Transgenic Bt Corn

Resistance to Stored Grain and Vegetable Insect Pests

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Importance of Corn

- Six nations (USA, China, Brazil, Mexico, France and Argentina) produce 75% of world’s supply of corn
- USA produces 39%
- Six states (Iowa, Illinois, Nebraska, Minnesota, Indiana and Ohio) account for 82% of USA production
- Iowa produces 22% of USA and 8.5% of world stocks
USA Corn Production

- 81 million acres planted
- 73.6 million harvested
- 11.8 billion bu harvested
- $23 billion in value
Introduction

- Corn is a major crop grown in the U.S.
- Has a value of 20 - 25 billion dollars
- Grown on 75-80 million acres annually
- Half of crop is placed in storage annually
Corn/Maize – *Zea mays*
Primary Preharvest Field Corn Insect Pests

- Fall Armyworm
- Black cutworm
- European corn borer
European Corn Borer  Whorl Damage
Western Corn Rootworm
$1-$1.25 billion in losses due to insect infestation in USA stored shelled corn
Pests of Stored Grain

- Indian meal moth
- Sawtooth grain beetle
- Maize weevil
- Angoumois grain moth
- Red flour beetle
Major Types of Control

Chemical- Organophosphates and Synthetic Pyrethroids

Host resistance- traditional plant breeding and transgenic insecticidal cultivars

Biological- use of parasitoids, predators, and/or pathogens

Cultural- cleaning crop residues in and around fields and grain bins
**Bacillus thuringiensis** (Bt)

- Bt is a pathogenic gram positive bacterium used in biological control
- Bt synthesizes Insecticidal Crystal Proteins called α-endotoxins or cry proteins
- Cry proteins have a relatively narrow spectrum of activity
Cry protein activity

- Cry I active against Lepidoptera larvae
- Cry II active against Diptera and Lepidoptera
- Cry III active against Coleoptera
- Cry IV active against Diptera
- Cry V-IX active against various orders
Mode of Action

• Upon ingestion by susceptible larvae, Bt crystal protein is dissolved in the alkaline midgut.

• These protein fragments are then further cleaved by midgut proteinases.

• After cleavage, activated toxin diffuses through the peritrophic membrane and binds to cells causing pore development leading to septicemia and death.
Host Resistance

- The manipulation of plants in order to gain characteristics which will resist pest invasion
- Transgenic crop plants are in this category
- Several seed companies such as Pioneer Hi-Bred International (DuPont), Mycogen (Dow), Garst (Aventis) and Dekalb (Monsanto) have developed transgenic corn hybrids
Transgenic Corn

- Genes encoding Bt toxin expression have been incorporated into corn plant genome
- These plants express delta endotoxin in various tissues (e.g., kernels, pollen, roots)
- Delta endotoxin is lethal to larval European corn borer, fall armyworm, southwestern corn borer, corn earworm, Indian meal moth, Angoumois grain moth and corn rootworm
Typical gene sequence

Marker: Gene coding antibiotic resistance

Promoter: CaMV 35S or PEPC

Transgene: activated Cry toxin [1Ab, 1Ac, etc.]

Termination sequence: stop code for protein synthesis
Gold or tungsten pellets are then coated with desired genes and fired into corn callus on growing media. The callus tissue then differentiates into individual corn plants which are then transplanted to isolated fields.
## Types of Bt Corn

<table>
<thead>
<tr>
<th>Event</th>
<th>Company</th>
<th>Bt Gene</th>
<th>Tradename</th>
<th>Toxin Content Grain (μg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>176</td>
<td>Mycogen</td>
<td>Cry1Ab</td>
<td>NatureGard™ / Knockout®</td>
<td>None</td>
</tr>
<tr>
<td>Bt 11</td>
<td>Syngenta</td>
<td>Cry1Ab</td>
<td>YieldGard® / Attribute</td>
<td>1.4</td>
</tr>
<tr>
<td>MON 810</td>
<td>Monsanto</td>
<td>Cry1Ab</td>
<td>YieldGard®</td>
<td>0.19-0.91</td>
</tr>
<tr>
<td>MON 863</td>
<td>Monsanto</td>
<td>Cry3Bb1</td>
<td>YieldGard®</td>
<td>49-86</td>
</tr>
<tr>
<td>MON 84006</td>
<td>Monsanto</td>
<td>MPG2</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
| DAS-59122-7| Dow      | Cry34Ab1/     | Herculex™ / Herculex ™ EXTRA | 28.9-117  
|           |          | Cry35Ab1      |                               | 0-1.83                    |
| TC1507    | Dow       | Cry1F         | Herculex™                     | 71.2-114.8                |
| CBH 351   | Aventis   | Cry9C         | Starlink™                     | 18.6                      |
Increase of 20%, 13.3 million hectares or 32.9 million acres between 2003 and 2004.

Source: Clive James, 2004
GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996 to 2004)

- Total
- Industrial Countries
- Developing Countries

Increase of 20%, 13.3 million hectares or 32.9 million acres between 2003 and 2004.
Source: Clive James, 2004
Biotech Crop Countries and Mega-Countries*, 2004

1. USA - 5.4 Million Hect. Maize
2. Argentina* - 5.0 Million Hect. Soybean, Maize, Cotton
3. Canada* - 4.7 Million Hect. Maize, Soybean, Canola
4. Brazil - 5.0 Million Hect. Soybean
5. China* - 3.7 Million Hect. Cotton
6. Paraguay* - 1.2 Million Hect. Soybean
7. India* - 0.5 Million Hect. Cotton
8. Australia* - 0.2 Million Hect. Cotton
9. Uruguay* - 0.5 Million Hect. Soybean, Maize
10. Mexico* - 0.3 Million Hect. Cotton, Soybean
11. Romania* - 0.1 Million Hect. Maize
12. Germany - 0.1 Million Hect. Maize
13. Spain* - 0.1 Million Hect. Maize
14. Philippines* - 0.1 Million Hect. Maize
15. Honduras - <0.05 Million Hect. Maize
16. South Africa* - <0.05 Million Hect. Maize

*4 biotech mega-countries growing 50,000 hectares or more of biotech crops.

Source: Clive James, 2004
<table>
<thead>
<tr>
<th>Year</th>
<th>Planted acreage</th>
<th>Yield increase</th>
<th>Reduction in production costs</th>
<th>Net economic impact</th>
<th>Pesticide use reduction&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>106 Million acres</td>
<td>5.34 Billion pounds</td>
<td>1.5 Billion dollars</td>
<td>1.9 Billion dollars</td>
<td>46.4 Million lbs.</td>
</tr>
<tr>
<td>2001</td>
<td>80 Million acres</td>
<td>3.79 Billion pounds</td>
<td>1.2 Billion dollars</td>
<td>1.5 Billion dollars</td>
<td>45.7 Million lbs.</td>
</tr>
</tbody>
</table>

<sup>1</sup>Refers to active ingredients.
**Table 2**

Adoption of biotechnology-derived crops in the United States in 2003

<table>
<thead>
<tr>
<th>Case study</th>
<th>Crop</th>
<th>Trait</th>
<th>Percentage adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2003</td>
</tr>
<tr>
<td>1</td>
<td>Papaya</td>
<td>Virus-resistant</td>
<td>46</td>
</tr>
<tr>
<td>2</td>
<td>Squash*</td>
<td>Virus-resistant</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>Canola</td>
<td>Herbicide-tolerant</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>Corn</td>
<td>Herbicide-tolerant</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>Cotton</td>
<td>Herbicide-tolerant</td>
<td>74</td>
</tr>
<tr>
<td>6</td>
<td>Soybean</td>
<td>Herbicide-tolerant</td>
<td>82</td>
</tr>
<tr>
<td>7</td>
<td>Corn</td>
<td>Insect-resistant (1)*</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>Corn</td>
<td>Insect-resistant (2)*</td>
<td>0.5</td>
</tr>
<tr>
<td>9</td>
<td>Corn</td>
<td>Insect-resistant (3)*</td>
<td>0.6</td>
</tr>
<tr>
<td>10</td>
<td>Cotton</td>
<td>Insect-resistant (1)*</td>
<td>46</td>
</tr>
<tr>
<td>11</td>
<td>Cotton</td>
<td>Insect-resistant (2)*</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Adoption in GA and R. only

*European corn borer/southwestern corn borer/com earwormresistant.com (includes YieldGard Corn Borer and Herculex I)

*Bollwormresistant.com (YieldGard Rootworm)

*European corn borer/southwestern corn borer/black cutworm/that armyworm/com earwormresistant.com (Herculex I)

*Bollworm and budworm-resistant cotton (Bollgard I)

*Bollworm/budworm/looper/armywormresistant cotton (Bollgard I)
<table>
<thead>
<tr>
<th>Trait</th>
<th>Production</th>
<th>Total net value</th>
<th>Reduction in pesticide use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume</td>
<td>Value</td>
<td>Costs</td>
</tr>
<tr>
<td>Herbicide-tolerance</td>
<td>0</td>
<td>0</td>
<td>-1,519.64</td>
</tr>
<tr>
<td>Insect-resistance</td>
<td>5,305.71</td>
<td>399.31</td>
<td>48.7</td>
</tr>
<tr>
<td>Virus-resistance</td>
<td>32.98</td>
<td>9.95</td>
<td>0.48</td>
</tr>
<tr>
<td>Total</td>
<td>5,339</td>
<td>409</td>
<td>-1,471</td>
</tr>
</tbody>
</table>

$^1$ai refers to active ingredients.
<table>
<thead>
<tr>
<th>#</th>
<th>Crop</th>
<th>Production</th>
<th>Total net value</th>
<th>Reduction in pesticide use</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume</td>
<td>Value</td>
<td>Costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Million lbs.</td>
<td>Million $</td>
<td>Million $</td>
<td>lbs. ai^1</td>
</tr>
<tr>
<td>1</td>
<td>Papaya</td>
<td>8.98</td>
<td>2.96</td>
<td>0.05</td>
<td>2.91</td>
</tr>
<tr>
<td>2</td>
<td>Squash</td>
<td>24</td>
<td>6.99</td>
<td>0.43</td>
<td>6.56</td>
</tr>
<tr>
<td>3</td>
<td>Canola</td>
<td>0</td>
<td>0</td>
<td>-8.98</td>
<td>8.98</td>
</tr>
<tr>
<td>4</td>
<td>Soybean</td>
<td>0</td>
<td>0</td>
<td>-1,190</td>
<td>1,190</td>
</tr>
<tr>
<td>5</td>
<td>Field Corn</td>
<td>4,941</td>
<td>216.36</td>
<td>-42.04</td>
<td>258.39</td>
</tr>
<tr>
<td>6</td>
<td>Cotton</td>
<td>365.21</td>
<td>182.95</td>
<td>-229.92</td>
<td>413.13</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5,339</td>
<td>409</td>
<td>-1,471</td>
<td>1,890</td>
</tr>
</tbody>
</table>

^1 ai refers to active ingredients.
### Table 6: Total impact of biotechnology-derived crops by state in 2003

<table>
<thead>
<tr>
<th>State</th>
<th>Production</th>
<th>Total net value</th>
<th>Pesticide use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume 000 lbs.</td>
<td>Value 000 $</td>
<td>Costs 000 $</td>
</tr>
<tr>
<td>Alabama</td>
<td>9.128</td>
<td>4.564</td>
<td>-11,426</td>
</tr>
<tr>
<td>Arkansas</td>
<td>99.450</td>
<td>32,998</td>
<td>-97,963</td>
</tr>
<tr>
<td>Arizona</td>
<td>17.315</td>
<td>6.129</td>
<td>-6,579</td>
</tr>
<tr>
<td>California</td>
<td>10.290</td>
<td>5.145</td>
<td>-27,850</td>
</tr>
<tr>
<td>Colorado</td>
<td>97.563</td>
<td>4.267</td>
<td>-249</td>
</tr>
<tr>
<td>Connecticut</td>
<td>728</td>
<td>32</td>
<td>-21</td>
</tr>
<tr>
<td>Delaware</td>
<td>10.304</td>
<td>451</td>
<td>-4,241</td>
</tr>
<tr>
<td>Florida</td>
<td>4.990</td>
<td>2.150</td>
<td>-774</td>
</tr>
<tr>
<td>Georgia</td>
<td>53.833</td>
<td>18.835</td>
<td>-20,988</td>
</tr>
<tr>
<td>Hawaii</td>
<td>8.980</td>
<td>2.960</td>
<td>-53</td>
</tr>
<tr>
<td>Idaho</td>
<td>0</td>
<td>0</td>
<td>-142</td>
</tr>
<tr>
<td>Illinois</td>
<td>45.2464</td>
<td>19.798</td>
<td>-157,340</td>
</tr>
<tr>
<td>Indiana</td>
<td>74.734</td>
<td>3.272</td>
<td>-171,531</td>
</tr>
<tr>
<td>Iowa</td>
<td>1,079,275</td>
<td>47.352</td>
<td>-192,447</td>
</tr>
<tr>
<td>Kansas</td>
<td>309.863</td>
<td>13.569</td>
<td>-29,708</td>
</tr>
<tr>
<td>Kentucky</td>
<td>56.784</td>
<td>2.483</td>
<td>-7,940</td>
</tr>
<tr>
<td>Louisiana</td>
<td>72.148</td>
<td>15.182</td>
<td>-25,789</td>
</tr>
<tr>
<td>Maryland</td>
<td>60.872</td>
<td>2.663</td>
<td>-5,696</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>168</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>State</td>
<td>Production</td>
<td>Total net value</td>
<td>Pesticide use</td>
</tr>
<tr>
<td>---------------</td>
<td>------------</td>
<td>-----------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td>Volume 000 lbs</td>
<td>Value 000 $</td>
<td>Costs 000 $</td>
</tr>
<tr>
<td>Michigan</td>
<td>73,419</td>
<td>3,214</td>
<td>27,662</td>
</tr>
<tr>
<td>Minnesota</td>
<td>525,975</td>
<td>23,012</td>
<td>153,721</td>
</tr>
<tr>
<td>Mississippi</td>
<td>86,187</td>
<td>32,886</td>
<td>61,816</td>
</tr>
<tr>
<td>Missouri</td>
<td>311,369</td>
<td>23,017</td>
<td>91,644</td>
</tr>
<tr>
<td>North Carolina</td>
<td>36,354</td>
<td>11,215</td>
<td>40,541</td>
</tr>
<tr>
<td>North Dakota</td>
<td>58,240</td>
<td>2,549</td>
<td>49,104</td>
</tr>
<tr>
<td>Nebraska</td>
<td>743,375</td>
<td>32,525</td>
<td>49,497</td>
</tr>
<tr>
<td>New Jersey</td>
<td>4,200</td>
<td>183</td>
<td>-1,357</td>
</tr>
<tr>
<td>New Mexico</td>
<td>8,708</td>
<td>1,083</td>
<td>-739</td>
</tr>
<tr>
<td>New York</td>
<td>4,368</td>
<td>192</td>
<td>-3,758</td>
</tr>
<tr>
<td>Ohio</td>
<td>23,047</td>
<td>1,010</td>
<td>-68,586</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>44,332</td>
<td>5,712</td>
<td>-7,940</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>37,968</td>
<td>1,658</td>
<td>-4,246</td>
</tr>
<tr>
<td>South Carolina</td>
<td>19,294</td>
<td>1,708</td>
<td>-8,700</td>
</tr>
<tr>
<td>South Dakota</td>
<td>468,639</td>
<td>20,503</td>
<td>55,862</td>
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<tr>
<td>Tennessee</td>
<td>72,148</td>
<td>21,307</td>
<td>36,321</td>
</tr>
<tr>
<td>Texas</td>
<td>281,442</td>
<td>39,246</td>
<td>35,338</td>
</tr>
<tr>
<td>Utah</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Virginia</td>
<td>6,985</td>
<td>1,348</td>
<td>6,307</td>
</tr>
<tr>
<td>Vermont</td>
<td>2,184</td>
<td>96</td>
<td>11</td>
</tr>
<tr>
<td>West Virginia</td>
<td>1,176</td>
<td>51</td>
<td>-151</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>109,796</td>
<td>4,805</td>
<td>-9,739</td>
</tr>
<tr>
<td>Wyoming</td>
<td>0</td>
<td>0</td>
<td>71</td>
</tr>
</tbody>
</table>

<sup>1</sup> ai refers to active ingredients.
Resistance Management - Refuge
Background

- Initial laboratory experiments 1998-2000
- Determined: Bt 11 and MON 810 Cry 1Ab delta-endotoxin transformed corn negatively impacted IMM and AGM survival, fecundity, and dur. of dev.

Sedlacek, J.D., S.R. Komaravalli, A.M. Hanley, B.D. Price and P.M. Davis. 2001. Life history attributes of Indian meal moth (Lepidoptera: Pyralidae) and Angoumois grain moth (Lepidoptera: Gelechiidae) reared on transgenic corn kernels. J. Econ. Entomol. 94: 586-592.
Indian meal moth (*Plodia interpunctella*)

- IMM is widely distributed and infests stored food globally
- Feeds on a variety of grains and grain products
- Larvae spin silk, damaging grain and machinery
Angoumois Grain Moth (*Sitotroga cerealella*)

- Infests all cereal grains
- Damages corn in fields and grain bins
- Larvae develop in corn kernels, which causes damage to product
- Found globally
Habrobracon hebetor
Indian meal moth and Angoumois grain moth Populations in Grain Bins Containing MON 810 Cry 1Ab Transgenic Corn Kernels

John D. Sedlacek, Anthony M. Hanley, and Bryan D. Price
Grain Bins at KSU Farm
IMM Seasonal Populations
2000-2001

Avg. No. Moth

Date

DK679 - DK679BTY

DK679 - DK679BTY

Date
## IMM damage assessment

### 2000 season

<table>
<thead>
<tr>
<th>Corn Hybrid</th>
<th>light</th>
<th>moderate</th>
<th>heavy</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dekalb 679 BtY</td>
<td>0.6125 (B)</td>
<td>0.075 (B)</td>
<td>0.0 (B)</td>
<td>0.0 (B)</td>
</tr>
<tr>
<td>Dekalb 679</td>
<td>3.1875 (A)</td>
<td>1.725 (A)</td>
<td>0.8875 (A)</td>
<td>0.4750 (A)</td>
</tr>
</tbody>
</table>

### 2001 season

<table>
<thead>
<tr>
<th>Corn Hybrid</th>
<th>light</th>
<th>moderate</th>
<th>heavy</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dekalb 679 BtY</td>
<td>1.4778 (B)</td>
<td>0.1667 (B)</td>
<td>0.0 (B)</td>
<td>0.0333 (A)</td>
</tr>
<tr>
<td>Dekalb 679</td>
<td>2.2000 (A)</td>
<td>0.7889 (A)</td>
<td>0.2222 (A)</td>
<td>0.1333 (A)</td>
</tr>
</tbody>
</table>
AGM Seasonal Populations
2000-2001

AGM Seasonal Populations
2000-2001
## AGM damage assessment

<table>
<thead>
<tr>
<th></th>
<th>Corn Hybrid</th>
<th># kernels w/exit holes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2000 season</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dekalb 679 BtY</td>
<td>3.1± 0.8b</td>
<td></td>
</tr>
<tr>
<td>Dekalb 679</td>
<td>15.5± 2.6a</td>
<td></td>
</tr>
<tr>
<td><strong>2001 season</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dekalb 679 BtY</td>
<td>7.9± 0.9b</td>
<td></td>
</tr>
<tr>
<td>Dekalb 679</td>
<td>30.0± 2.3a</td>
<td></td>
</tr>
</tbody>
</table>
**H. hebetor Seasonal Populations**

**2000-2001**

- **Graph 1:**
  - Average number of parasites (y-axis) vs. date (x-axis).
  - Graph shows two lines: one for DK679 and another for DK679BTY.
  - Both lines peak around late July to early August.

- **Graph 2:**
  - Similar to Graph 1, but with a different scale for the y-axis.
  - Both lines show a secondary peak in late September.
Pteromalid Seasonal Populations
2000-2001

Date

Avg. No. Parasitoid

DK679 - - - DK679BTY

DK679 - - - DK679BTY
Summary

• There was a significant reduction of IMM and AGM in bin stored Dekalb 679 BtY corn in 2000
• Magnitude of this reduction was larger for AGM than IMM
• There was a sporadic reduction of IMM and a consistent reduction of AGM populations in 2001 on Dekalb 679 BtY
• There was an 80-94% reduction in moth damage to Dekalb 679 BtY both years
Summary

- There were significantly more *Habrobracon hebetor* in Dekalb 679 than 679 BtY in year 1
- There were significantly more *H. hebetor* in 679 BtY in year 2
- There were significantly more Pteromalids in bins containing Dekalb 679 BtY
- Data do not suggest any direct negative impact on *H. hebetor* or Pteromalids
- Potential international impact
- Potential resistance development
Impact of Cry 1 Ab Corn on *Habrobracon hebetor*, a Parasitoid of Indian Meal Moth

Anthony M. Hanley, Tonja M. Wilkins, and John D. Sedlacek
Summary

• Results indicate that Dekalb 679 BtY (Cry 1Ab Bt corn) has no apparent effect on *H. hebetor*

• Adult emergence of F$_1$ generation (48 hour exposure) was statistically different in control and Bt treatments, however longevity was the same
Summary

• Longevity and adult emergence of F_{3} generation, which came from adults reared on Bt corn for two generations was statistically the same in control and Bt treatments
Other Studies

Impact of Single and Multiple Toxin Bt Transgenic Corn Kernels on Indian Meal Moth and Angoumois Grain Moth

Impact of Cry 1F Bt Transformed Corn Kernels on Indian Meal Moth and Angoumois Grain Moth

Impact of Cry 3Bb Transgenic Corn Kernels on Several Stored Grain Beetle Pests
Mechanisms of Resistance to Bt

1) Reduction in affinity for gut toxin-membrane binding (Van Rie et al. 1990)

2) Reduction of gut proteinase activity (Oppert et al. 1997)
Conclusions

• IMM can develop resistance to transgenic Bt corn hybrids in a short period of time
• There were significant changes in midgut proteinase activity which may have played a role in resistance development
• Other binding detection methods need to be investigated before ruling it out as resistance mechanism
Summary

• More research is needed to fully characterize potential benefits vs. drawbacks of Bt grain in storage
• Most importantly we need to investigate potential for resistance in laboratory and field
• Determine mechanisms of resistance
Acknowledgments

- Monsanto
- Dow AgroScience
- USDA/GMPRC
- Kentucky State University Land Grant Administration
Caterpillars in Your Corn Puddin’? Sweet Corn Research at Kentucky State University

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What’s Been Eating What You’ve Been Eating? Sweet Corn Research at Kentucky State University

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Ecological Impact of Organic, Conventional, and Biotechnology Enhanced Cropping Methods
Using Sweet Corn as a Model

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Introduction

- Sweet corn grown annually on 7,000 acres $15,000,000
- Growers sell at roadside and local customers
- Western Kentucky Growers Co-op for wholesale
- Value added enterprise packaging and freezing
The overall goal of this research is to identify minimally disruptive approaches to insect pest management and to conserve biodiversity in the sweet corn agroecosystem in order to promote sustainable insect pest management practices.
Objectives

1. Conduct comparative analyses of the ecological/environmental impact of organic, conventional, and biotechnology enhanced production practices.

   a. examine control of major insect pest species of sweet corn including an evaluation of Entrust™ as an organic option in the field

   b. examine biodiversity of insects and other arthropods in all three cropping methods

   c. conduct dislodgeable foliar residue and human exposure studies studies of Warrior Insecticide in conventional systems
Methods of Sampling Insects
Objectives con’t.

2. Conduct comparative analyses of economic and social impact using organic, conventional, and biotechnology enhanced production practices. These studies will:
   a. conduct economic analyses of the three cropping systems to include economic inputs, ear quality, yield, and profits.
   b. examine consumer considerations concerning production practices and taste preferences
Objectives con’t.

3. Examine effects of insect protected (Bt) corn on non-target beneficial insects in the laboratory. These studies will include:
   a. impact of Bt corn on predators such as twelve spotted lady beetle and big eyed bugs
   b. impact of Bt corn on a parasitoid of corn earworm (*Microplitis croceipes*)
   c. impact on honey bee queen bee and drone feeding, development, and reproductive biology
Objectives con’t.

4. **Evaluate/develop organic methods of sweet corn insect control.**
   a. evaluate **Benallure™** as a predaceous insect attractant for pest suppression in sweet corn
   b. conduct laboratory assays of **pawpaw extracts** on corn earworm and European corn borer larvae.
   c. evaluate other novel compounds such as **epoxy fatty acids** on corn earworm and European corn borer larvae.
Sweet Corn Pests

- Corn earworm
- European corn borer
- Southwestern corn borer
Ecological Impact of Organic, Conventional, and Biotechnology Enhanced Cropping Methods Using Sweet Corn as a Model
Table 1. Ear pests found on organic, conventional and Bt sweet corn.

<table>
<thead>
<tr>
<th>Crop</th>
<th>n</th>
<th>Corn earworm</th>
<th>European corn borer</th>
<th>Southwestern corn borer</th>
<th>Sap beetle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bt</td>
<td>210</td>
<td>0.00a</td>
<td>0.00a</td>
<td>0.00a</td>
<td>0.04b</td>
</tr>
<tr>
<td>Conventional</td>
<td>225</td>
<td>0.07b</td>
<td>0.10b</td>
<td>0.009a</td>
<td>0.17a</td>
</tr>
<tr>
<td>Organic</td>
<td>224</td>
<td>0.15b</td>
<td>0.06c</td>
<td>0.004a</td>
<td>0.09b</td>
</tr>
</tbody>
</table>

F=7.31 d.f.=2, 657
F=0.88 d.f.=2, 655
F=17.46 d.f.=2, 654
F=5.6 d.f.=2, 655
F=0.88 d.f.=2, 655

Table 2. Damage to and size of organic, conventional and Bt sweet corn ears

<table>
<thead>
<tr>
<th>Crop</th>
<th>n</th>
<th>Tip damage</th>
<th># kernels damaged</th>
<th>Ear length</th>
<th>Ear weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bt</td>
<td>210</td>
<td>0.0005a</td>
<td>0.005a</td>
<td>17.9ab</td>
<td>170.7a</td>
</tr>
<tr>
<td>Conventional</td>
<td>225</td>
<td>0.2889b</td>
<td>2.16b</td>
<td>17.7b</td>
<td>163.1b</td>
</tr>
<tr>
<td>Organic</td>
<td>224</td>
<td>0.36c</td>
<td>4.46c</td>
<td>18.1a</td>
<td>160.1b</td>
</tr>
</tbody>
</table>

F=43.5 d.f.=2, 655
F=46.7 d.f.=2, 653
F=3.21 d.f.=2, 655
F=4.45 d.f.=2, 655

P<0.0001 P=0.0001 P=0.0408 P=0.0119
Acknowledgments

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- Dow AgroScience