Updates on Insect Resistance: Corn Rootworm & Western Bean Cutworm

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Western Corn Rootworm

- Crop rotation
- Bt traits and seed treatments
- At-plant insecticides targeting larvae
- Aerial insecticide applications for adults
- Biological controls

WCR Resistance History

1960 2020
Aldrin, Dieldrin
Chlordane, Endrin, HCH-gamma
Carbofuran, Carbaryl, Parathion-methyl
Bt proteins: Cry3Bb1 & mCry3Aa & eCry3.1Ab
Pyrethroids
Bt proteins: Cry34/35Ab1

Arthropod Pesticide Resistance Database

Areas with Confirmed Bt Resistance

Cry3Bb1
mCry3Aa
eCry3.1Ab
Cry34/35Ab1
Corn Rootworm-Targeting Bt Proteins (examples)

- **Cry3Bb1**
- **Cry34/35Ab1**
- **mCry3Aa**
- **Cry3Bb1 x Cry34/35Ab1**
- **mCry3Aa x Cry34/35Ab1**
- **mCry3Aa x eCry3.1Ab**

Common Characteristics of Problem Areas

- Continuous corn
- Intensive livestock production areas
- History of repeated use of the same, single protein Bt traits
- Moderate-severe larval rootworm injury in problem areas
- High adult WCR rootworm densities
- Increasing use of at-plant soil insecticides with trait, chemigation or aerial application to rescue Bt fields or to lower adult density

Pyrethroid Resistance Studies

- Reports of problems controlling adult beetles with pyrethroid foliar applications (first half of the 2010’s) in Nebraska and Kansas
- Test how susceptible western corn rootworm are to bifenthrin (Brigade, Capture, etc. AI)
- Establish LC99 (concentration that kills 99%) for susceptible rootworm beetles
- Expose field-collected beetles to the LC99 to see how many survive
Summary of First Study

• Bifenthrin (common pyrethroid) resistance in western Nebraska and Kansas

• This first study showed that resistance to pyrethroids was emerging as a problem as early as 2014

❖ How does the LC$_{99}$ used in this study relate to insecticide concentrations applied in the field? What is the level of practical resistance?

Exploring What is Really Happening in the Field

1. Determine how much insecticide AI and in what pattern reaches the target pest with an aerial application.

2. Reproduce these application characteristics in the laboratory using wind tunnel and spray chamber.

3. Test how application methods affect susceptible and resistant western corn rootworm beetles.
Measuring Spray Deposition in the Field

- Water sensitive papers placed at Top, Middle, and Bottom canopy

- Aerial applications made with AirTractor at 2 and 5 GPA

Souza et al. 2019, Scientific Reports

Deposition at the Middle Canopy

- For 2 GPA application = 1.17 GPA
- For 5 GPA application = 1.76 GPA
- 50th percentile droplet size = 299-346 μm (1/100 of an inch)

Souza et al. 2019, Scientific Reports

Reproducing Aerial Application in the Spray Chamber

Assessing Mortality to Rootworm Beetles

- Tested against two resistant and two susceptible beetle populations

Souza et al. 2019, Scientific Reports
Results

• Carrier volume (2 vs. 5 GPA) did not affect results
• Insecticide rate was a significant factor:

![Graph showing WCR populations for different carrier volumes and insecticide rates.](Souza et al. 2019, Scientific Reports)

Pyrethroids In-Furrow for Larvae

• So far, experiments looked only at the adults (beetles)
  ➢ But is pyrethroid resistance passed on to the larvae?
  ➢ Unfortunately, yes– pyrethroid in-furrow at-plant products performed worse in areas with resistant adult rootworms

![Bar chart showing insecticide efficacy.](Souza et al. 2020, Pest Management Science)

Corn Rootworm Take-Home Points

• Resistance to Cry3 Bt proteins is present in western NE and KS
• Pyrethroid insecticides no longer highly effective against WCR adults and larvae in southwest NE & KS
  ➢ Rotate MOA!
  ➢ Check AI on labels, especially for adults/larvae
• Rootworm management is not a “what is the best single trait or insecticide” situation
  ➢ Use of multiple tactics and rotation: crop rotation, planting effective Bt traits, judicious use of insecticides for adult or larval control, biological control
• The broad goal should be to limit both rootworm economic injury & limit the evolution of resistance

Western Bean Cutworm

1. Bt trait selection
2. Scouting
3. Biocontrol
4. Insecticides
5. Evaluate treatments
Western Bean Cutworm

1. Bt trait selection

- July-August
- August-September
- October-June

2. Scouting

- Late June-July
- August-September
- October-June

Bt Trait Updates

- Not all caterpillar traits will affect WBC
- Cry1F: Herculex, SmartStax
  - 88% of NE crop consultants reported that Cry1F Bt corn is providing less control (2014-2016)
  - Confirmed resistance to Cry1F in Nebraska (2017-2018)
  - WBC removed from label of all Cry1F products
- Vip3A: Viptera, Leutra, Trecepta
  - Traits provide very good control, but resistance is always on the horizon

Handy Bt Trait Table

Archibald et al. 2017, Journal of IPM
Coates et al. 2020, Journal of Economic Entomology

When to Start Scouting

- Be informed about moth flight predictions from the degree-day model:
  - CropWatch article
  - AgriTools App
- Monitor moth flights through trapping:
  - UNL black light trap data online
  - Green bucket and pheromone
Western Bean Cutworm Scouting

- Select 20 plants in 5 different parts of each field (100 plants)
  - Or reduce # of plants using WBC Speed Scout App
- Examine the surface of corn leaves in the upper third of the plant for egg masses and the tassel, leaf axils, and ear tips for larvae
- Treatment is recommended if 5-8% of plants are infested with eggs or larvae
- If corn is at milk stage (R3) before eggs are laid, no treatment is needed

How Often Should You Scout?

- A lot of the older recommendations say that eggs hatch in approximately 5-7 days
- Egg hatching time highly dependent on temperature:
  - 4.6 days at average 79.9 °F
  - 5.9 days at average 75.6 °F
- Scouting once per week may be missing a lot of egg masses; every 4-5 days can be more accurate
- Crop growth stage is critical
  - Moths prefer late whorl to early tasseling plants
  - Larvae that hatch and have access to fresh tassel survive the best

WBC Egg Identification

- ECB: Underside of leaves, often in the middle third of plant
- WBC: Top side of leaves in the upper third of plant (prefers late whorl stage corn prior to tasseling)
- FAW: On immature leaves (earlier V stages)
- CEW: On fresh silks
- Stink bug

Western Bean Cutworm

- July-August
- August-September
- October-June

Biocontrol

- 3
The Good Guys At Work!

Spying on Egg Masses in the Field

- Larvae may stay near the egg mass for 12 h
- Hatching not synchronized, may take 10 h
- Neonates not disrupted by a rainstorm
- Minute pirate bugs feed on egg masses

How Can You Support the Good Guys?

- Plant non-crop, perennial, diverse habitat around crop fields
- Use thresholds to avoid unnecessary insecticide spraying; choose products that are less toxic to beneficials

Western Bean Cutworm

- July-August
- August-September
- October-June

Insecticides: 4
Insecticides: Timing

- Threshold of >5-8% of plants infested has been met through scouting
- Plants are at ~95% tassel
- Egg masses are purple to hatching
- Peak of moth flight has been reached
- Favorable environmental conditions

Perfect alignment of the stars?? Does the “perfect” timing actually exist?

North Platte Moth Flight Over Time:

![North Platte Moth Flight Over Time](image)

Insecticides: Product Choice

- Between 2014-2016, 88% of NE crop consultants treated at least once for WBC
- Pyrethroids comprise 80% of insecticides used
  - Bifenthrin and zeta-cypermethrin most common AI’s: Brigade, Hero, Mustang Maxx, Capture
- 51% of crop consultants reported decreased pyrethroid efficacy

Archibald et al. 2017, Journal of IPM

WBC Pyrethroid Study Results

- Nebraska WBC less susceptible to bifenthrin than Canadian population
- No differences between NE locations
- Resistance ratios reflect partial resistance or resistance in progress
- When applications are “ideal” they are effective
- Resistance not the whole story:
  - Application timing and technique
  - Temperature or other environmental conditions
  - Pest and crop phenology
30 Years of Light Trap Data!

WBC Flights: Total # Increasing

WBC Flights: Length Increasing

WBC Flights: 2nd Half Longer
Why Does the 2nd Half of Flight Have Greater Impact?

<table>
<thead>
<tr>
<th>Corn tissue</th>
<th>Larval survival (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf only</td>
<td>3.6 (± 3.0)</td>
</tr>
<tr>
<td>Leaf + Tassel</td>
<td>74 (± 17)</td>
</tr>
<tr>
<td>Pollen</td>
<td>31 (± 8)</td>
</tr>
<tr>
<td>Silk</td>
<td>45 (± 10)</td>
</tr>
<tr>
<td>Silk + Pollen</td>
<td>56 (± 10)</td>
</tr>
</tbody>
</table>

Paula-Moraes et al. 2012, Environmental Entomology

Insecticide Trials: Grant 2018

- Medium pressure (17% egg masses)
- Mixed population of WBC (72%) and CEW (28%) upon assessment of ear damage

Can insecticides kill WBC eggs?

- No evidence for ovicidal effects at the low and high label rates of:
  - Mustang Maxx
  - Brigade
  - Hero
  - Prevathon
  - Steward
- But, after hatching larvae died quickly in all treatments but Steward (needs ingestion for higher efficacy)
- Lab conditions were ideal for up to 5 days of insecticide residual
- Lady beetles that ate eggs sprayed with Mustang Maxx did not die, but were severely disoriented compared to eating eggs sprayed by Prevathon
Western Bean Cutworm Take-Home Points

• Western bean cutworm has evolved resistance to the Cry1F Bt protein (a trait found in Herculex and SmartStax), leaving Vip3A as the sole highly effective protein
• There are many beneficial insects that help out by eating WBC eggs and larvae
• Insecticide applications should be made only when the economic threshold has been met and timing is carefully considered
• Insecticide product choice is important to minimize resistance and risk to beneficial insects