2013 BT-Corn Rootworm Failure in CNY: A canary in the coal mine?

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Corn Rootworm Adults
Northern corn rootworm is on the left.
Western corn rootworm is on the right.

Root damage from corn rootworm larval feeding.

Lodging caused by severe CRW larval feeding.
Cayuga Co  2013
BT-Rootworm Failure
Field History

8-10 years continuous corn

Corn varieties with single Monsanto event (Cry 3Bb1)

No legal refuges for many years (infield or immediate adjacent to)

Damage and high beetle populations since 2011
Anybody Surprised?
Bt-RW Performance Issues: Eyota MN - 2009
Bt-RW Corn Performance Problems in 2010
1) Resistance to GM-Rootworm Corn has been documented in field populations at Iowa State University in 2010 and published in 2011.

2) Resistance primarily YieldGard but also reduced performance with Herculex.
How did this Happen?

Refuges were not planted!
Many excuses by farmers
Dismissed by seed salesmen

How did we know properly deployed refuges would defeat resistance?

30-40 years of soil insecticide with no resistance detected
Soil Insecticide Over Conventional Corn

Soil Insecticide Refuge

No Selection

Soil Insecticide
Deciphering GM Corn Technology

Source of GMO-RW Insect events:

1) YieldGard – Rootworm (Monsanto) (Cry3Bb1)

2) Syngenta – Rootworm (mCry3 . .)

3) Herculex – Rootworm (Dow) (Cry 34/35)

4) SmartStax – Rootworm (Cry3Bb + Cry 34/35) (mCry3 + Cry 34/35)
NY GM – Rootworm Comparative Field Trial - 2010
<table>
<thead>
<tr>
<th>GMO event</th>
<th>0-3 scale (nodes of roots)</th>
<th>1-6 scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Check</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Seed treatment (1250)</td>
<td>0.5</td>
<td>2.9</td>
</tr>
<tr>
<td>Herculex</td>
<td>0.25</td>
<td>1.5</td>
</tr>
<tr>
<td>Yieldgard VT-Pro</td>
<td>0.25</td>
<td>1.5</td>
</tr>
<tr>
<td>SmartStax</td>
<td>0.25</td>
<td>1.5</td>
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</tbody>
</table>
# Adult Beetle Emergence

<table>
<thead>
<tr>
<th>GMO Event</th>
<th>Beetles/ft²</th>
<th>R R 0-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Check</td>
<td>18.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Seed treatment (1250)</td>
<td>5.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Yieldgard VT-Pro</td>
<td>3.9</td>
<td>0.25</td>
</tr>
<tr>
<td>Herculex</td>
<td>2.6</td>
<td>0.25</td>
</tr>
<tr>
<td>Herculex seed mix (5.6%)</td>
<td>4.4</td>
<td>0.25</td>
</tr>
<tr>
<td>SmartStax</td>
<td>1.1</td>
<td>0.25</td>
</tr>
</tbody>
</table>
# Adult Beetle Emergence

<table>
<thead>
<tr>
<th>GMO Event</th>
<th>Beetles/ft²</th>
<th>% Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>untreated check</td>
<td>18.2</td>
<td>---</td>
</tr>
<tr>
<td>seed treatment (1250)</td>
<td>5.9</td>
<td>32%</td>
</tr>
<tr>
<td>Herculex</td>
<td>2.6</td>
<td>14%</td>
</tr>
<tr>
<td>Herculex seed mix (5.6%)</td>
<td>4.4</td>
<td>24%</td>
</tr>
<tr>
<td>Yieldgard VT-Pro</td>
<td>3.9</td>
<td>21%</td>
</tr>
<tr>
<td>SmartStax</td>
<td>1.1</td>
<td>6%</td>
</tr>
</tbody>
</table>
What is the significance of adult survival in resistance development

Write a computer model to predict resistance development.
Inheritance Characteristics

Cry 3Bb1 (Monsanto - YieldGard)

Resistance Inheritance is mostly Recessive.
Impact of No Refuges on Resistance Development

Cry 3Bb1
**Yieldgard VT Pro?**

Allele freq 0.01, Environmental survival 10%, SS toxin survival 1%, RS toxin survival 21%, RR toxin survival 100%
Impact of a 20% Refuge on Resistance Development

Cry 3Bb1
Yieldgard VT Pro?

Allele freq 0.01, Environmental survival 10%, SS toxin survival 1%, RS toxin survival 21%, RR toxin survival 100%
Impact of a 10% Refuge on Resistance Development

Cry 3Bb1
Yieldgard VT Pro?

Allele freq 0.01, Environmental survival 10%, SS toxin survival 1%, RS toxin survival 21%, RR toxin survival 100%
Impact of a 5% Refuge on Resistance Development

Cry 3Bb1
Yieldgard VT Pro?

Allele freq 0.01, Environmental survival 10%, SS toxin survival 1%, RS toxin survival 21%, RR toxin survival 100%
Summary - Cry 3Bb1

No Refuge = Predicted Resistance
Development within 10 years
(2-10% of the population)

As little as 5% Refuge holds Resistance
to less than 1% of the population after
10 years.
What about Herculex?

Cry 34/35
Inheritance Characteristics

Cry 34/35 (Dow - Herculex)

Resistance Inheritance is additive dominant.

Rs = 88% survival
RR = 100 % survival
Impact of No Refuges on Resistance Development

Cry 34/35
Herculex  No Refuge
0.01 initial Allele Frequency
Impact of a 10% Refuge on Resistance Development

Cry 34/35
Herculex 10% Refuge
0.01 initial Allele Frequency
Summary - Cry 34/35

No Refuge = Predicted Resistance
Development within 3-5 years
(40% - 50% of the population)

10% refuge hold down the resistance to less than 15% of the population after 10 years.
Resistance Status of Each Event

Cry-3Bb1 (Monsanto YieldGard)

Widespread reported failure since before 2009.
Also in the “Rotation Resistant” population in Illinois.

Resistance Inheritance is Recessive

Reported in Nebraska, Iowa, S. Dakota, Minn. Wisc, Illinois, Michigan, NY
Resistance Status of Each Event

mCry-3 . . (Syngenta)

High Potential of Cross-Resistance reported from Laboratory studies
Resistance Status of Each Event

Cry 34/35 (Dow Herculex)

First suspected widespread failure in 2013 in Northwest Texas (Irrigated corn).

Laboratory studies report the inheritance of this resistance is “additive dominant”. Rs = survival of 88%
Strategies to Preserve the Technology
Fields with Control Problems

**ROTATE!  ROTATE!  ROTATE!**

**DO NOT PLANT SMART STAK!**
(5% refuge, only 1 toxin working)

Do Not Layer a soil insecticide over a failing BT event
Layering Soil Insecticide Over a BT Toxin

Only BT toxin active, resistance selection continues.
1250 Seed Treatment layered over BT Toxin

Roots toxic with 1250 rate of seed treatment
Fields with Control Problems

If corn needs to be planted:

Conventional corn + insecticide
(1250 seed treatment or soil insecticide)

Herculex-Rootworm (Cry 34/35)
with 10% RIB (Refuge in a Bag)
Soil Insecticide Over Conventional Corn

Soil Insecticide Refuge

No Selection
## Corn Rootworm Damage

<table>
<thead>
<tr>
<th>Year of Corn Production</th>
<th>% Acreage over Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>25-35%</td>
</tr>
<tr>
<td>3</td>
<td>50-70%</td>
</tr>
<tr>
<td>4 +</td>
<td>80-100%</td>
</tr>
</tbody>
</table>
Strategies to Prevent Resistance

1\textsuperscript{st} Year Corn: No action necessary

2\textsuperscript{nd} year Corn: High Rate of Seed Treatment (Cruiser 1.25, Poncho 1250)

3\textsuperscript{rd} - 4\textsuperscript{th} + year Corn:
   1) High Rate of Seed Treatment
   2) BT – Rootworm Corn
      (Herculex, YieldGard)
Questions?

Discussion?