Resistance Management for Western Corn Rootworm

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Corn Rootworms: Two pest species

- Northern corn rootworm

- Western corn rootworm

Corn Rootworm Larvae: Small (max size-1/2")

- Dark head and anal plate
- Looks like they have two heads.

Head capsule

Anal plate (tail)

Life Cycle: One Generation Per Year (usually)

- Eggs laid in corn fields, overwinter
- Hatch in early June.
- Damage corn roots when it is rapidly growing.
- Peak damage in late June – early July

Corn rootworm larvae damage

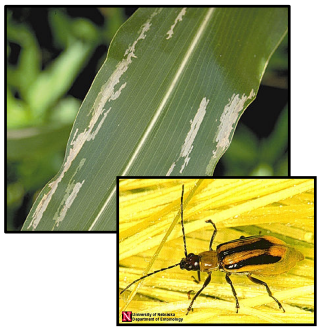
Roughly 50% of lodged fields are caused by other factors

Rootworm damage to 1st year corn

- Diagnose in July/August
  - Lodging ≠ rootworms
  - Dig roots, wash and rate
  - Presence of adults doesn't mean that they emerged in that field
  - WCR may lay eggs in soybeans with volunteer corn, grassy weeds
  - NCR any pollen source, lay eggs in corn
  - Rootworm scouting records from previous years most helpful

Adults Emerge Early in July

- Feed on corn leaves, pollen, silks
- Begin egg-laying about last week in July
- Start scouting mid-July

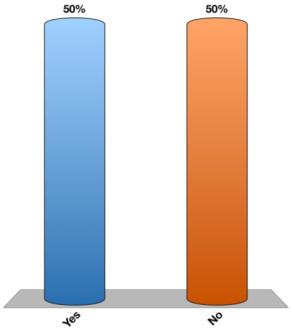


Adult Sampling: Decisions Used To -

- Control adults
  - Prevent injury to corn silks
  - Prevent egg laying in continuous corn fields.
- Determine actions following year
  - Rotate to non-host crop
  - Use planting time insecticide
  - Chemigate
  - Transgenics

Do you use insecticides to control adult rootworms?

1. Yes
2. No



Response Counter

Sampling: Beetle Counts = Number of beetles/plant.

- Cover silks with hand
- Work down plant from tassel to soil
- Examine leaf axils carefully
- Count beetles in silks

Sampling: Beetle Counts = Number of beetles/plant.

- Economic threshold varies
- 0.5 - 1 beetle per plant
- Ear zone count

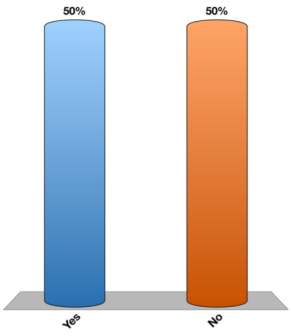
Sticky Traps are an Alternative to Beetle Counts

Economic threshold:

Six beetles per trap per day = 1 beetle per plant at plant population of 24,000 plants per acre

Do you use at plant soil insecticides to manage corn rootworms?

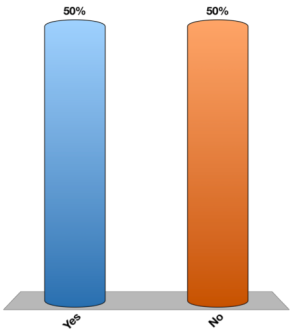
1. Yes
2. No



Response Counter

Do you use Bt corn hybrids to manage corn rootworms?

1. Yes
2. No



Response Counter

Corn Rootworm-Protected Bt Transgenics

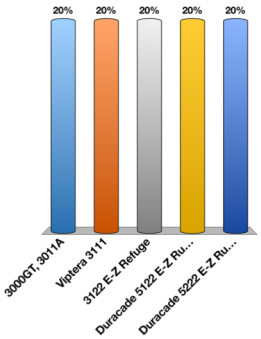
Event	Bt Proteins
MON 88017	*Cry*3Bb1
DAS 59122-7	*Cry*34/35Ab1
MIR 604	m*Cry*3Aa
MIR 162	*VIP3a*
	eCry3.1Ab

Bt Corn: Rootworm Pyramids

Pyramid	Companies
• Cry3Bb1 x Cry34/35	Monsanto, Dow
SmartStax® Genuity® SmartStax® RIB Complete®	
• mCry3A x Cry34/35	Syngenta, Dupont-Pioneer
Agrisure 3122 E-Z Refuge™ Optimum® AcreMax® XTreme	

Which Agrisure trait family hybrids do you plant on your farm(s)?

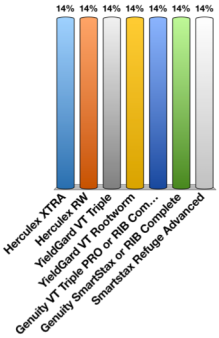
1. 3000GT, 3011A
2. Viptera 3111
3. 3122 E-Z Refuge
4. Duracade 5122 E-Z Rufuge
5. Duracade 5222 E-Z Rufuge



Response Counter

Which trait family hybrids do you plant on your farm(s)?

1. Herculex XTRA
2. Herculex RW
3. YieldGard VT Triple
4. YieldGard VT Rootworm
5. Genuity VT Triple PRO or RIB Complete
6. Genuity SmartStax or RIB Complete
7. Smartstax Refuge Advanced

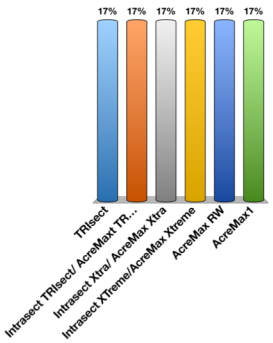


Response Counter

Which Optimum trait family hybrids do you plant on your farm(s)?

1. TRIsect
2. Intrasect TRIsect/ AcreMaxt TRIsect
3. Intrasect Xtra/ AcreMax Xtra
4. Intrasect XTreme/AcreMax Xtreme
5. AcreMax RW
6. AcreMax1

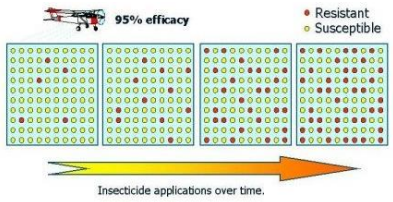
Response Counter



Pesticide Resistance

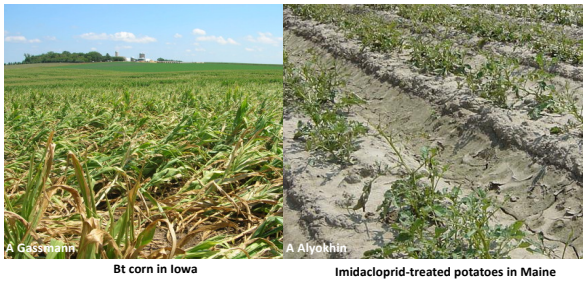
Decreased response of a population to a pesticide or control agent as a result of previous exposure to the pesticide

- Within a population, some % have genes that confer an increased ability to survive the insecticide
- Application of insecticide creates selection pressure, survival of individuals that possess genes conferring resistance
- % of population with resistance increases with selection over time



Impact of Resistance

- Over 540 species of insects and mites have developed pesticide resistance worldwide
- $1.4 billion lost per year in the US



Bt corn in Iowa

Imidacloprid-treated potatoes in Maine

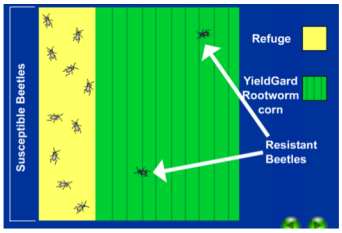
Resistance Management: Basic Principles

Effort to delay or prevent adaptation to pesticides by preserving the genes that confer susceptibility

1. Choose pest-tolerant crop varieties
2. Include non-chemical control methods in an IPM plan
3. Preserve beneficial insects
4. Use products at full, recommended doses
5. Maintain application equipment
6. Target pests at younger/smaller stages
7. Follow economic thresholds and spray intervals
8. Alternate mode of action
9. Do not reapply the same product in event of a failure

Resistance Management for Bt Crops: Refuges & Pyramiding

Maintain susceptible insects in the population that can mate with any resistant insects that emerge

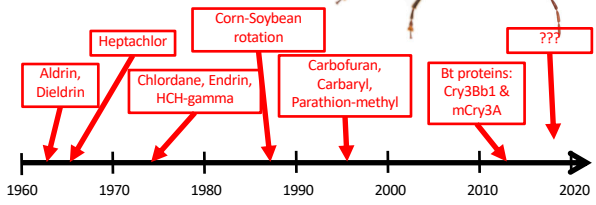


- Unlike ECB, rootworm beetles will not move far prior to mating

Images: Monsanto

Resistance Case Study in Nebraska: Western corn rootworm

WCR Resistance



Arthropod Pesticide Resistance Database

Rotation Resistance

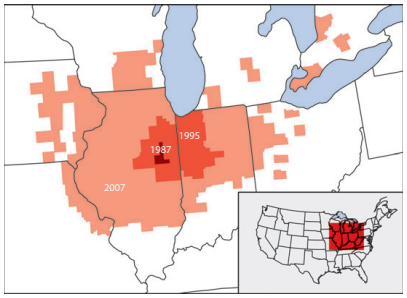


Figure 4

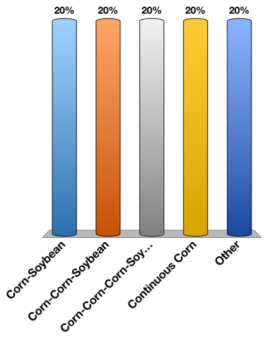
Range expansion of the variant western corn rootworm, *Diabrotica virgifera virgifera* LeConte, in the United States Corn Belt through 2007.

From Gray et al. 2009. *Adaptation & Invasiveness of Western Corn Rootworm: Intensifying Research on a Worsening Pest*. Annu. Rev. Entomol. 2009. 54:303-321.

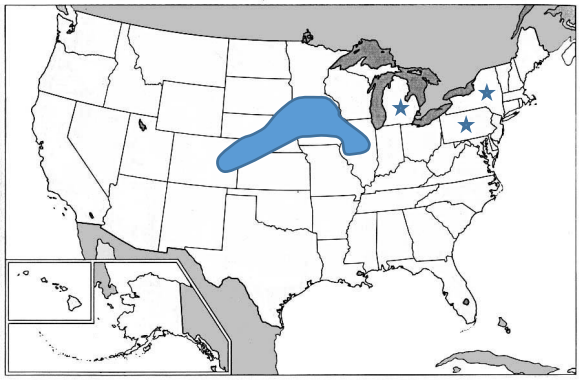
Which of these rotations do you use on your farm(s)?

1. Corn-Soybean
2. Corn-Corn-Soybean
3. Corn-Corn-Corn-Soybean
4. Continuous Corn
5. Other

Response Counter



Cry3Bb1 Unexpected Injury Zone



Nebraska Situation

- Greater than expected corn rootworm injury (NIS >1) in Cry3Bb1 fields during 2011-2014.
- Initially Northeast & Southwest NE.
- More recently, Central NE also.

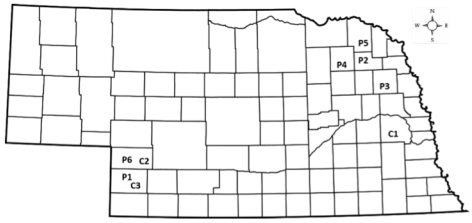
Common Characteristics of Problem Areas

- Continuous corn
- Intensive livestock production areas
- History of repeated use of Cry3Bb1 hybrids
- 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 Cry3Bb1 fields or to lower adult density (2010-2013)

2012-2014 Research

1. Conduct whole-plant bioassays to evaluate WCR survival of Cry3Bb1 problem area populations vs. control populations
2. Conduct on-farm rootworm trials in Cry3Bb1 problem fields to evaluate rootworm active trait/conventional insecticide combinations

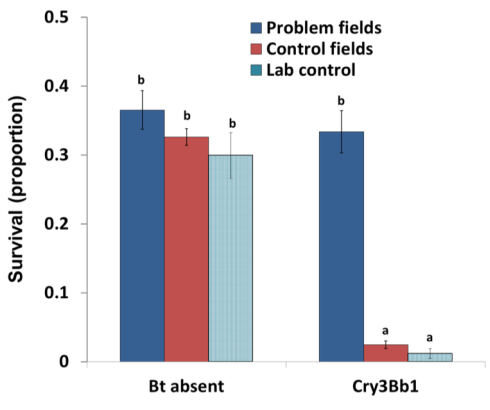
WCR Populations Included In Bioassays

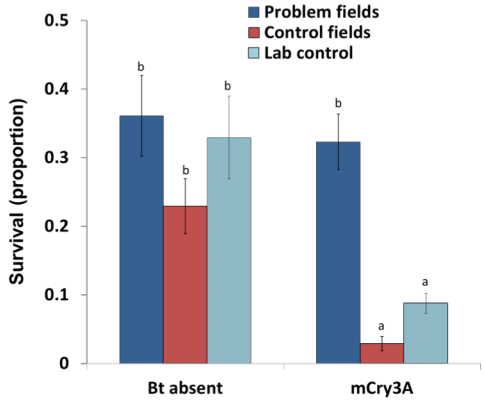


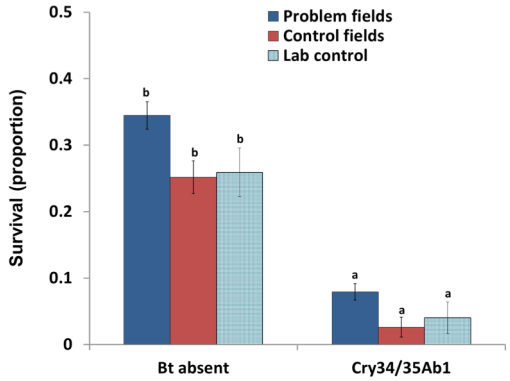
Also included 6 WCR lab colonies that had never been exposed to Cry proteins

Rearing

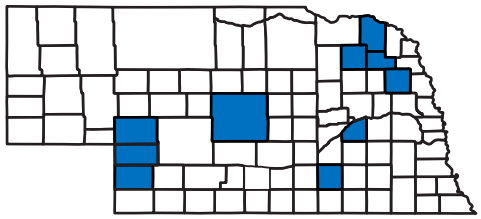
Bioassays: Methods







Confirmed WCR Resistance to Cry3Bb1



Some level of WCR resistance to Cry3Bb1 and cross-resistance to mCry3A detected from one or more fields per shaded county in UNL lab bioassays.

Wangila and Meinke 2013-2014.

Field Study Treatments

Rootworm Trait(s)

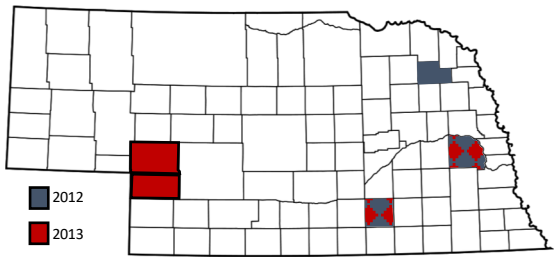
- Cry3Bb1
- Cry3Bb1, Cry34/35Ab1
- Non-Bt near isoline
- mCry3A
- mCry3A, Cry34/35Ab1
- Non-Bt near isoline
- Cry34/35Ab1
- Non-Bt near isoline

Supplemental Insecticide

Each trait was included in the trial with and without Aztec 2.1G placed infurrow; rate: 0.14 oz ai / 1000 ft

All seed was treated with clothianidin seed treatment; rate: 0.25 mg ai / seed

Field Study Sites



Cry3Bb1 & mCry3A Root Ratings: Conclusions

- Relative level of root protection was significantly lower at Cry3Bb1 problem sites than the control field
- Relative susceptibility per site relationship in problem fields was consistent across WCR densities
  - suggests trait/control relationship may be independent of density

Cry34/35Ab1 Root Ratings: Conclusions

- Relative root protection was consistent across all sites and WCR densities
- Greatest root protection achieved with single trait Cry34/35 or pyramid of Cry3Bb1 or mCry3A with Cry34/35

Aztec 2.1G Root Ratings: Conclusions

- Root protection benefit occurred when AZ was applied to non-Bt or single traits exhibiting greater than expected relative injury
- Little root protection benefit obtained by adding AZ to Cry34/35 or pyramids containing Cry34/35

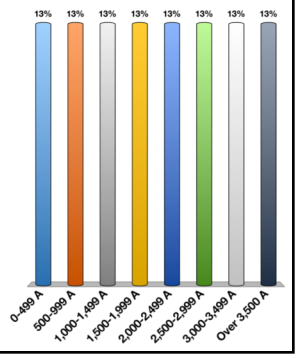
So, how do we control rootworm?

- This is not a "what is the best single trait or insecticide" situation.
- A rootworm management solution is required that incorporates IPM and IRM principles.
  - Refuge compliance, field scouting, long-term planning, using knowledge of the region and field history to make decisions
- Use of multiple tactics and rotation of tactics is key to slowing resistance.
  - 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.

How many acres do you or the operation you are a part of farm?

1. 0-499 A
2. 500-999 A
3. 1,000-1,499 A
4. 1,500-1,999 A
5. 2,000-2,499 A
6. 2,500-2,999 A
7. 3,000-3,499 A
8. Over 3,500 A

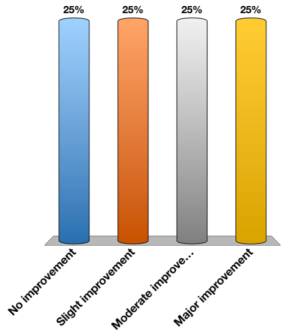
Response Counter



How would you rate your increase in knowledge about corn rootworm biology from today's training?

1. No improvement
2. Slight improvement
3. Moderate improvement
4. Major improvement

Response Counter



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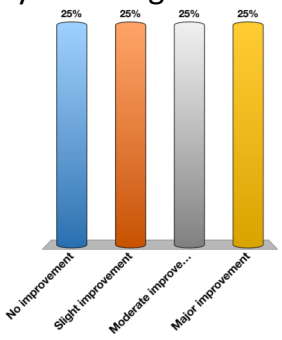
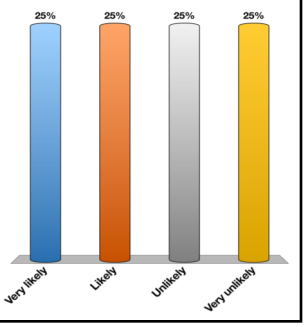


As a result of today's training do you plan to adopt/implement practices to prevent the development of rootworm resistance on your farm(s)?

1. Very likely
2. Likely
3. Unlikely
4. Very unlikely

Response Counter



Would you plant a non-corn crop to preserve the effectiveness of Bt resistance genes, even if the rotation cost you some money in the short term, but made you money in the long term?

1. Yes
2. No

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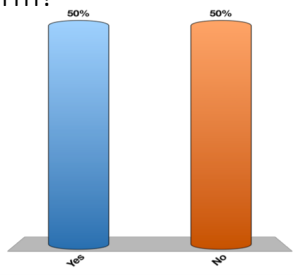
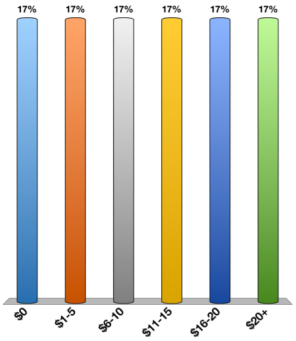


How would you value the information received today on a per acre basis?

1. $0
2. $1-5
3. $6-10
4. $11-15
5. $16-20
6. $20+

Response Counter



Support Tools & Further Information

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