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Proceedings of the

2015 Crop Pest Management Shortcourse &

Minnesota Crop Production Retailers Association Trade Show

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Soil Insecticides, Bt Traits & Corn Rootworm: Are We Coming Full Circle?

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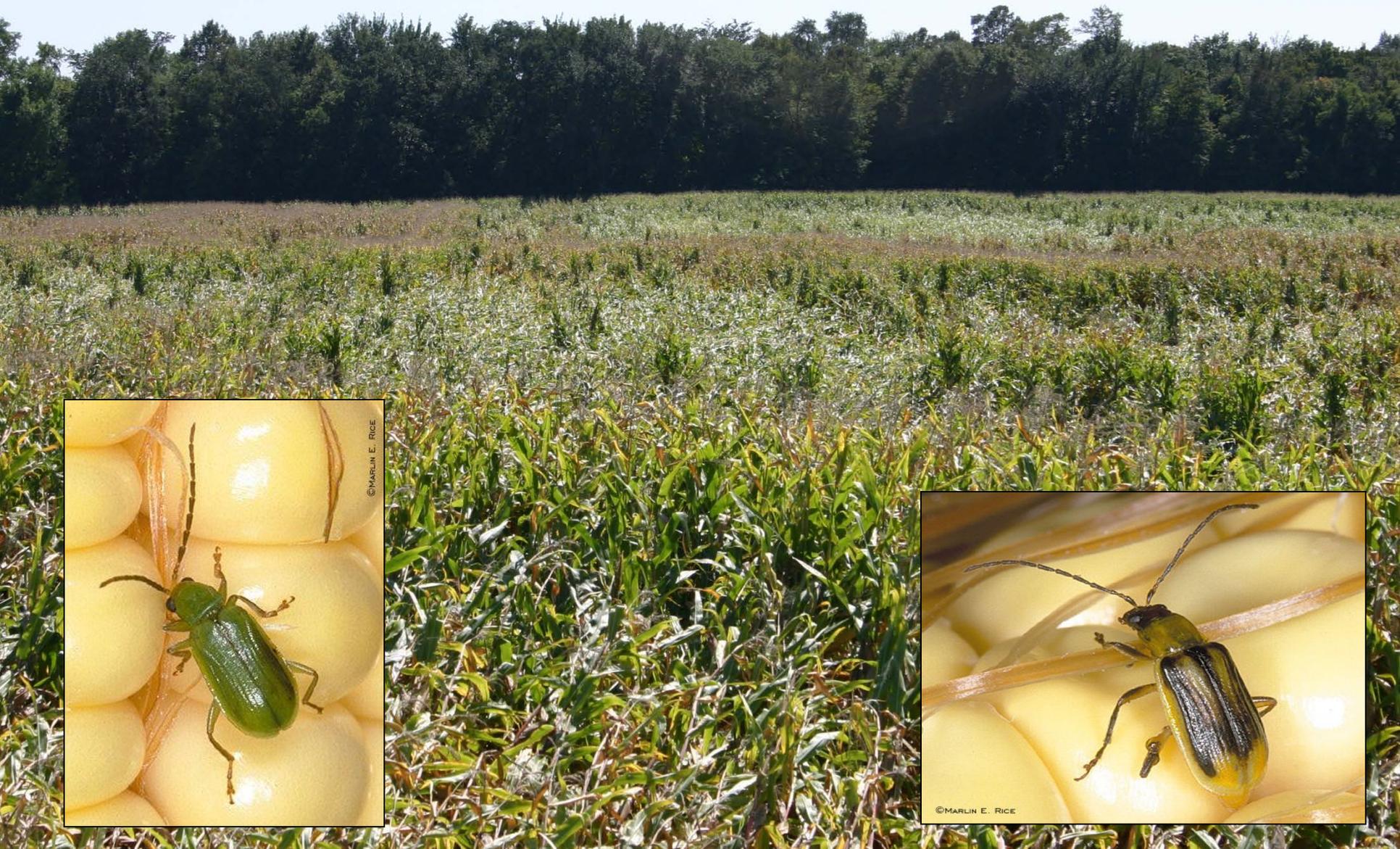
What's the Current Situation with Corn Rootworms and Bt-RW Resistance?

- ◆ Roller coaster ride in resistance-related Bt-RW performance problems (peaking in 2012-2013)
- ◆ Only western corn rootworm issue so far
- ◆ Majority of fields corn after corn with multiple-year history of trait; no problems in rotated fields so far
- ◆ Cry3Bb1 (VT3 / VT3P) dominated but is phasing out
- ◆ Scattered performance issues all traits; even pyramids
- ◆ Resistance detected to all proteins, primarily Cry3Bb1
- ◆ Cross-resistance documented with mCry3A (Agrisure) and eCry3.1A (present in Duracade)
- ◆ Reports have decreased markedly, reflecting weather, greater use of pyramids, and soil insecticides
- ◆ Resistance genes have not disappeared!

Status of Bt-RW Resistance

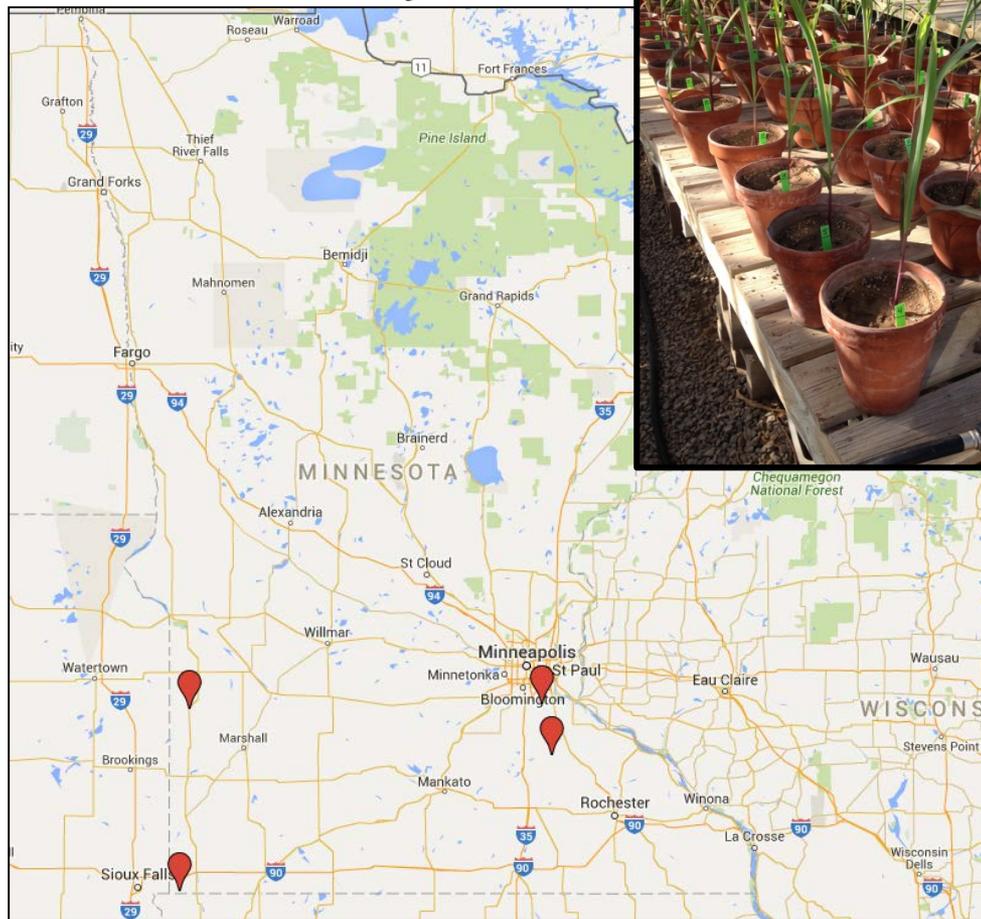
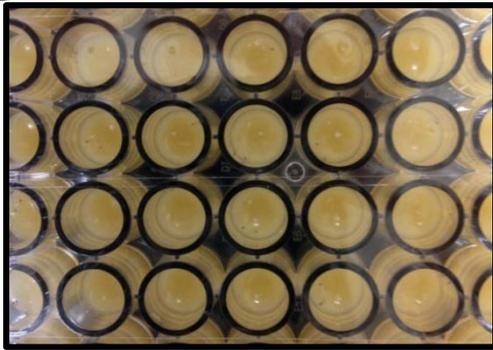
- ℓ **Bt-RW resistance confirmed for every trait but risk is not equal (Cry3Bb1 >> mCry3A > Cry34/35Ab1, eCry3.1Ab ?)**
- ℓ **Resistance is not complete; cross-resistance detected with all Cry3 proteins**
- ℓ **Soil insecticide overlay 25% rotated corn, >50% continuous corn;**
- ℓ **Insecticides cannot make up for a failing trait**
- ℓ **Seed industry shifting to pyramids of Bt-RW traits**
- ℓ **New traits probably not available until later this decade**

Corn Rootworms in Minnesota – Interplay of Resistance and Climate



Evaluating MN Populations for Bt-RW Resistance

- *Two Plant Assays (seedling and greenhouse) and Diet Assay*



Seedling - Relative Survival (Bt/Isoline) When Compared to Rosemount

Population	Cry3Bb1	eCry3.1Ab	Cry34/35Ab1	mCry3A
Rosemount	Susceptible	Susceptible	N.S.	Susceptible
Canby	Resistant	Resistant	N.S.	Intermediate
Hills	Resistant	Resistant	N.S.	Resistant
Brookings, SD	Susceptible	Susceptible	N.S.	Susceptible

Greenhouse - Relative Survival (Bt/Isoline) When Compared to Rosemount

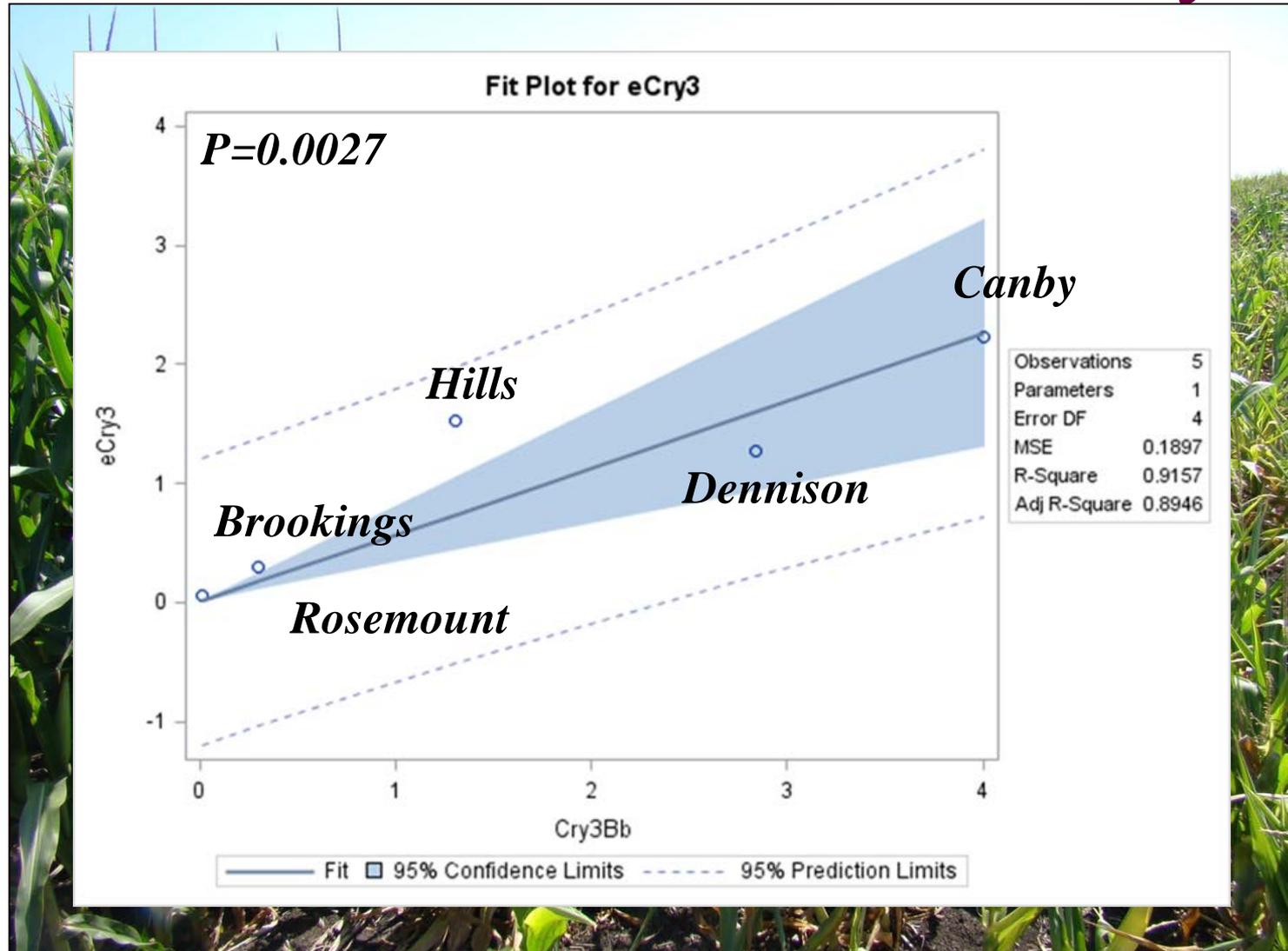
Population	Cry3Bb1	eCry3.1Ab	Cry34/35Ab1	mCry3A
Rosemount	Susceptible	N.S.	N.S.	Susceptible
Canby	Intermediate	N.S.	N.S.	Susceptible
Hills	Intermediate	N.S.	N.S.	Susceptible
Brookings, SD	Susceptible	N.S.	N.S.	Susceptible
Dennison	Resistant	N.S.	N.S.	Susceptible

Diet Toxicity Assay - LC₅₀ µg/cm² (95% C.I.)

Population	Cry3Bb1	eCry3.1Ab	Cry34/35Ab 1	mCry3A
Rosemount	16.2 (5.3-27.8)	0.8 (0.5-1.1)	0.9 (0.5-1.5)	0.7 (0.4-1.2)
Canby	555.2 (278.8-5109.6)	9.7 (5.6-21.5)	4.1 (1.7-8.2)	11.9 (5.2-56.3)
Hills	65.9 (22.4-133.7)	5.0 (2.9-9.7)	3.8 (2.4-5.6)	8.2 (4.3-22.3)
Dennison	199.7 (82.0-1419843)	3.0 (1.9-5.5)	1.5 (1.0-2.1)	1.8 (1.2-2.6)
Brookings	0.4	0.4 (0.2-0.6)	1.8 (1.1-2.6)	0.9 (0.6-1.3)

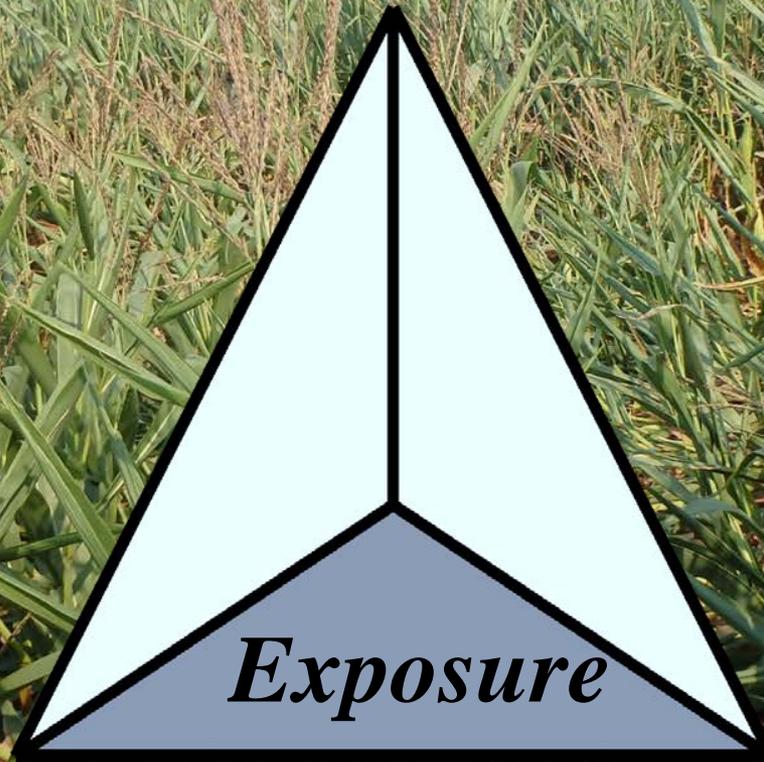


Cross-Resistance in Diet Bioassays



Rootworm Populations Dynamics: What's Needed for Resistance to Appear (or Re-appear)?

Time = Density



Resistance Genes

Corn Trait

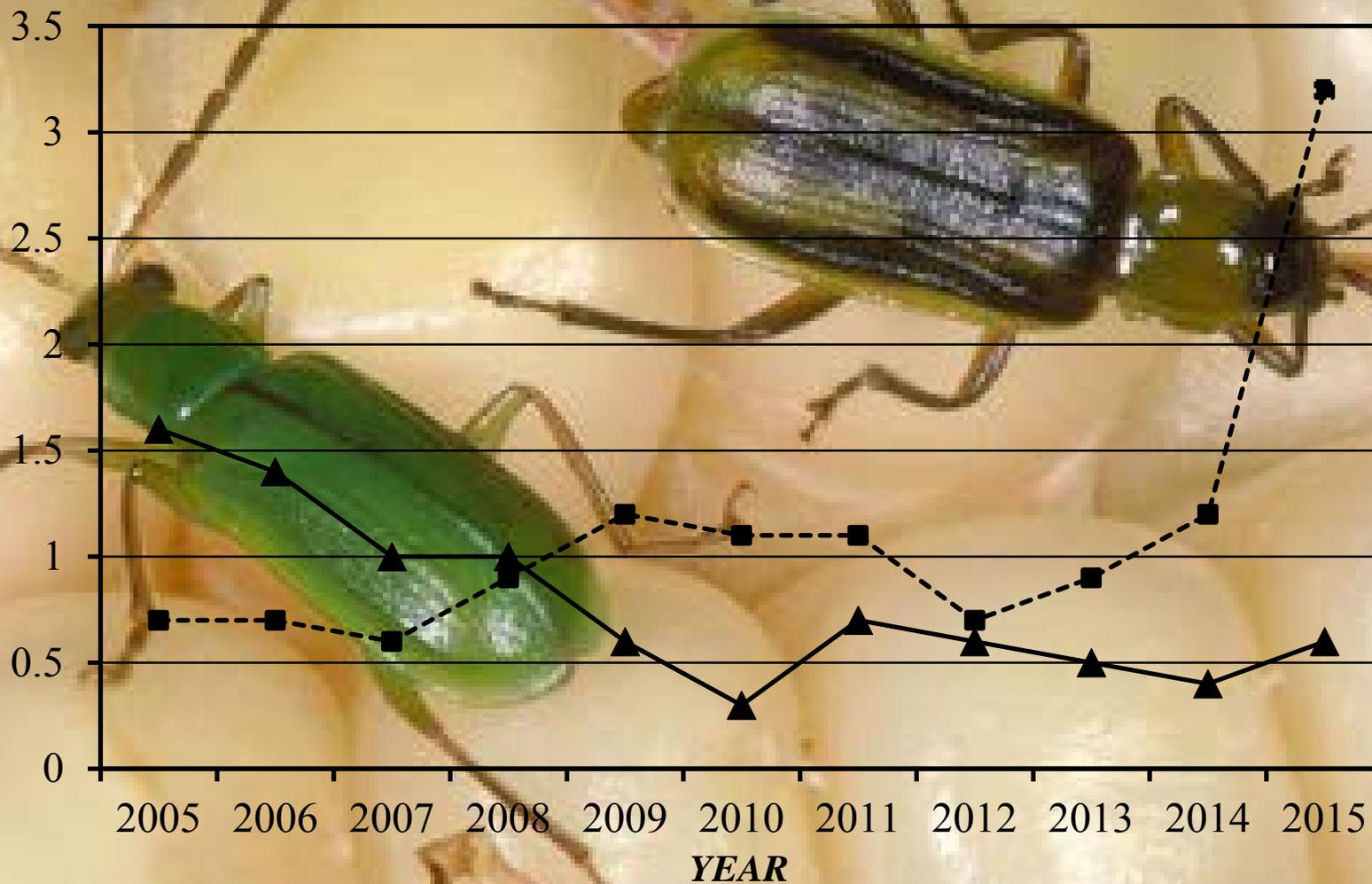


**Extended diapause problem fields
re-emerged in 2015**

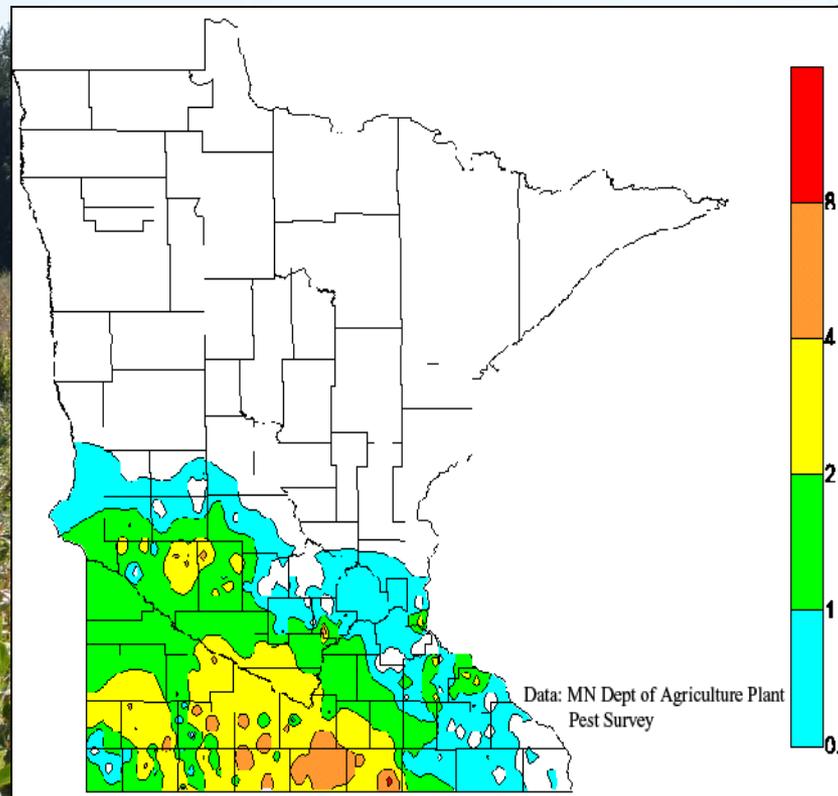
WI Corn Rootworm Beetle Counts

(WI Department of Agriculture)

▲ Beetle/Plant -■- N:W Ratio

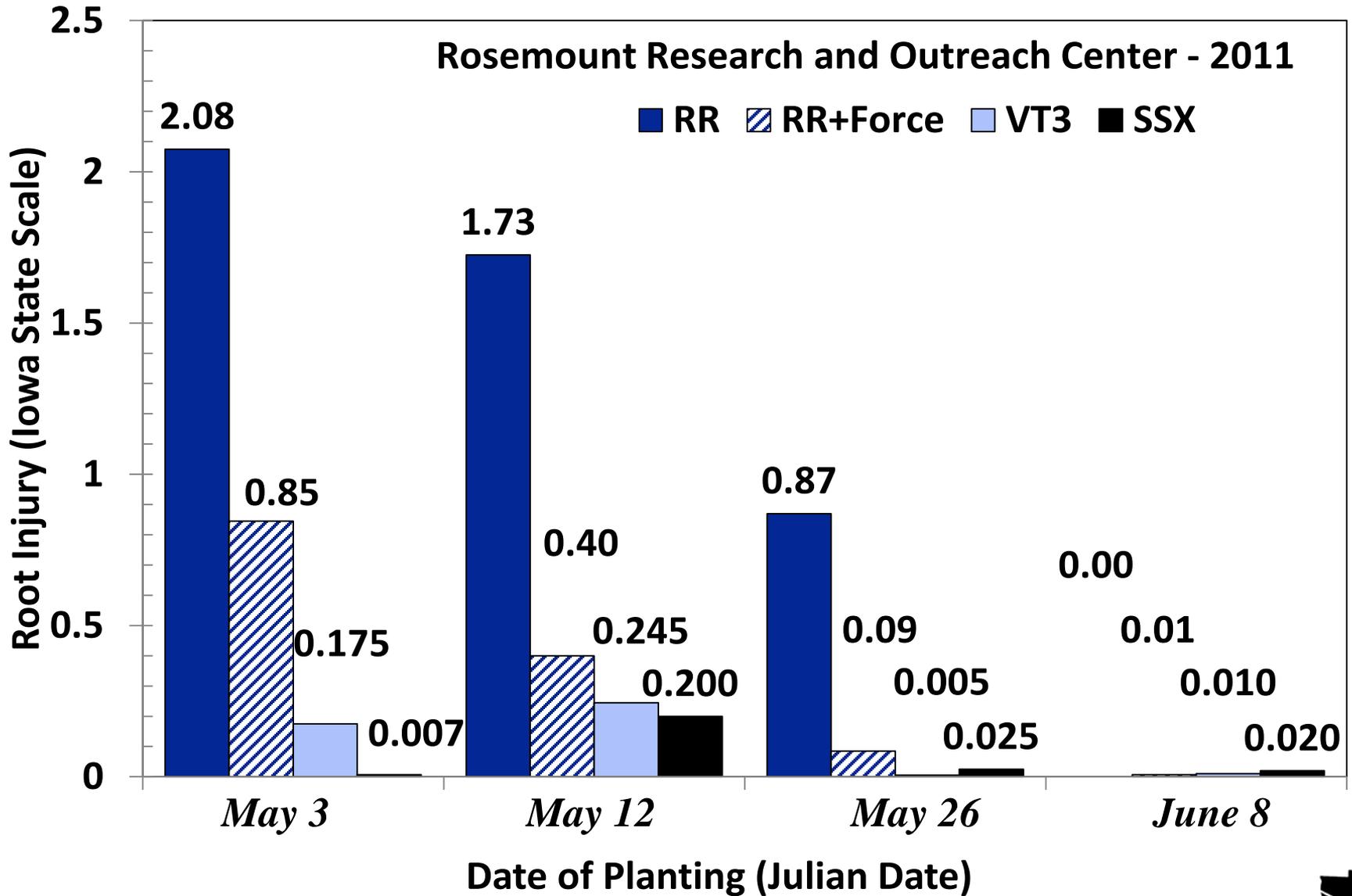


What's the Prognosis for Extended Diapause Problems?

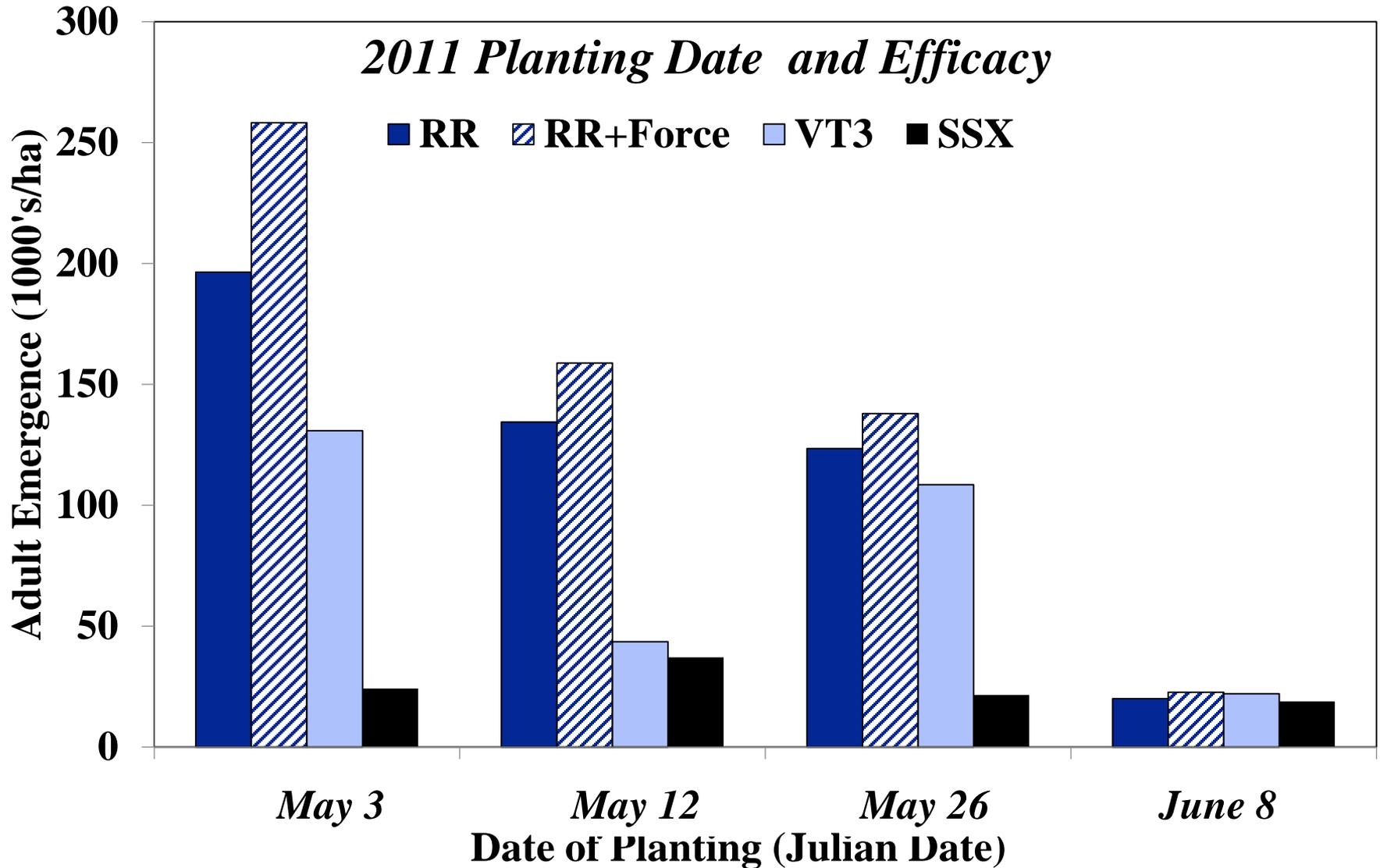


Remember: We'll be dealing with eggs laid by 2014 corn rootworm beetles in rotated corn and by 2014-5 beetles in continuous corn!

Planting Date Effects on CRW Management



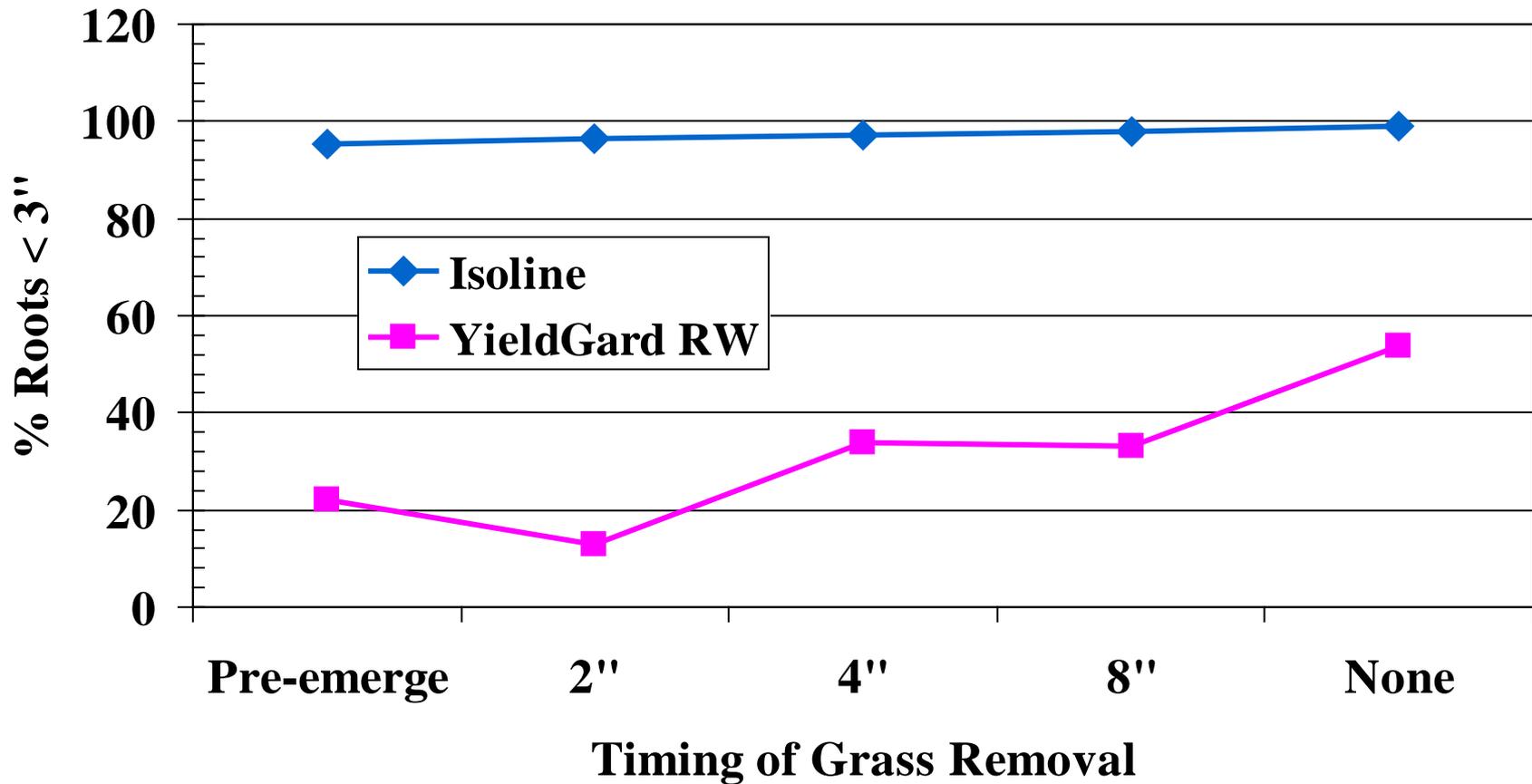
Planting Date Effects on CRW Management



*A New Complication?
Corn Rootworm Egglaying
Near RoundUp Ready[®] Volunteer Corn
and Late-Season Resistance Weeds*



Your Challenge: Control Weedy Grass Hosts Early in Bt - RW Corn

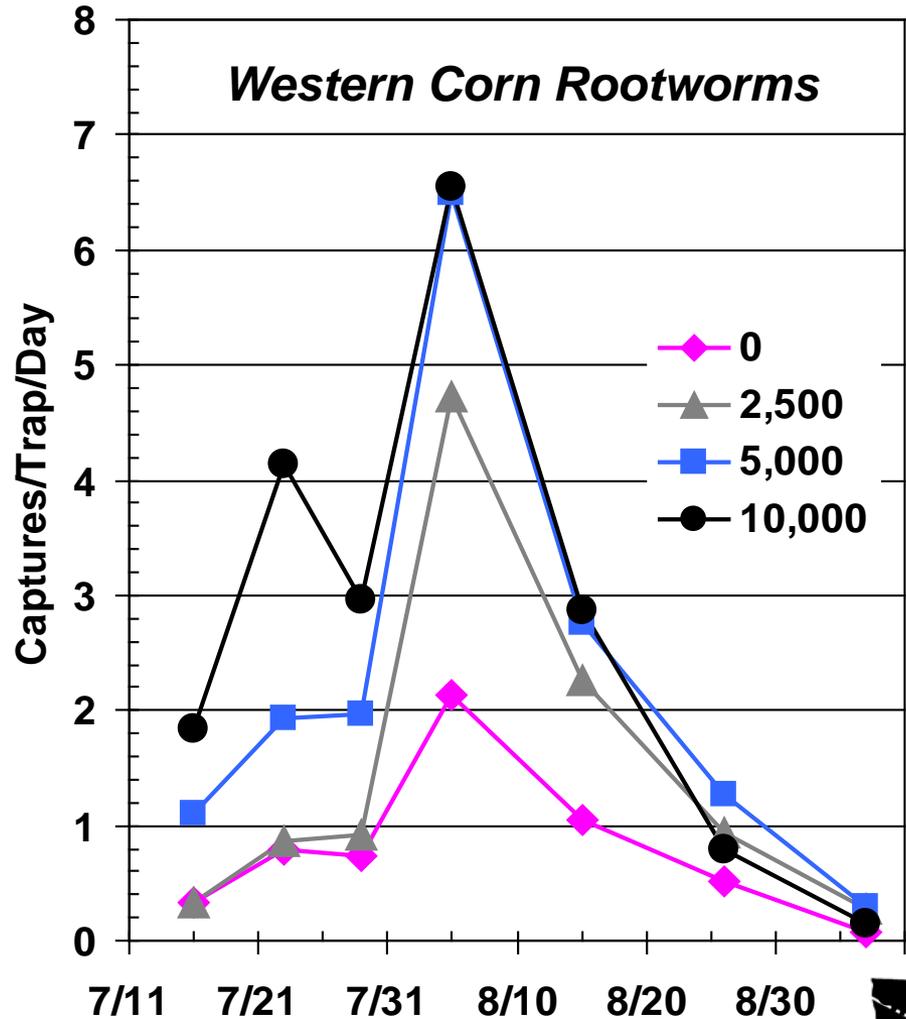
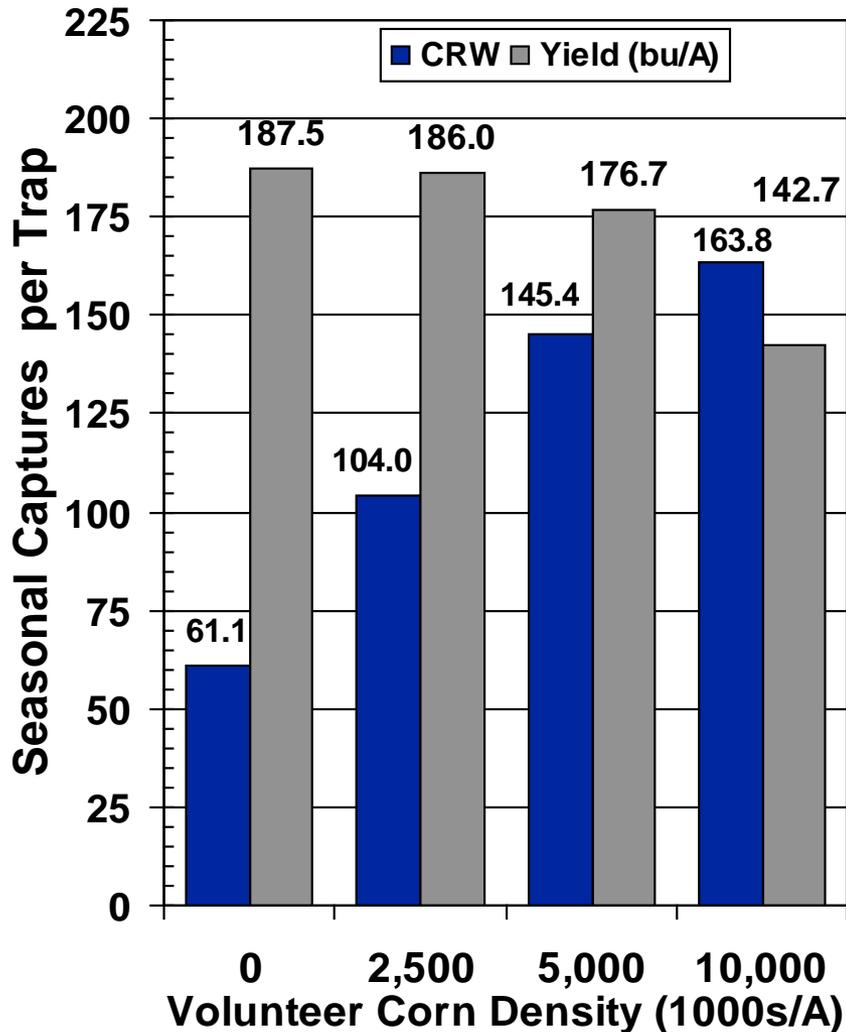


Stewardship critical: Keep early-season weedy grasses under control!



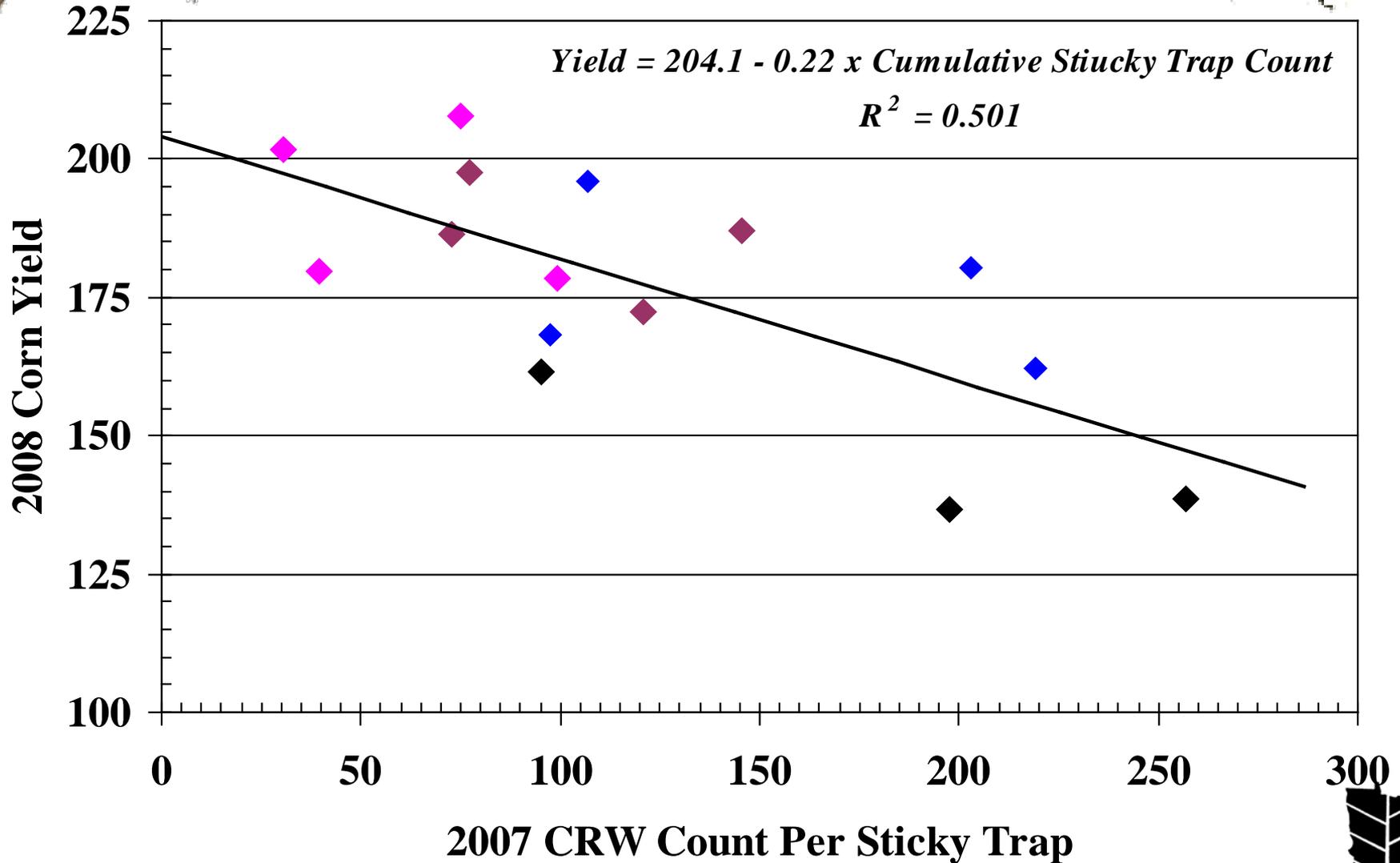
Corn Rootworms, Volunteer Corn and 2008 Corn Yield

Rosemount, MN



2007 Corn Rootworms, Volunteer Corn and 2008 Corn Yield

Rosemount, MN

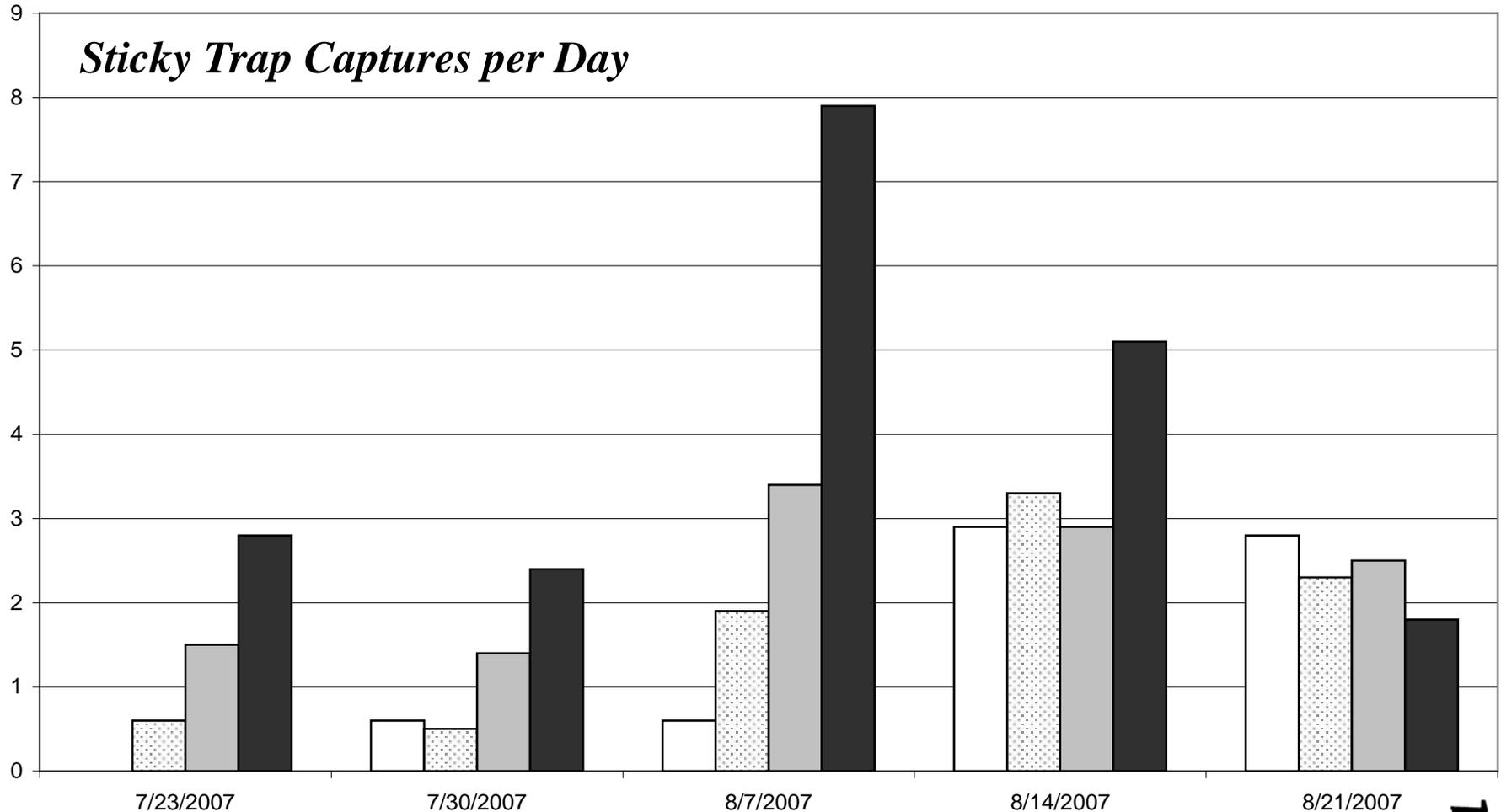




Volunteer Corn Density and Northern Corn Rootworm Activity



□ no volunteer corn □ volunteer corn (1875 ppa) □ volunteer corn (3750 ppa) ■ vol. corn (7500 ppa)



A close-up photograph of a corn root system. The roots are numerous, thin, and light green, appearing somewhat tangled. Three yellowish-brown corn rootworms are visible, crawling on the roots. The background is dark and out of focus.

Hints of Bt-RW Performance Issues Surfaced w/ Northern CRW in 2013

**What about Bt-RW Trait Performance
Against Northern Corn Rootworms?**

How Well do Bt-RW Events Perform Against Northern Corn Rootworms?

<i>Hybrid Family / Event</i>	<u>Northern Corn Rootworm</u>			
	<i>Refuge Hybrid</i>	<i>Refuge + Force 3G</i>	<i>Bt-RW Hybrid</i>	<i>Bt-RW + Force 3G</i>
DK 5263/5259 VT3	545	277 49.2%	78 85.7%	67 87.7%
P37Y13/14 Herculex Xtra	418	351 16.2%	94 77.5%	56 86.6%
N40T Agrisure	297	304 -2.4%	92 69.0%	52 82.5%

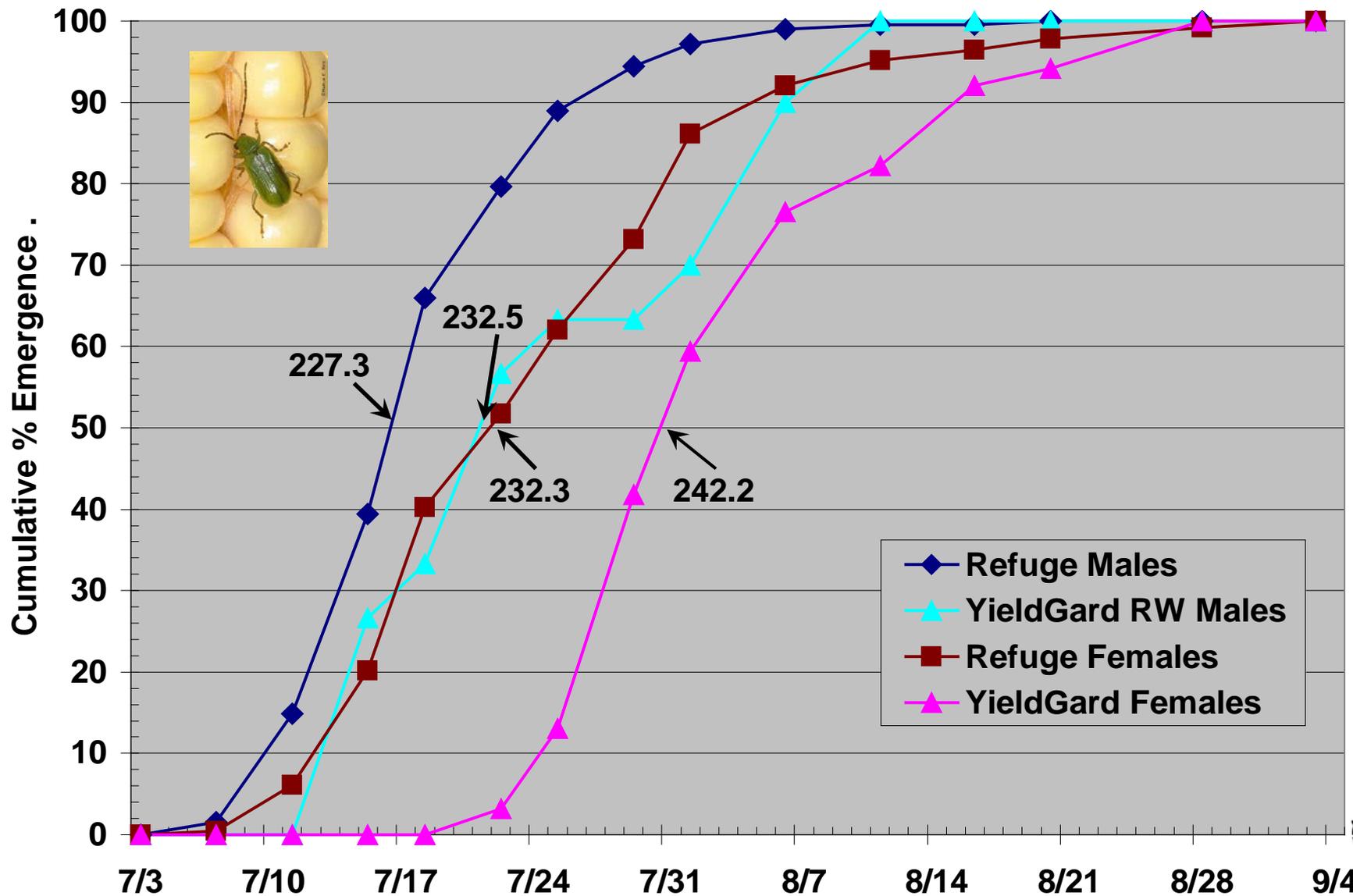
Data represents sum of seasonal emergence from 16 traps covering 32 plants.

Sponsored by MN Corn Research & Promotion Council

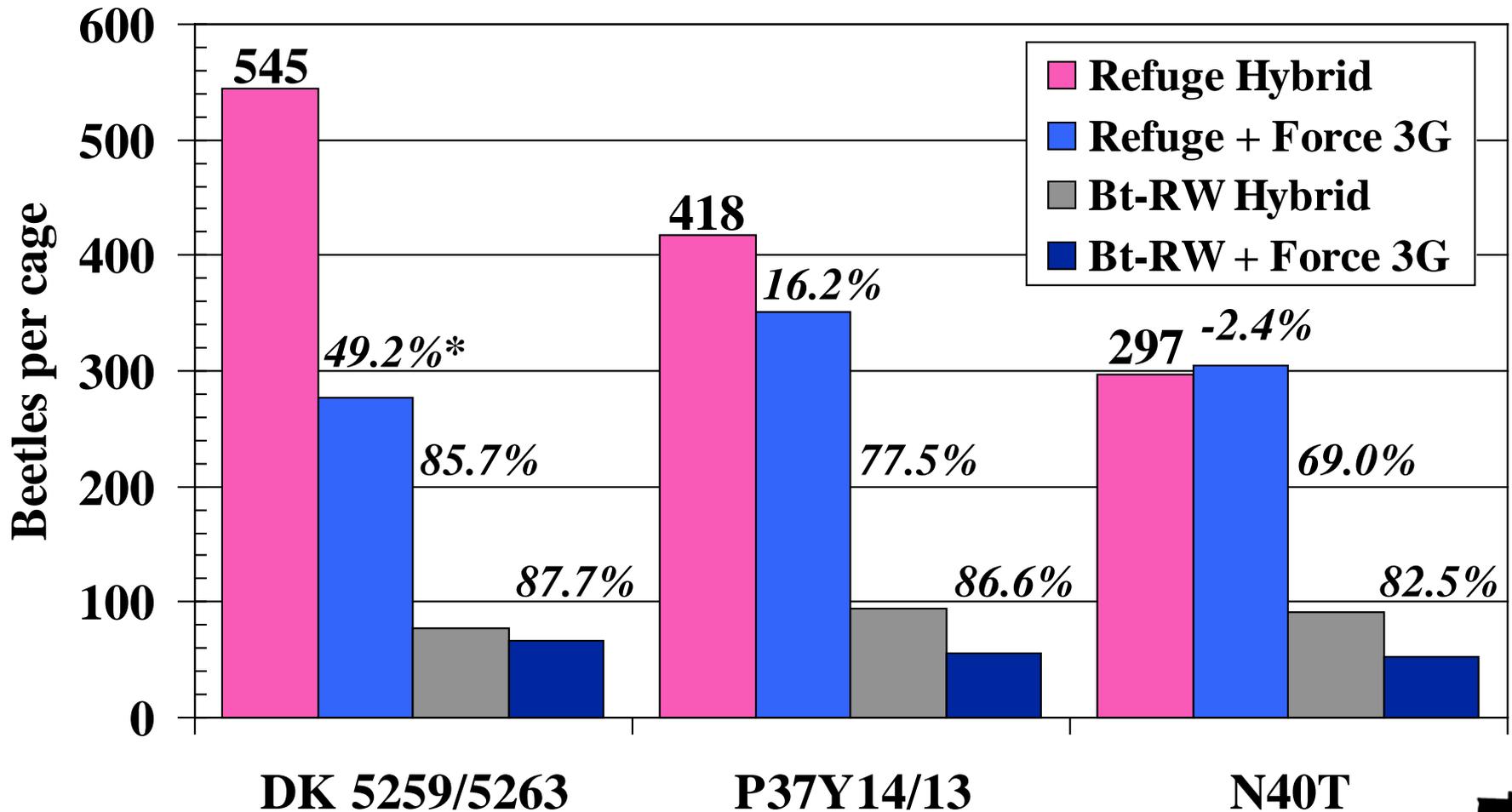
MN Legislative Rapid Agricultural Response Fund



YieldGard IRM Considerations: Northern Corn Rootworm Emergence



How Well do Bt-RW Events Perform Against Northern Corn Rootworms?



*Efficacy expressed as % of emergence in refuge hybrid.



Comparative Efficacy of Bt - RW Events Against NCR

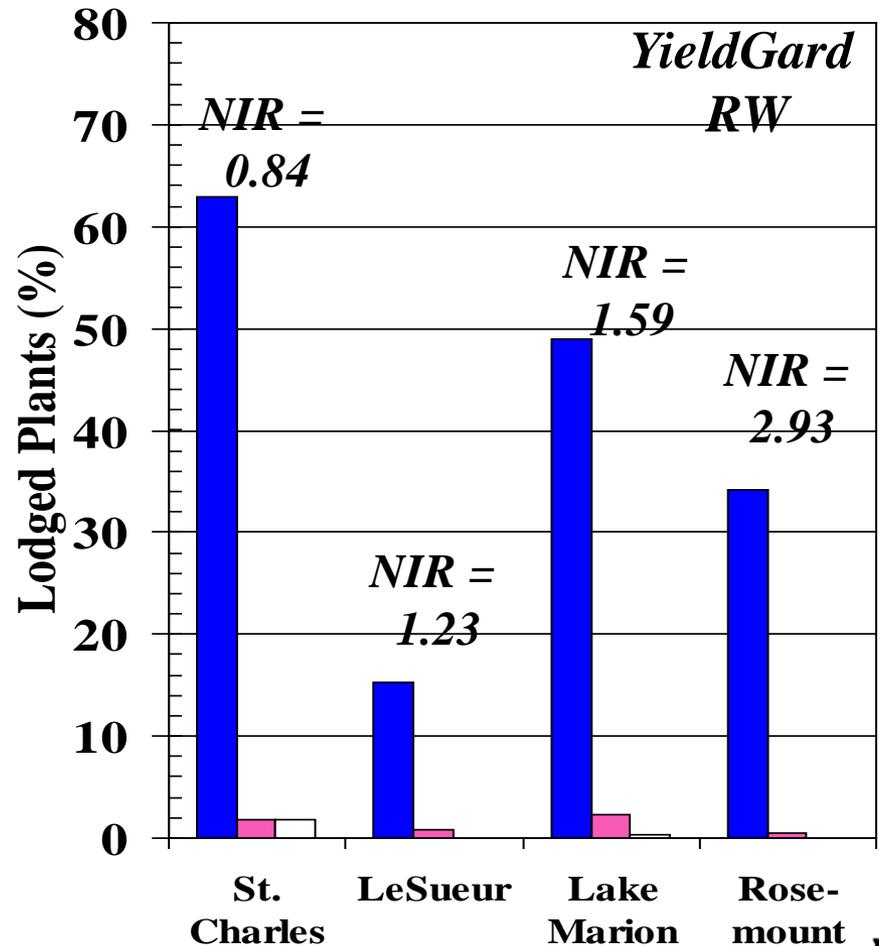
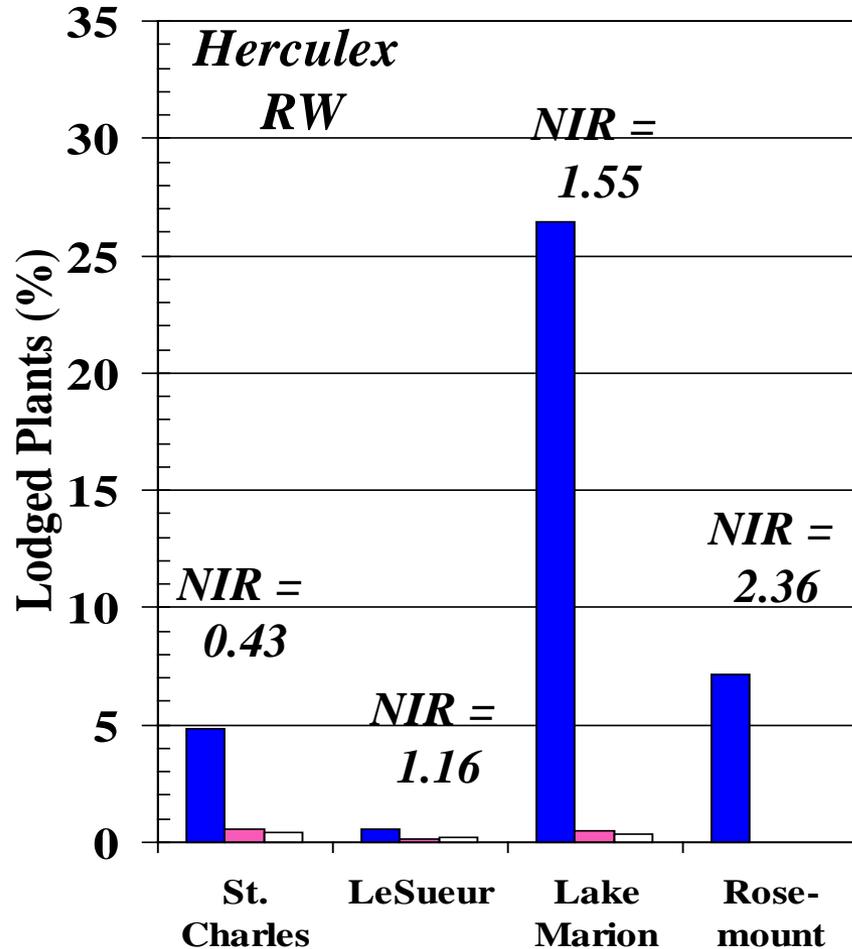


- **Design:** Factorial combinations of 3 Bt-RW events (YieldGard VT3, Herculex Xtra, Agrisure) and their isolines from the same genetic family.
- **Soil insecticide:** Force 3G only on both Bt-RW and non Bt-RW hybrids.
- **Seed treatment:** Poncho 250 on all seed.
- **Traps:** Placed in field July 2-3 with each covering two plants, 4 cages per plot, replicated 4 times.
- **Data collected:** Beetles collected three times per week. Identified by species and sex.
- **Funding:** Rapid Agricultural Response Fund, MN Corn Research & Promotion Council



Lodging under Different Corn Rootworm Management Strategies

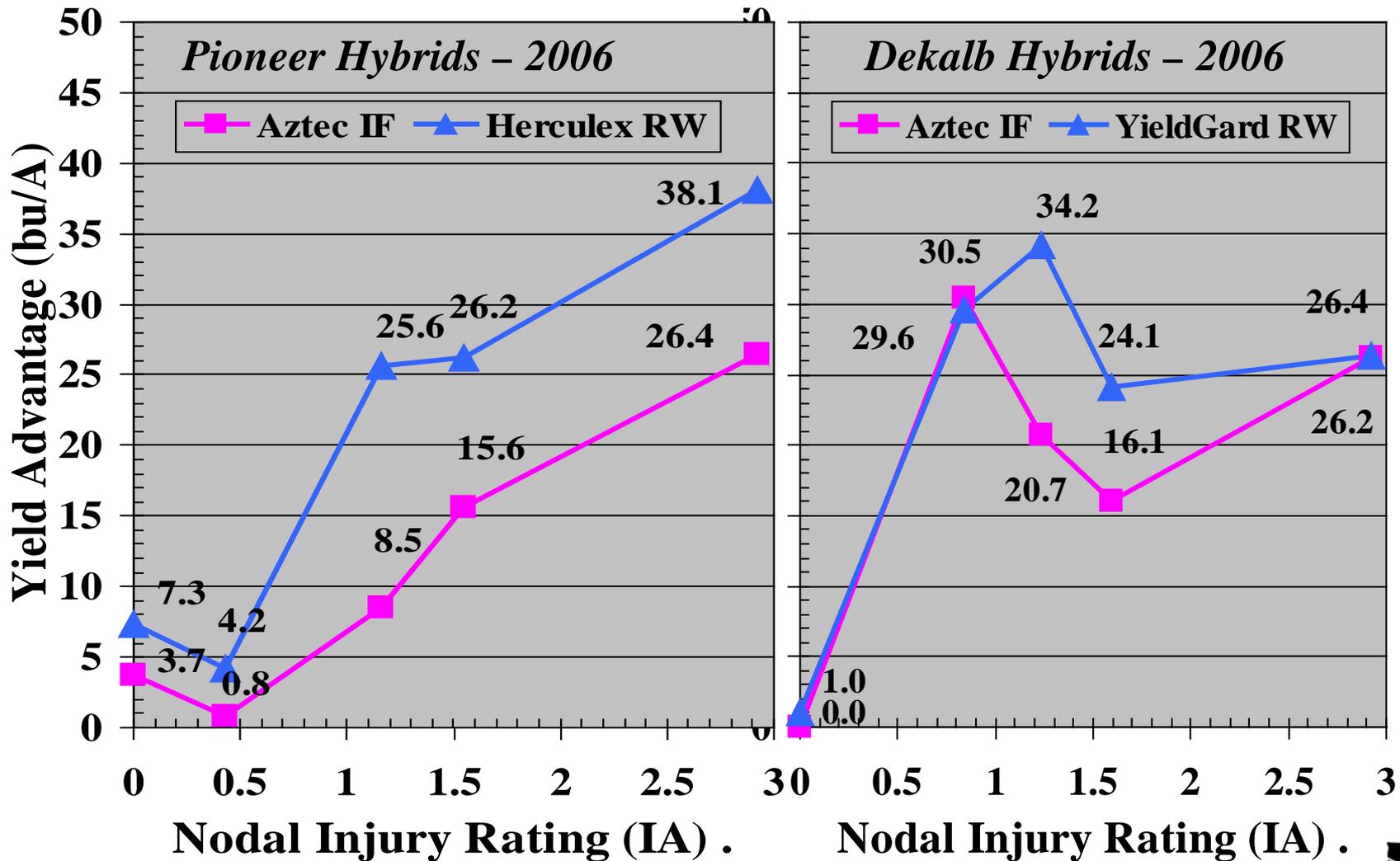
■ *Unprotected*
■ *Aztec IF*
 Bt-RW



Aztec and Bt-RW corn provided equal lodging protection!



Yield Response to Corn Rootworm Management



Do farmers have a handle on their risk level?



**Layer a
Soil Insecticide?**



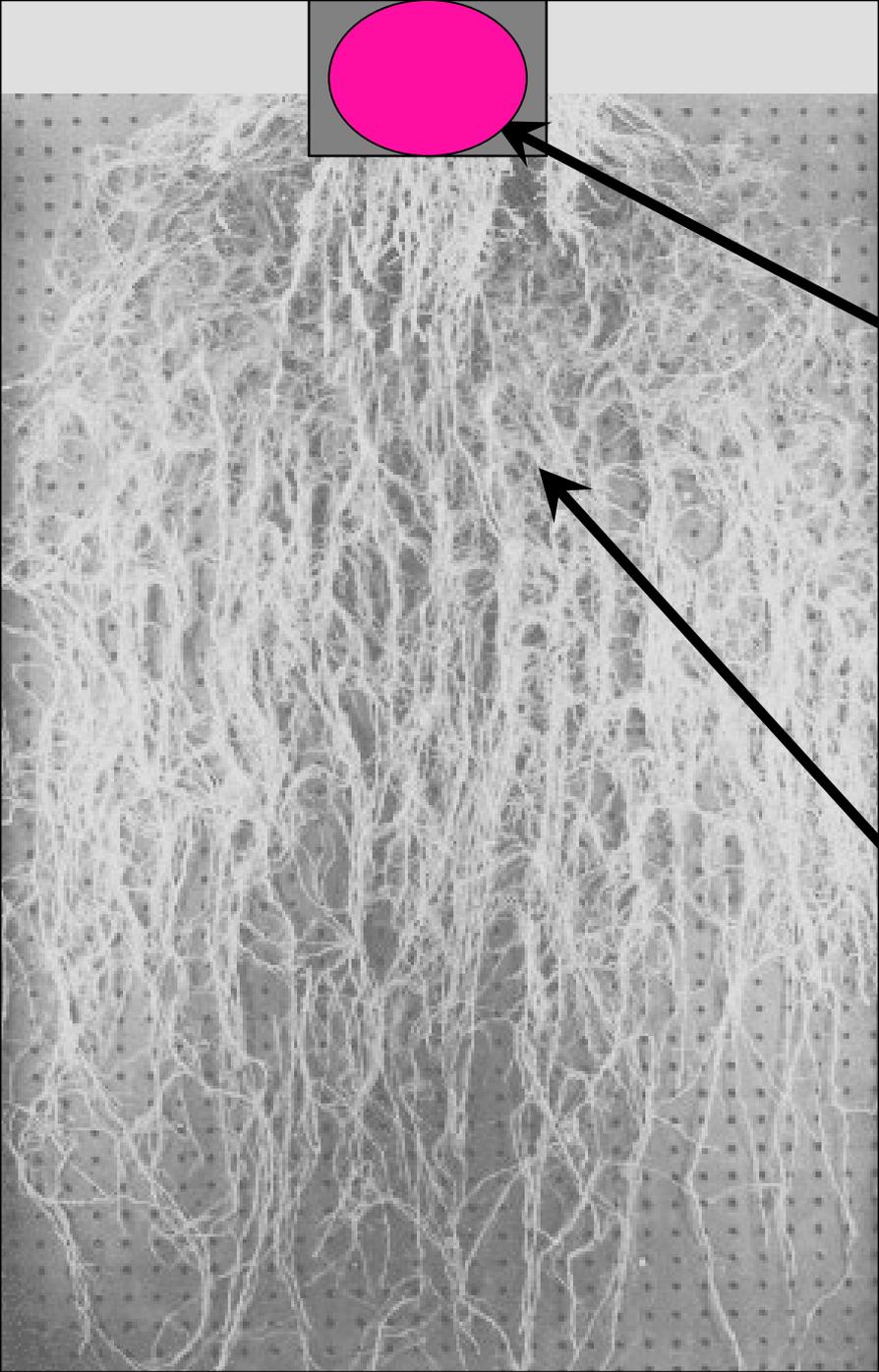
**Root
Protection
Strategy!**

Corn Root Protection: Insecticides vs Bt-RW Corn

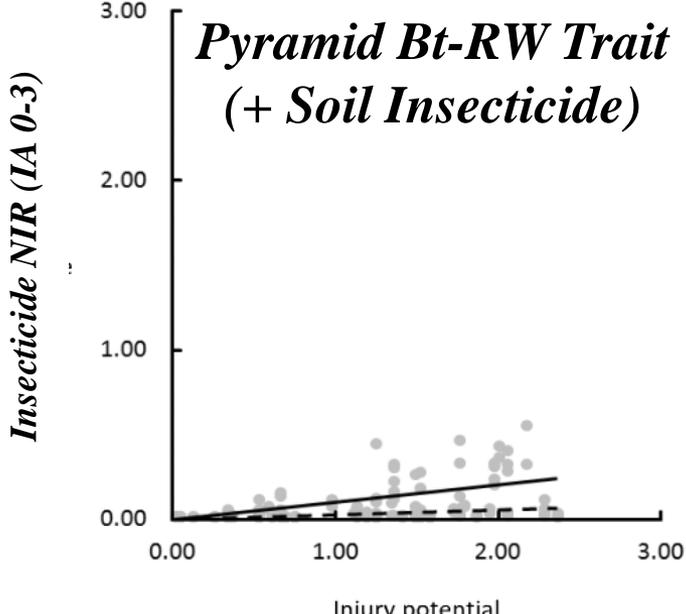
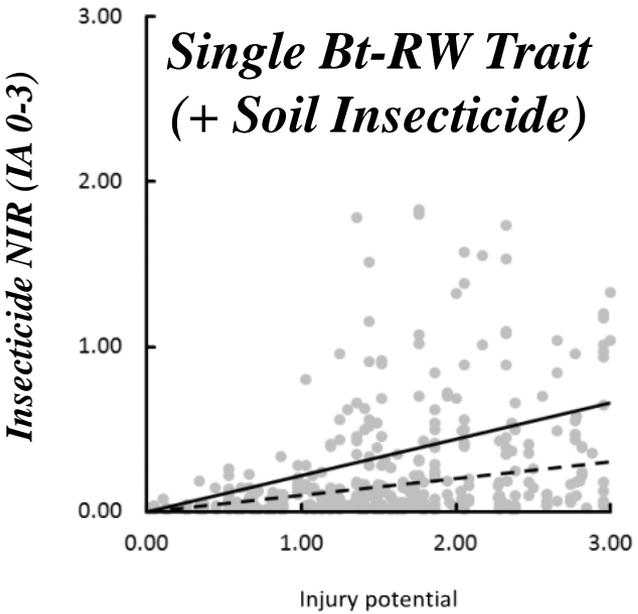
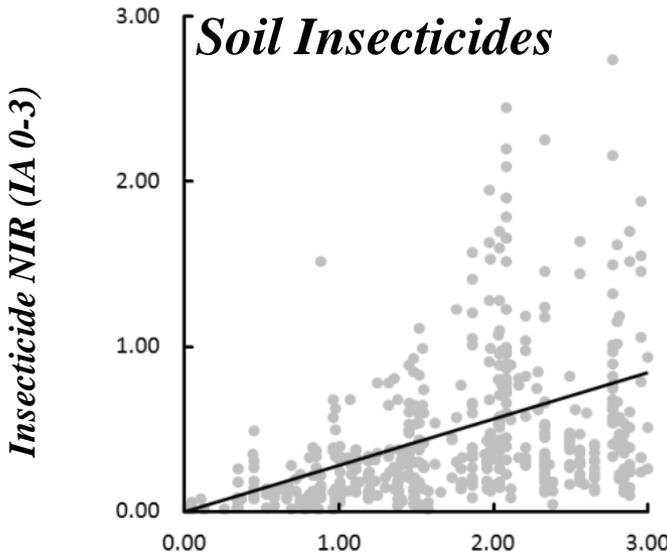
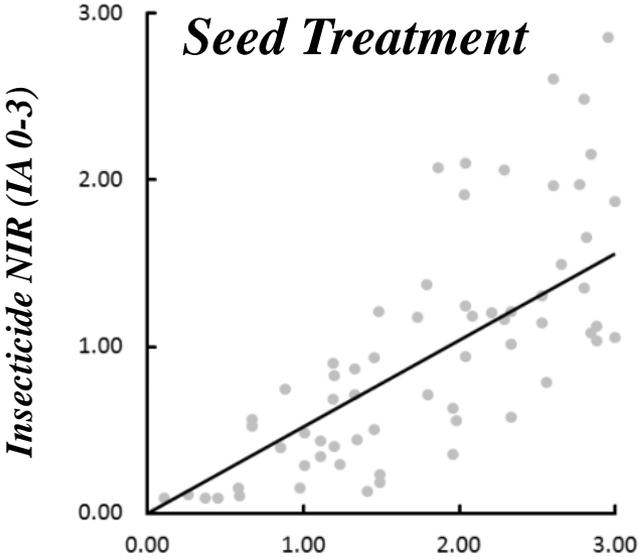
*Zone of
Root Protection for
T-band Insecticides &
Seed Treatments*



*Zone of
Root Protection
For Bt-RW Protein*



Performance of Insecticide vs Bt-RW Traits:

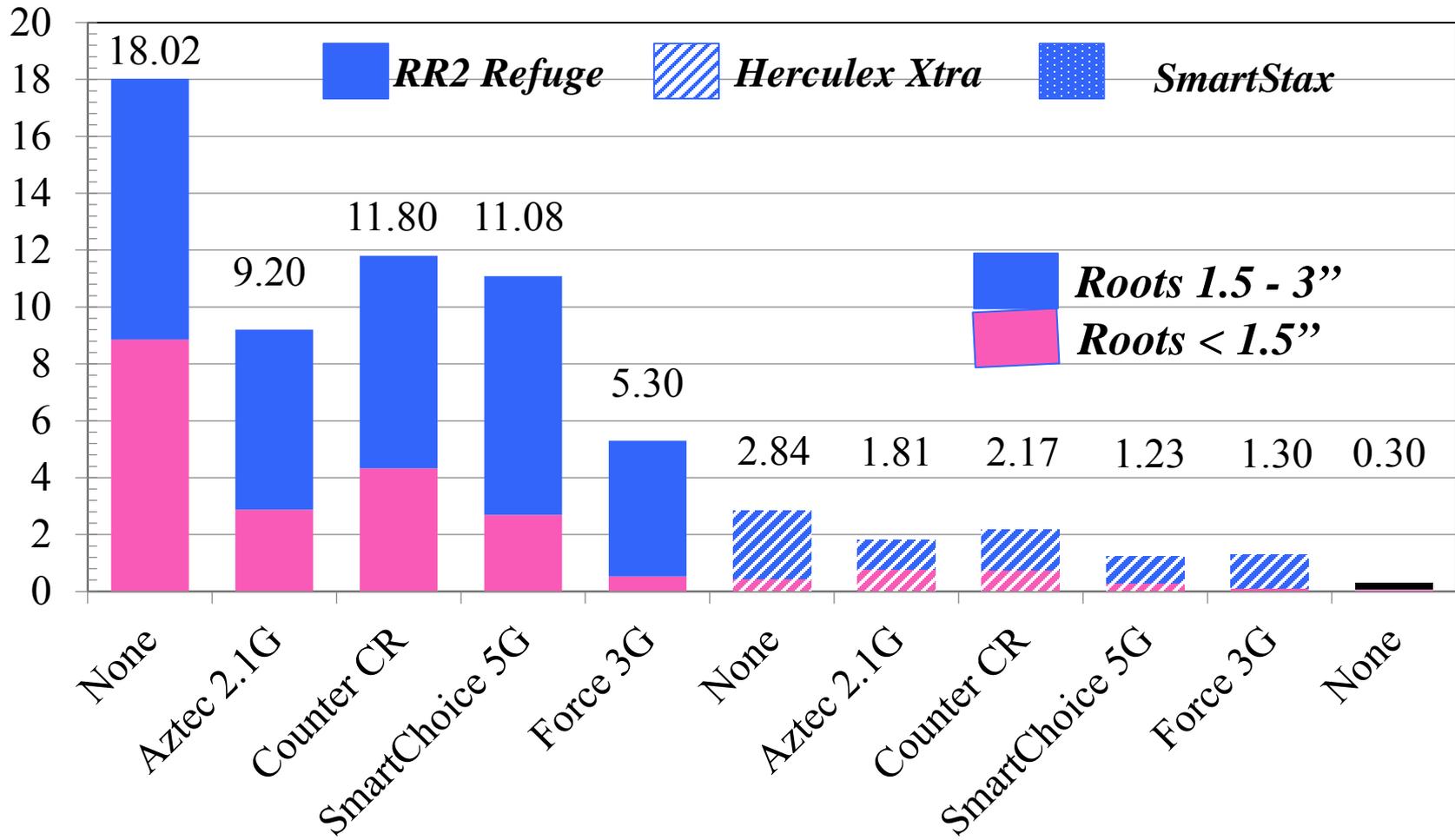


What about Insecticide Performance in MN Situations?



Soil Insecticide Overlay – Does it Protect More Roots?

Root Protection from Corn Rootworm Management

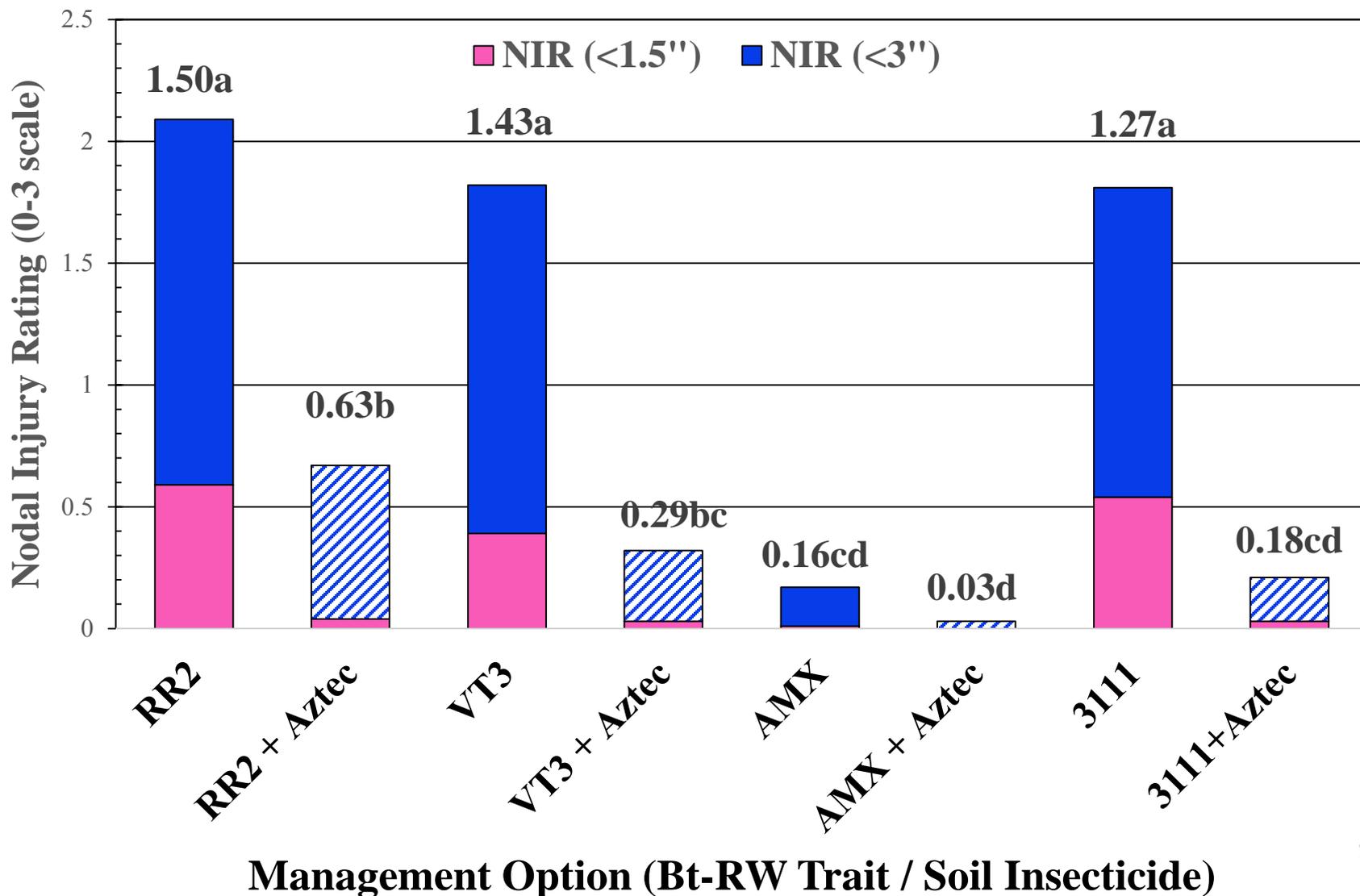


Rosemount MN 2011



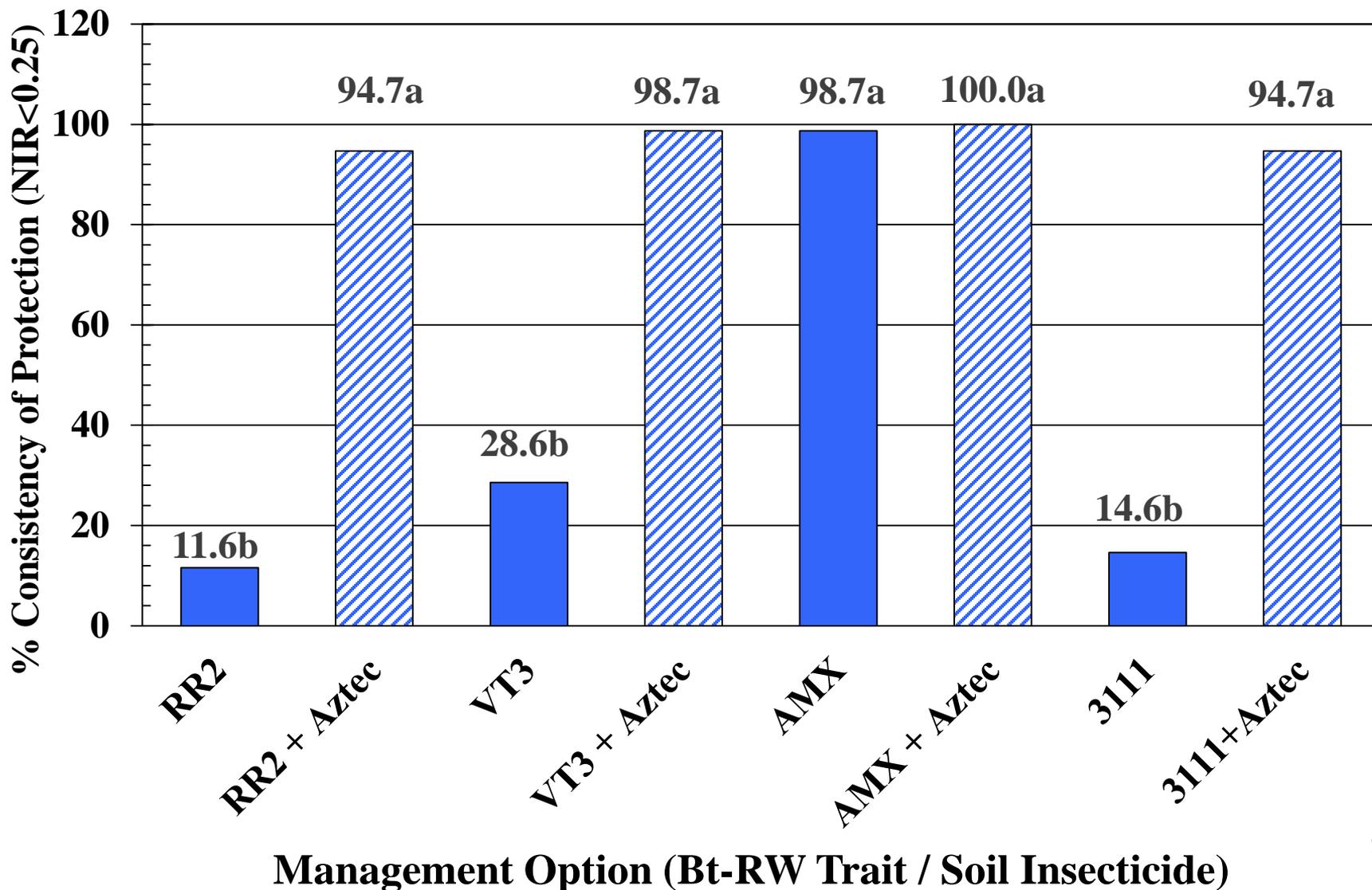
Soil Insecticide Overlays on Bt-Traits

2015 Rosemount MN – Field I7



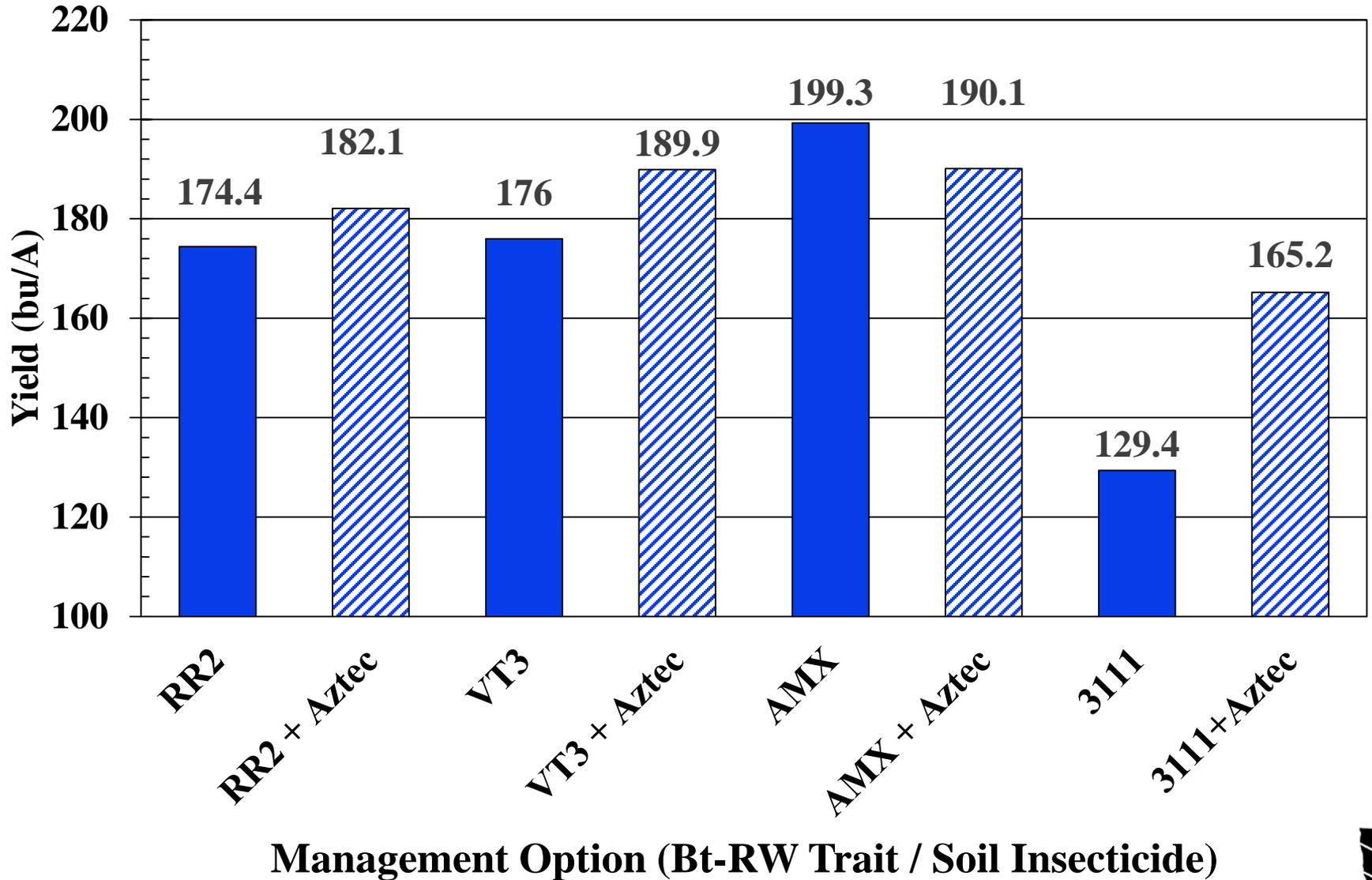
Soil Insecticide Overlays on Bt-Traits

2015 Rosemount MN – Field I7

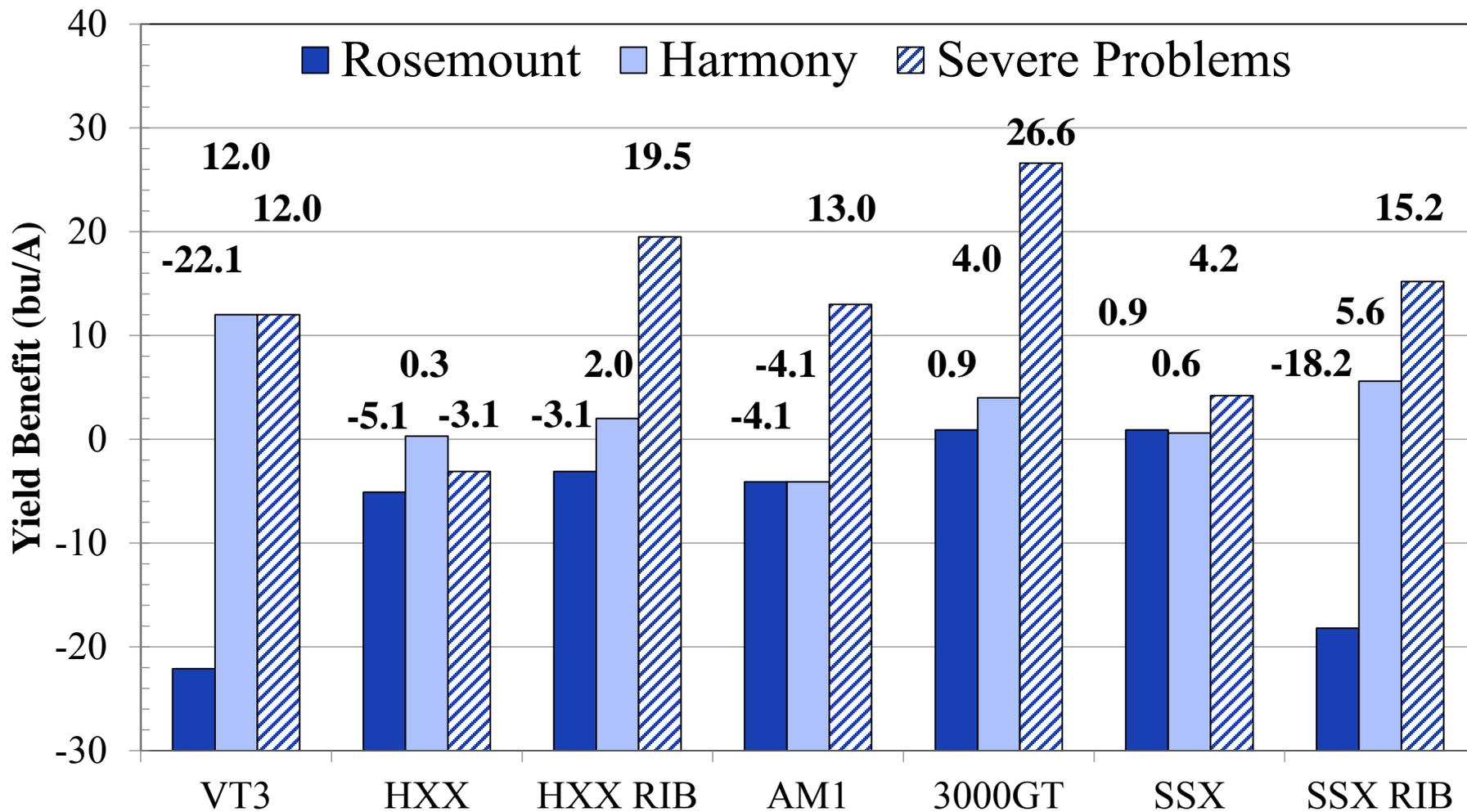


Soil Insecticide Overlays on Bt-Traits

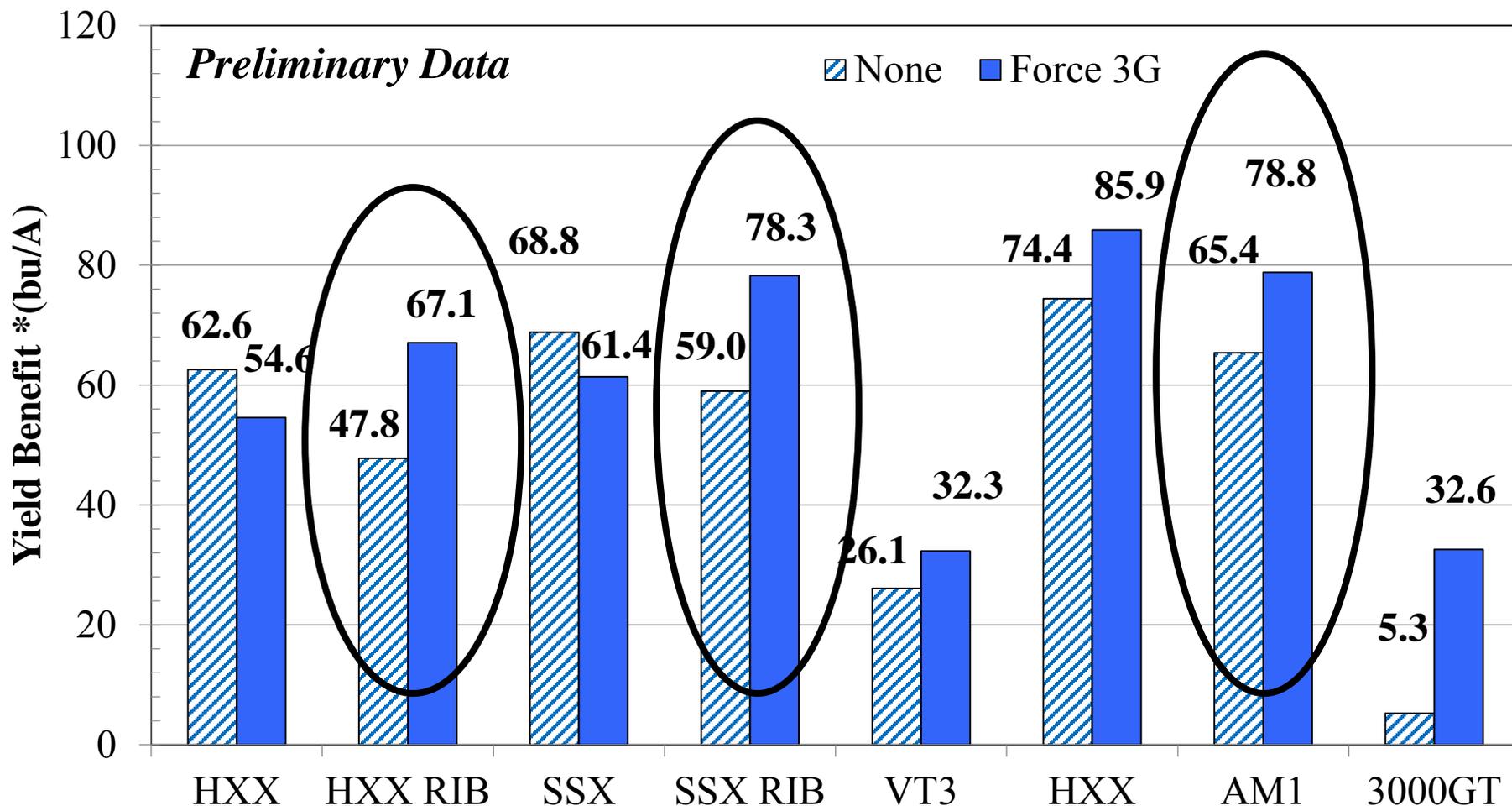
2015 Rosemount MN – Field I7



Managing Bt-RW Performance Problems: *Layering Insecticide on Traits (2012)*



Bt-RW Trait / Force 3G Performance in Cry3Bb1 Problem Field: *Northfield MN*



Soil Insecticides and Bt-RW Traits

2015 Rosemount MN

Trait	Insecticide	Nodal Injury Rating ($<3''$)	Yield (bu/A)
<i>Study #1 (Field D2)</i>			
None (RR2)	None	1.07	177.7
	Capture LFR	0.78	178.7
	Force CS	0.66	194.3
	Aztec 4.67G	0.45	217.0
	L.S.D.		
<i>Study #2 (Field E)</i>			
Cry3Bb1 (VT3)	None (RR2)	1.14	197.6
	None	0.58	213.6
	Capture LFR	0.16	213.7
	Force CS	0.34	214.4
	Aztec 4.67G	0.10	200.7
	L.S.D.		

Means followed by the same letter do not differ ($p=0.05$)



What to do? When “Simple” is Gone

KEY = IPM

Objective:

Manage Corn Rootworm Populations!

2012 Problem Field – Springfield MN



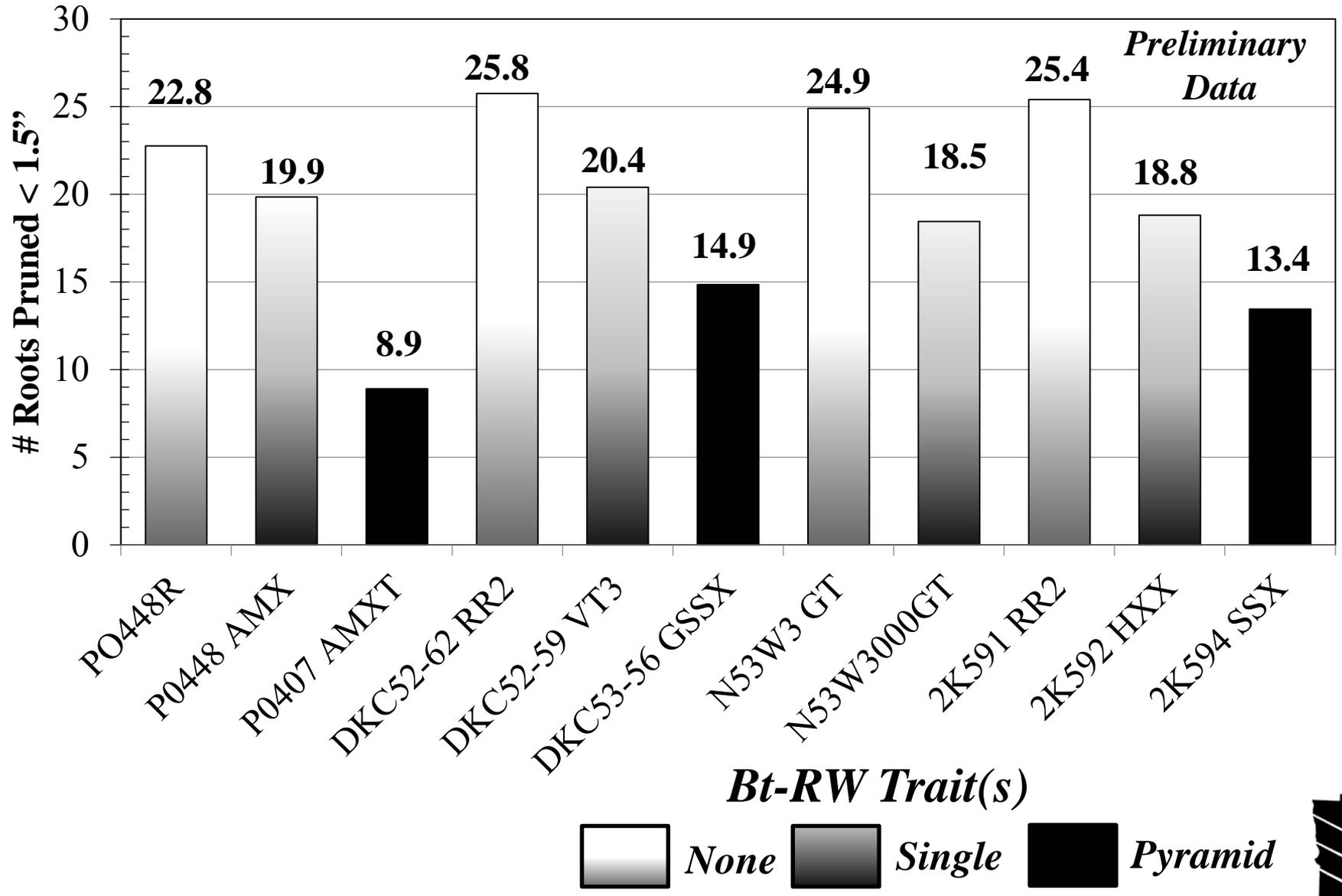
***Dual Challenges:
Trait Resistance &
Corn Rootworm
Density***



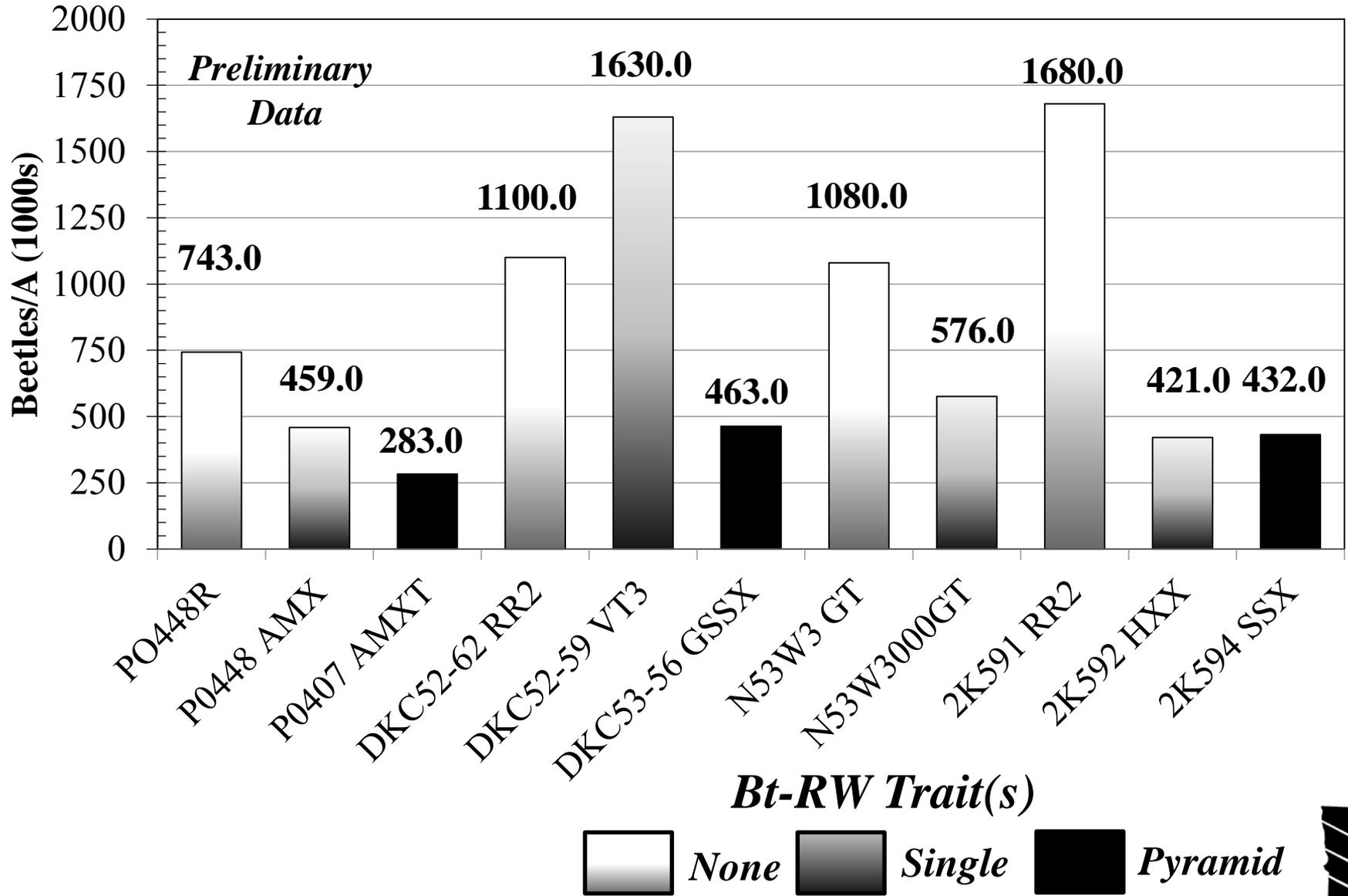
Photos by Bruce Potter



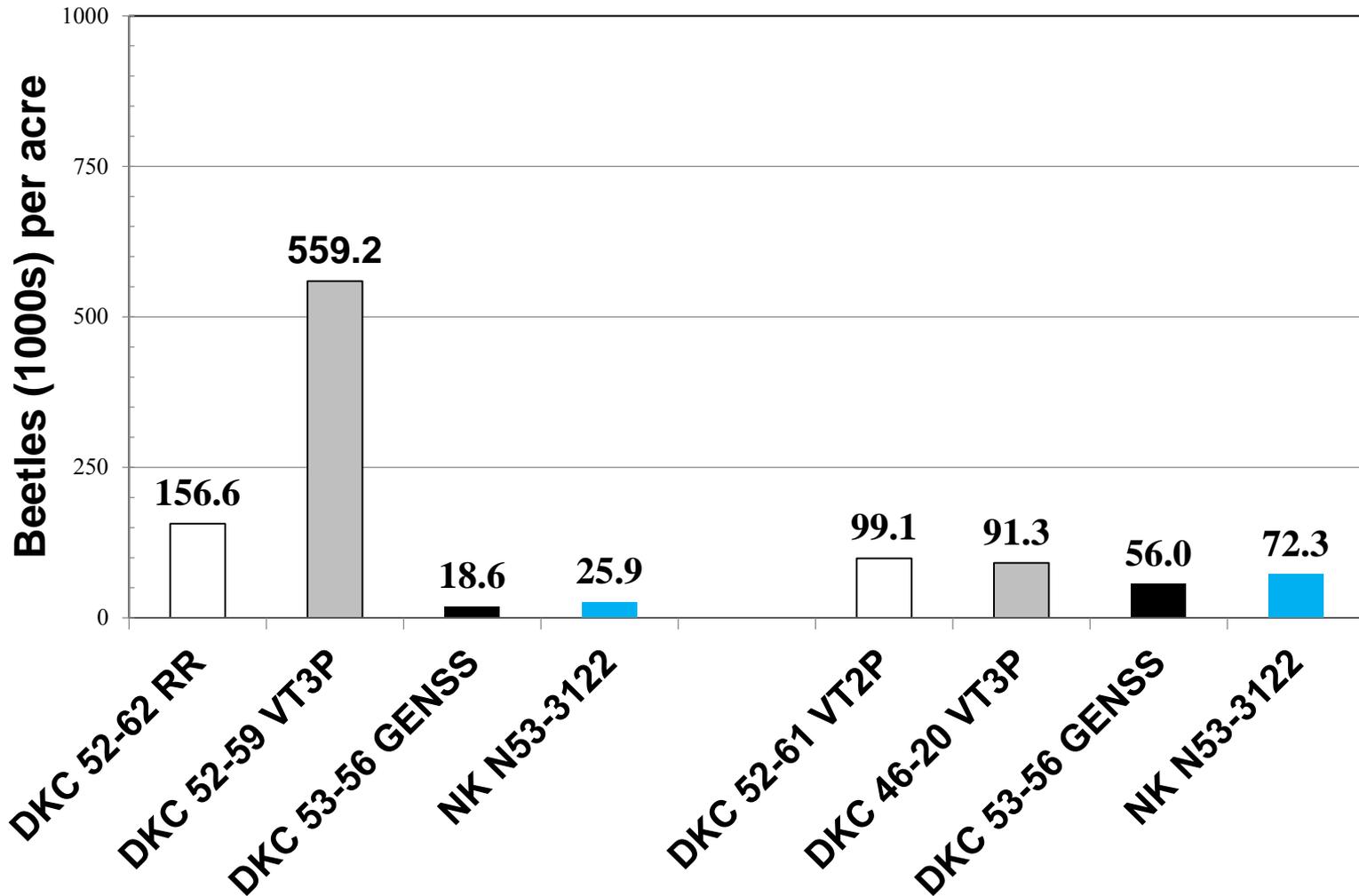
Trait Performance in Bt-RW Problem Field: Root Injury (*Ostlie - Springfield MN*)



Trait Performance in Bt-RW Problem Field: Beetle Emergence (*Ostlie - Springfield MN*)



Trait Effect on Corn Rootworm Beetle Production: 2014-5 Springfield MN



Resistance Taking Us Back to School on the Basics



Reality Check on Rootworm Tactics

<u>Control Tactic</u>	<u>Considerations</u>
Crop Rotation	Reduces pressure – watch variants, volunteer corn, weeds. Grain / forage demands (livestock), contracts (ethanol)
Pyramid traits	Resistance ?; Performance may be partially compromised by prior trait use, refuge less effective, selection pressure continues, rotate to avoid resistance
Single traits	Resistance confirmed (primarily VT3 / VT3 Pro). Cross-resistance w/ Agrisure, rotate to avoid resistance
Layer insecticide on refuge corn	Environmental/health issues, 40-60% kill, protection declines w/ pressure
Layer insecticide over pyramid	Masks resistance issues. Insurance use – benefit??? Depends on pressure, RIBs benefit under heavy pressure
Layer insecticide over single trait	Masks resistance issues. Benefit only under heavy pressure on refuge or if Bt-RW performance problem.
Spray beetles	Reduces pressure, multiple sprays needed, scouting costs & challenges, fungicide tankmix??, environment concerns

CRW Management: What's a Guy to Do?

- _ **This is a classic resistance situation => Be prepared to change management after 3-4 years in same trait.**
- _ **Preferred option – Crop rotation!!!! Watch for rotational resistance with western corn rootworm!**
- _ **If you can't rotate, be prepared to invest more money in corn rootworm management**
 - _ **Switch to different single trait or pyramid**
 - _ **Layer with a soil insecticide (bandaid)**
 - _ **Foliar sprays (multiple, well-timed) may be required to knock-down heavy populations**
- _ **Get a handle on corn rootworm pressure and trait performance => Scout!**
- _ **Take IPM (Integrated Population Management) approach**

Western Corn Rootworm Injury to First-Year Bt-RW Corn (*Gray - IL*)



Any Questions?

