
<td>3.5 &amp; 5.0 fl oz/ac</td>
<td>F</td>
</tr>
<tr>
<td>Rimon 0.83EC</td>
<td>novaluron</td>
<td>MoA 18</td>
<td>9, 8, and 7 fl oz / ac</td>
<td>F</td>
</tr>
</tbody>
</table>

* Not labeled on potato in Wisconsin
Benevia 10OD (54 dap)*
5.1 and 6.8 fl oz / acre

5.1 fl oz
1.5% defoliation

6.8 fl oz
2.0% defoliation

*Not currently registered in Wisconsin
Endigo ZC (54 dap)
4.0 and 4.5 fl oz / acre

4.0 fl oz
2.0% defoliation

4.5 fl oz
1.0% defoliation
Blackhawk 36WG (54 dap)
2.0, 2.5 and 3.3 oz / acre

2.0 oz
0.5% defoliation

2.5 oz
0.5% defoliation

3.3 oz
0.5% defoliation
Besiege (54 dap)
7.5 and 9.0 fl oz / acre

7.5 fl oz
1.5% defoliation

9.0 fl oz
1.0% defoliation
Athena (54 dap)
13.0 and 17.0 fl oz / acre

13.0 fl oz
1.0% defoliation

17.0 fl oz
0.5% defoliation
Agri-Mek 0.7SC (54 dap)
3.0 and 3.5 fl oz / acre

3.0 fl oz
1.5% defoliation

3.5 fl oz
0.5% defoliation
Coragen 1.67SC (54 dap)
3.5 and 5.0 fl oz / acre

3.5 fl oz
1.5% defoliation

5.0 fl oz
2.0% defoliation
Rimon 0.83EC (54 dap)
7.0, 8.0 and 9.0 fl oz / acre

7.0 oz
1.0% defoliation

8.0 oz
1.0% defoliation

9.0 oz
1.0% defoliation
Colorado Potato Beetle Management Hypothetical Program (No systemic)

- No at-plant neonicotinoid – 1st generation RR-foliar (Rimon® 0.83EC)

- 2nd generation foliar (neonicotinoid)

- Vine Kill

- 1st Gen CPB

- Potato Crop

- Actara® 25WG (@ 3.0 & 2.5 fl oz)

- 2nd Gen CPB

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

- Development threshold = 1st and 2nd instar stadia
Colorado Potato Beetle Management Hypothetical Program (At-Plant)

- At-plant neonicotinoid plus RR-foliar (Agri-Mek® 0.7SC)

- 2nd generation foliar (Coragen® 1.67SC)

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

Development threshold = 1st and 2nd instar stadia.

- Coragen 1.67SC (@ 5.0 & 3.5 oz)
- Platinum 75SG (@ 2.67 oz)
- Agri-Mek 0.7SC (@ 2.6 & 2.3 oz)

Potato Crop:
- 1st Gen CPB
- 2nd Gen CPB

Timeline:
- 15-Mar
- 14-Apr
- 14-May
- 13-Jun
- 13-Jul
- 12-Aug
- 11-Sep
- 11-Oct
Colorado Potato Beetle Management Hypothetical Program (Not Advised!!)

- At-plant neonicotinoid plus RR-foliar (Coragen® 1.67SC)
- 2nd generation foliar (Besiege®)

Hypothetical Program:

- 15-Mar
- 14-Apr
- 14-May
- 13-Jun
- 13-Jul
- 12-Aug
- 11-Sep
- 11-Oct

1st Gen CPB

Potato Crop

2nd Gen CPB

Coragen® 1.67SC (@ 5.0 & 3.5 oz)

Platinum® 75SG (@ 2.67 oz)

Besiege® (@ 9.0 & 6.5 oz)

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

Development threshold = 1st and 2nd instar stadia
<table>
<thead>
<tr>
<th>Product</th>
<th>Active Ingredient</th>
<th>Class</th>
<th>Rate</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Verimark 20SC</td>
<td>cyazypyr</td>
<td>anthranillic diamide</td>
<td>0.47 &amp; 0.62 fl oz/cwt 10.3 &amp; 13.5 fl oz/ac</td>
<td>ST IF</td>
</tr>
<tr>
<td>*A16901 40WG</td>
<td>thiamethoxam + CTPR</td>
<td>neonicotinoid + anthranillic diamide</td>
<td>6.5 &amp; 10 fl oz/ac</td>
<td>IF</td>
</tr>
<tr>
<td>AdmirePro 4.6FS</td>
<td>imidacloprid</td>
<td>neonicotinoid</td>
<td>0.26 &amp; 0.35 fl oz/cwt 8.7 fl oz/ac</td>
<td>ST IF</td>
</tr>
<tr>
<td>Cruiser 5FS</td>
<td>thiamethoxam</td>
<td>neonicotinoid</td>
<td>0.12 &amp; 0.16 fl oz/cwt</td>
<td>ST</td>
</tr>
<tr>
<td>Platinum 75SG</td>
<td>thiamethoxam</td>
<td>neonicotinoid</td>
<td>1.7 &amp; 2.67 oz/ac</td>
<td>IF</td>
</tr>
<tr>
<td>Belay 2.16SC</td>
<td>clothianadin</td>
<td>neonicotinoid</td>
<td>0.6 fl oz/cwt 12 fl oz/ac</td>
<td>ST IF</td>
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</tbody>
</table>

* *Not labeled on potato in Wisconsin*
Seed and In-Furrow Treatments for CPB Control – CPB Small Larvae / 10 plants

Mean CPB Small Larvae (L1-L2) (Jun 15 & 22)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean CPB Small Larvae</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTC</td>
<td>a</td>
</tr>
<tr>
<td>Verimark</td>
<td>b</td>
</tr>
<tr>
<td>Verimark 10.3</td>
<td>bc</td>
</tr>
<tr>
<td>A16901 (6.5)</td>
<td>c</td>
</tr>
<tr>
<td>A16901 (10)</td>
<td>c</td>
</tr>
<tr>
<td>AdmirePro (0.26)</td>
<td>c</td>
</tr>
<tr>
<td>AdmirePro (0.35)</td>
<td>c</td>
</tr>
<tr>
<td>AdmirePro (8.7)</td>
<td>c</td>
</tr>
<tr>
<td>Cruiser (0.12)</td>
<td>c</td>
</tr>
<tr>
<td>Platinum (1.67)</td>
<td>c</td>
</tr>
<tr>
<td>Platinum (2.67)</td>
<td>c</td>
</tr>
<tr>
<td>Belay (0.6)</td>
<td>c</td>
</tr>
<tr>
<td>Belay (12)</td>
<td>c</td>
</tr>
</tbody>
</table>

P < 0.0001

Seed Trt
In-Furrow
Seed and In-Furrow Treatments for CPB Control – CPB Large Larvae / 10 plants

Mean CPB Large Larvae (L3-L4) (Jun 22 & 29)

P < 0.0001

Seed Trt

In-Furrow

Treatment

A16901 (6.5)
A16901 (10)
AdmirePro (0.26)
AdmirePro (0.35)
Platinum (1.67)
Platinum (2.67)
Belay (0.6)
Belay (12)
Cruiser (0.19)
Cruiser (0.12)
Platinum (1.67)
Platinum (2.67)
Belay (0.6)
Belay (12)

UTC
Vermark (0.47)
Vermark (0.6)
Vermark 10.3
Vermark 13.5
AdmirePro (0.26)
AdmirePro (0.35)
Cruiser (0.12)
Platinum (1.67)
Belay (0.6)
Belay (12)
Seed and In-Furrow Treatments for CPB Control – CPB Adults / 10 plants

Mean CPB Large Larvae (L3-L4) (Jul 3 and 10)

P < 0.0001

Seed Trt

In-Furrow

UTC
Verimark (0.47)
Verimark (0.6)
Verimark 10.3
Verimark 13.5
A16901 (6.5)
A16901 (10)
AdmirePro (0.26)
AdmirePro (0.35)
Cruiser (0.12)
Platinum (1.67)
Platinum (2.67)
Belay (0.6)
Belay (12)

(b)
Seed and In-Furrow Treatments for CPB Control – % Defoliation / 10 plants

Mean Percent Defoliation (Jul 10)

Treatment

UTC  Verimark (0.47)  Verimark (0.6)  Verimark 10.3  Verimark 13.5  A16901 (6.5)  A16901 (10)  AdmirePro (0.26)  AdmirePro (0.35)  AdmirePro (0.42)  Cruiser (0.12)  Cruiser (0.16)  Platinum (1.67)  Platinum (2.67)  Belay (0.6)  Belay (12)

P < 0.0001

Seed Trt  In-Furrow

10% Defoliation Threshold
Seed and In-Furrow Treatments for CPB Control – PLH Adults / 20 sweeps

Mean Potato Leafhopper Adults (June 16, 21 & 29)

P < 0.0001

Seed Trt
In-Furrow

Treatment

PLH / sweep

UTC, Verimark (0.47), Verimark (0.6), Verimark 10.3, Verimark 13.5, A16901 (6.5), A16901 (10), AdmirePro (0.26), AdmirePro (0.35), AdmirePro (0.87), Cruiser (0.12), Cruiser (0.16), Platinum (1.67), Platinum (2.67), Belay (0.6), Belay (12)
Chronology of Insecticide Resistance in Colorado Potato Beetle: Long Island, NY

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>1\textsuperscript{st} Introduced</th>
<th>1\textsuperscript{st} Failed</th>
<th>Chemical Group</th>
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<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></td>
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<td>synergist</td>
</tr>
<tr>
<td>Esfenvalerate + PBO</td>
<td>1983</td>
<td>1984</td>
<td>Pyrethroid +</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>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>

**Dr. W. Tingey, Cornell University, Personal Communication**
**Wisconsin, 2011 Imidacloprid Bioassays**

- Topical Assays (2007-11)
- 6 populations
  - LC$_{50}$ range (0.02 – 4.46)
Neonicotinoid Insensitivity: CPB Survivorship

Seasonal, in-plant [imidacloprid]

Days (post-application)
Resistance Management for Sustainable Agriculture and Improved Public Health

SUSTAINABLE AGRICULTURE
Managing insect resistance to help ensure a future of sufficient, affordable and nutritious food.

LEARN MORE >

ABOUT IRAC
IRAC is an international group of more than 150 members of the Crop Protection Industry organised by sector and region to advise on the prevention and management of insecticide resistance.

Launch Presentation

RESISTANCE MANAGEMENT RESOURCES
Resistance is a heritable change in the genetic constitution of a population of organisms that reduces the efficacy of a pest management tool.

CROP PROTECTION
BIOTECHNOLOGY
PUBLIC HEALTH

MODE OF ACTION
METHODS
NEWSLETTER

eConnection

© BASF
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>
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<tr>
<td>1st Gen</td>
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<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 always applicable with good efficacy
Impediments to Resistance Management

- Must be implemented before resistance problem exists
- Involves added costs and/or complexity
- Pesticide dealers may not stock inventory for rotations and mixtures
- Sales incentives favor maximizing pesticide sales in short-term
- No positive feedback
http://www.entomology.wisc.edu/vegento/

Questions??