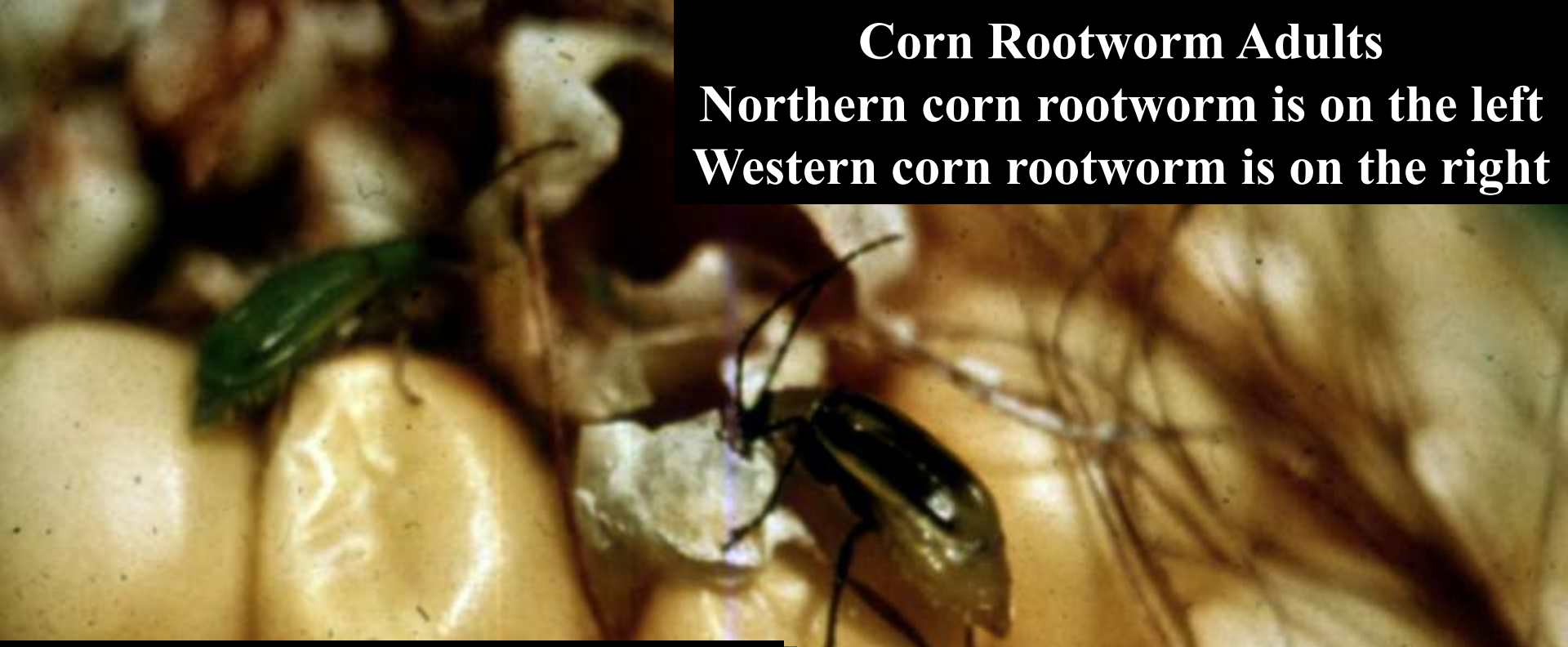


2013 BT-Corn Rootworm Failure in CNY: A canary in the coal mine?

**Elson Shields, Dept of Entomology
Cornell University, Ithaca**

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

2013/09/17

An aerial photograph of a large agricultural field, likely corn, showing distinct rows of crops. The field is green and occupies most of the frame. In the top right corner, there is a small area of dark green trees. The bottom left corner shows a portion of a white structure, possibly part of an aircraft or a camera rig, with a grey cylindrical component. The text 'Smart Stak' is overlaid in white in the upper right, 'Cry 3Bb1' is overlaid in white in the lower right, and '2013/09/17' is overlaid in yellow in the bottom right.

Smart Stak

Cry 3Bb1

2013/09/17

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*



An aerial photograph of a vast cornfield. The rows of corn are clearly visible, stretching across the landscape. There are some areas where the corn appears slightly less dense or shorter than other parts of the field, possibly indicating performance issues. The sky is not visible, and the field extends to the horizon.

**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

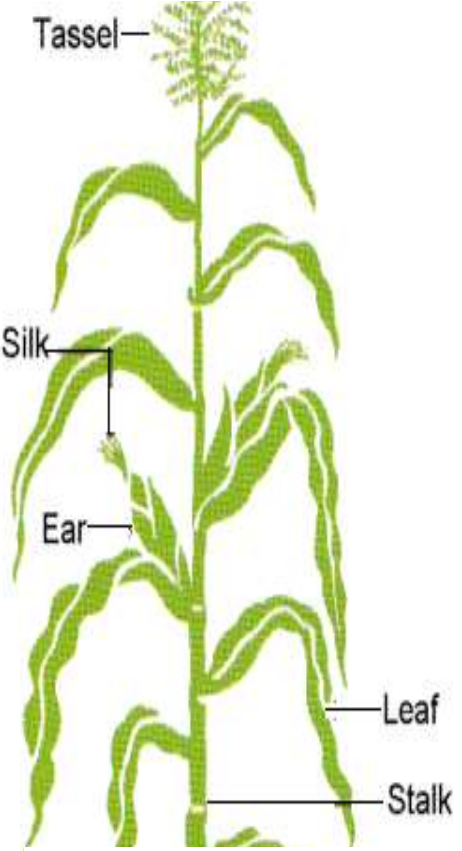
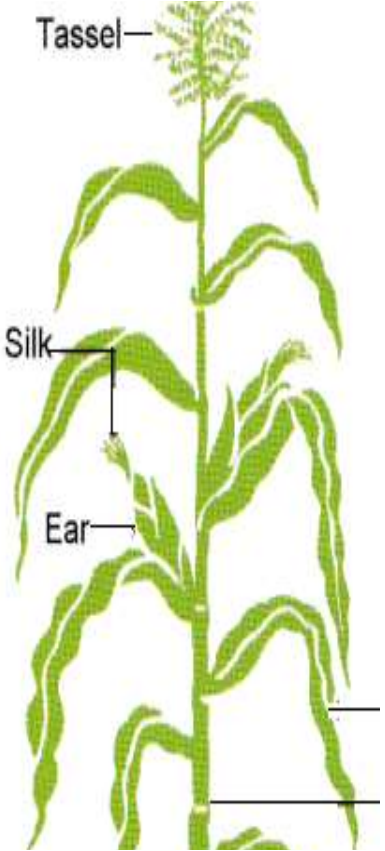
Dismissed by seed salesmen

**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

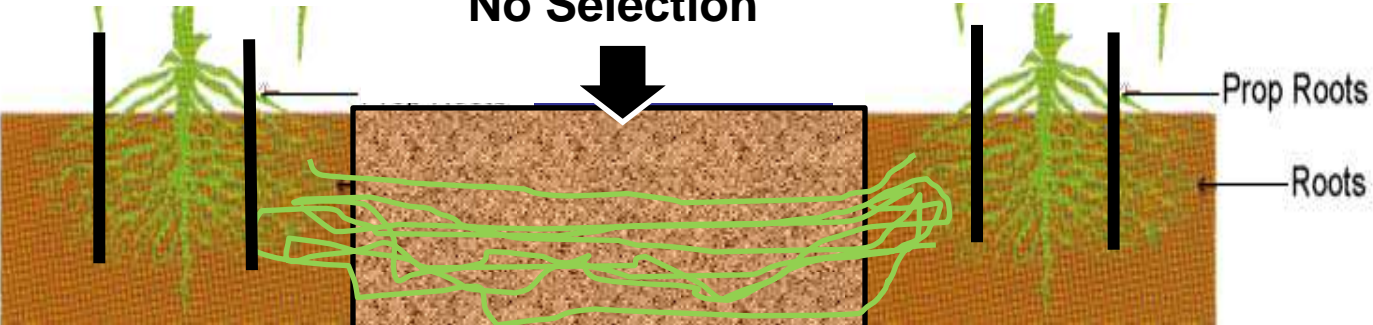


**Soil Insecticide
Refuge**

Soil Insecticide

Soil Insecticide

No Selection



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

Corn Rootworm Root Damage (Aurora-2010)

GMO event	0-3 scale (nodes of roots)	1-6 scale
Untreated Check	2.0	4.0
Seed treatment (1250)	0.5	2.9
Herculex	0.25	1.5
Yieldgard VT-Pro	0.25	1.5
SmartStax	0.25	1.5



Adult Beetle Emergence

<u>GMO Event</u>	<u>Beetles/ft²</u>	<u>R R 0-3</u>
Untreated Check	18.2	2.0
Seed treatment (1250)	5.9	0.5
Yieldgard VT-Pro	3.9	0.25
Herculex	2.6	0.25
Herculex seed mix (5.6%)	4.4	0.25
SmartStax	1.1	0.25

Adult Beetle Emergence

<u>GMO Event</u>	<u>Beetles/ft²</u>	<u>% Survival</u>
Untreated Check	18.2	---
Seed treatment (1250)	5.9	32%
Herculex	2.6	14%
Herculex seed mix (5.6%)	4.4	24%
Yieldgard VT-Pro	3.9	21%
SmartStax	1.1	6%

What is the significance of adult survival in resistance development

Write a computer model to predict resistance development.

Inheritance Characteristics

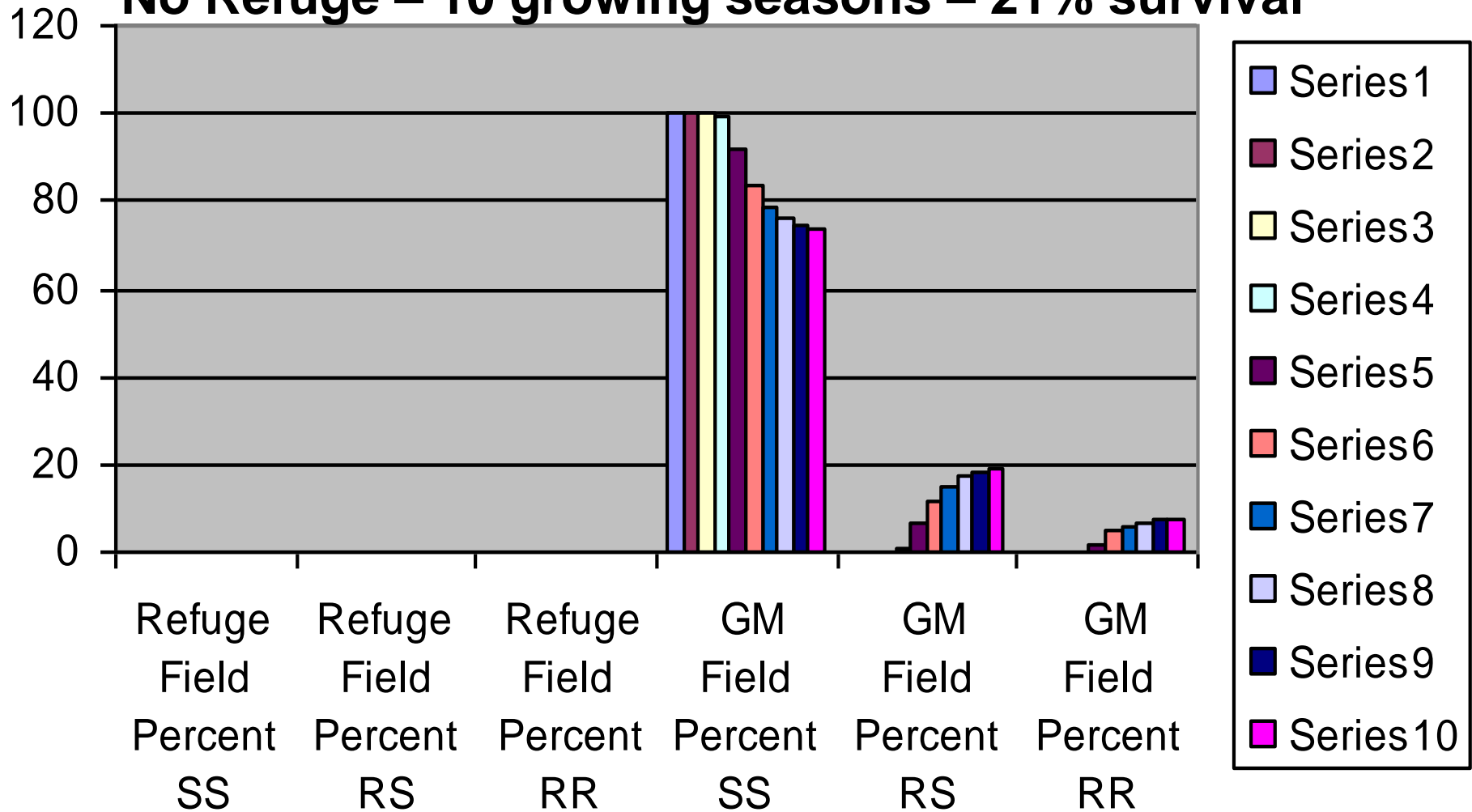
Cry 3Bb1 (Monsanto - YieldGard)

**Resistance Inheritance is mostly
Recessive.**

Impact of No Refuges on Resistance Development

Cry 3Bb1

No Refuge – 10 growing seasons – 21% survival



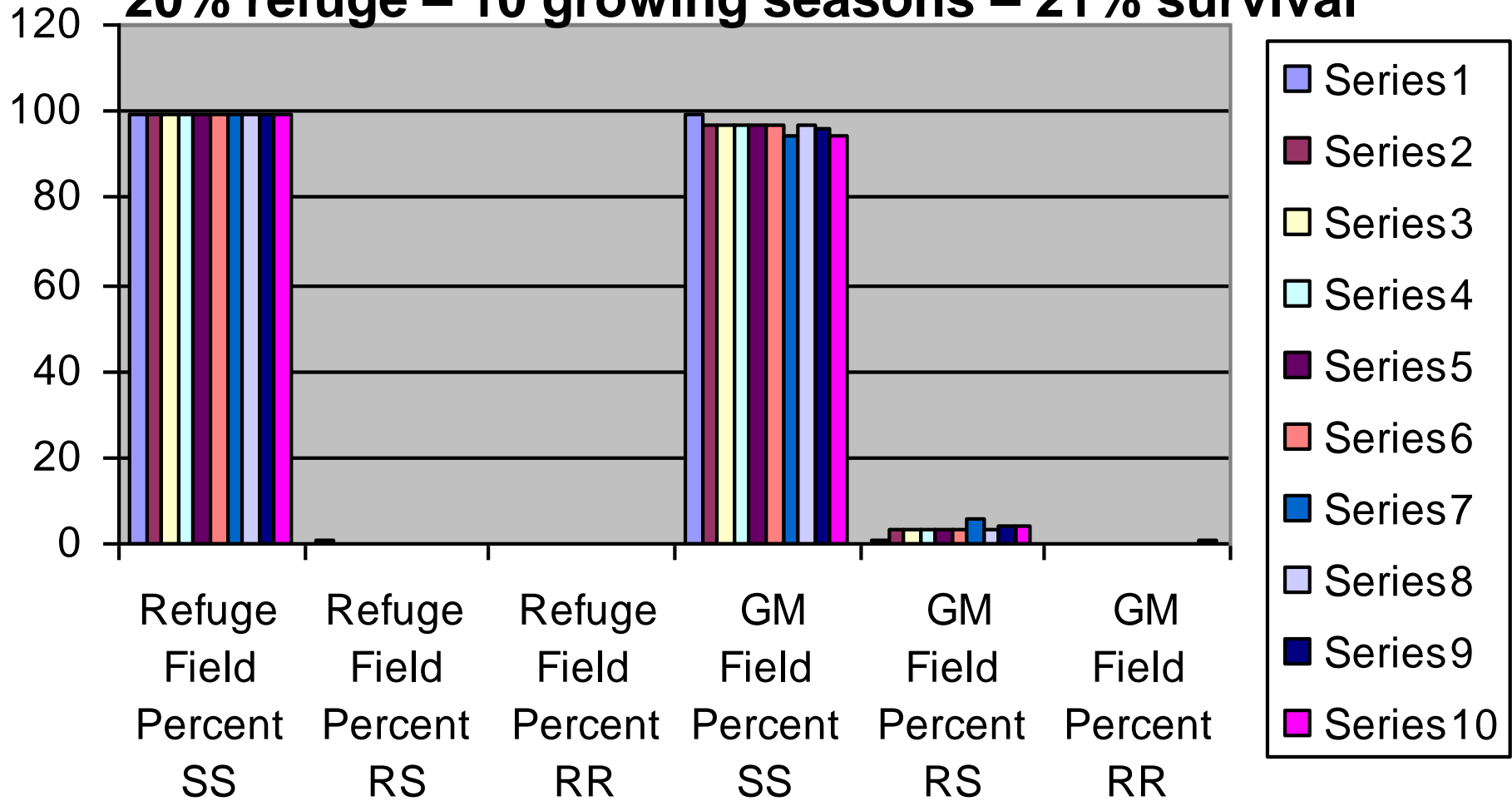
Yieldgard VT Pro?

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

20% refuge – 10 growing seasons – 21% survival



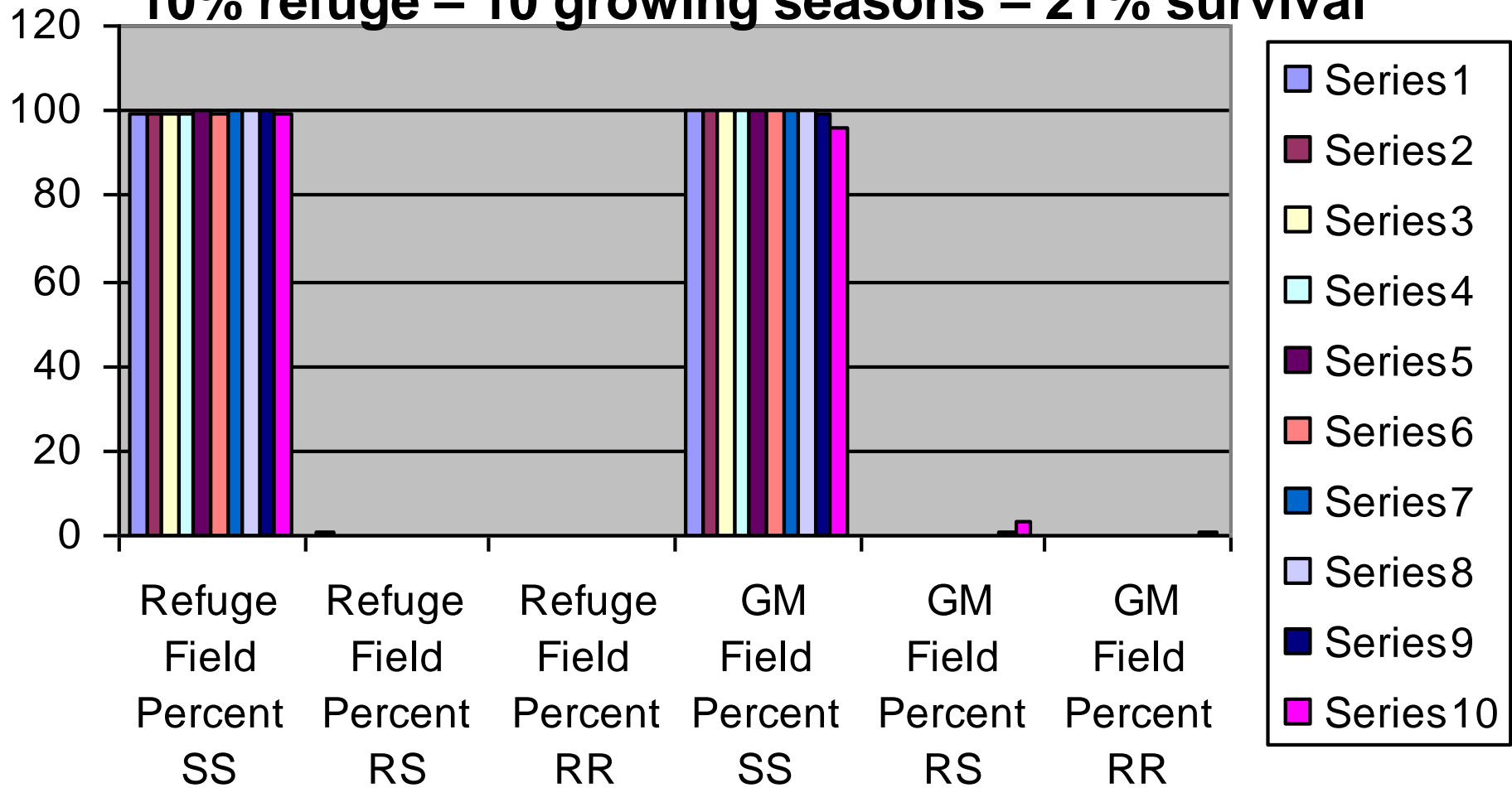
Yieldgard VT Pro?

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

10% refuge – 10 growing seasons – 21% survival



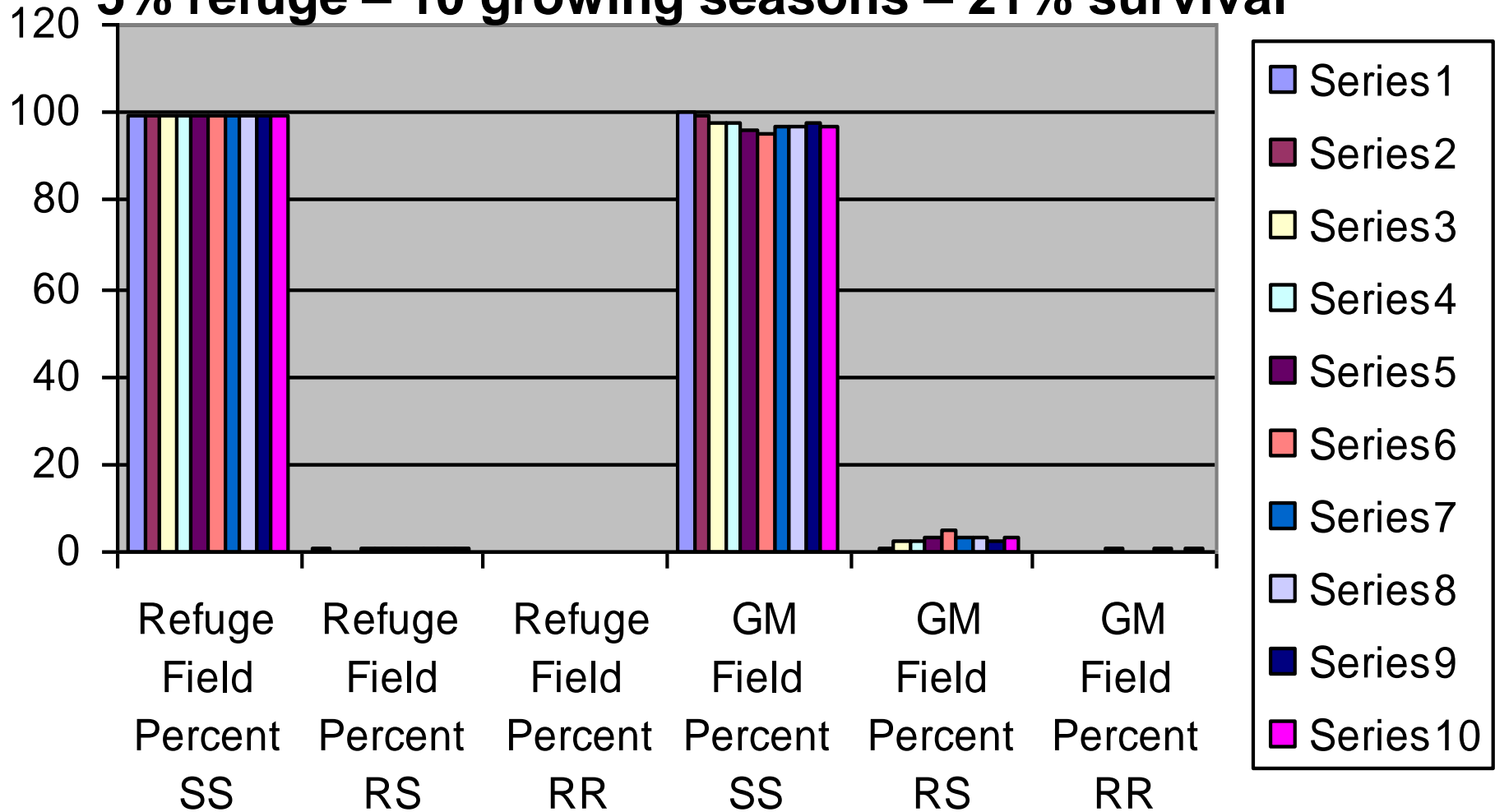
Yieldgard VT Pro?

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

5% refuge – 10 growing seasons – 21% survival



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)

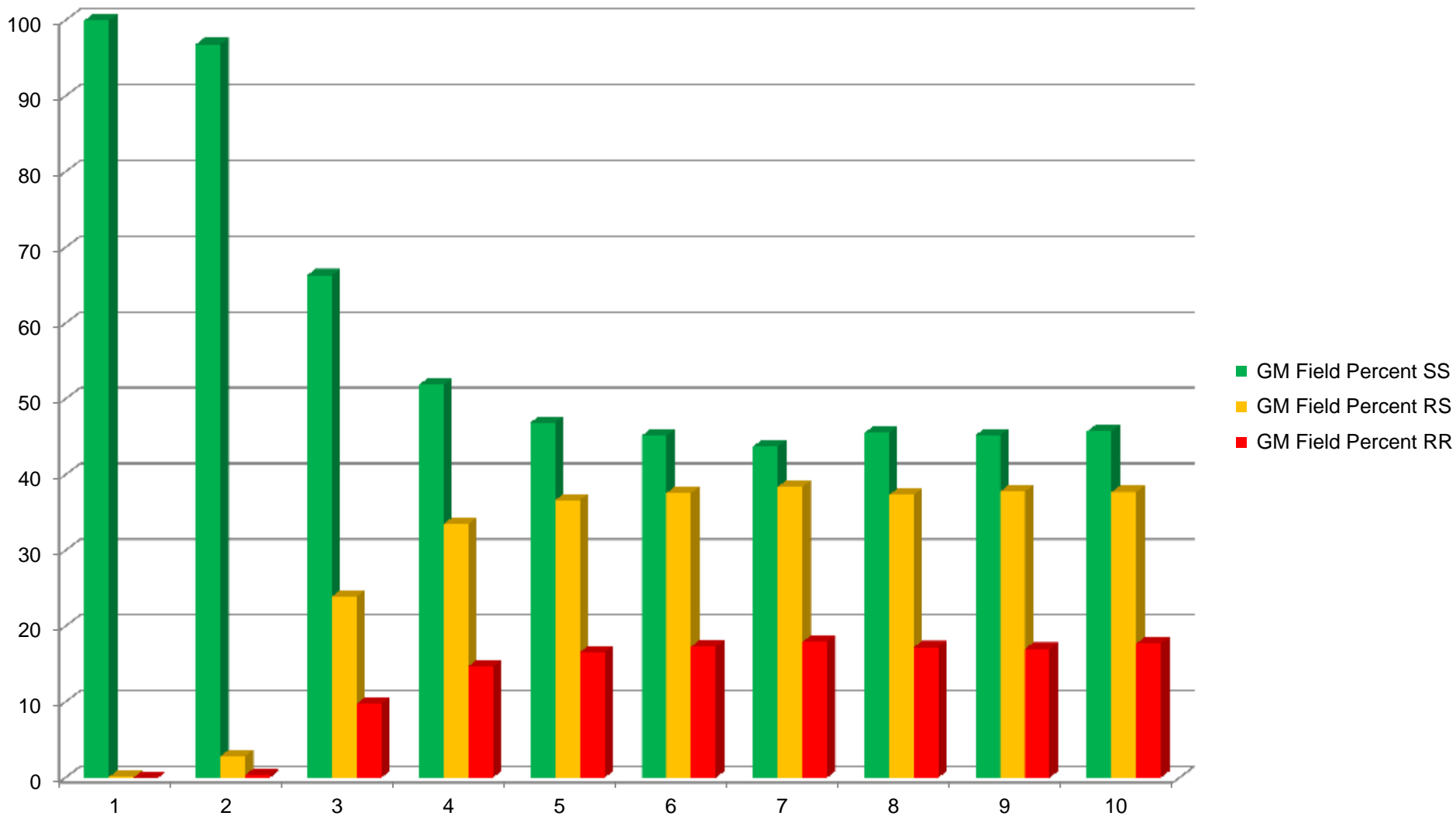
**Resistance Inheritance is additive
dominant.**

Rs = 88% survival

RR = 100 % survival

Impact of No Refuges on Resistance Development

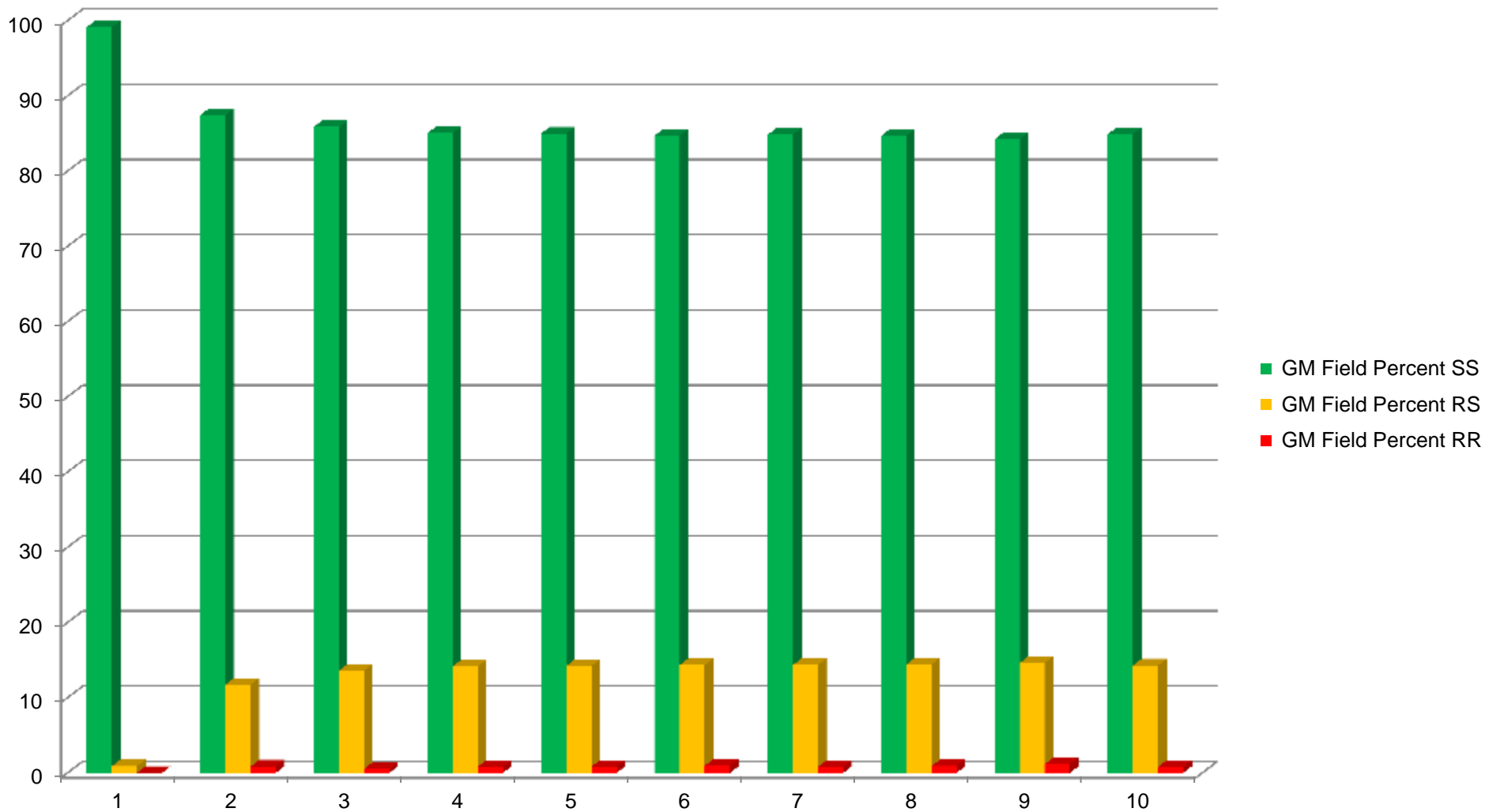
Cry 34/35



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

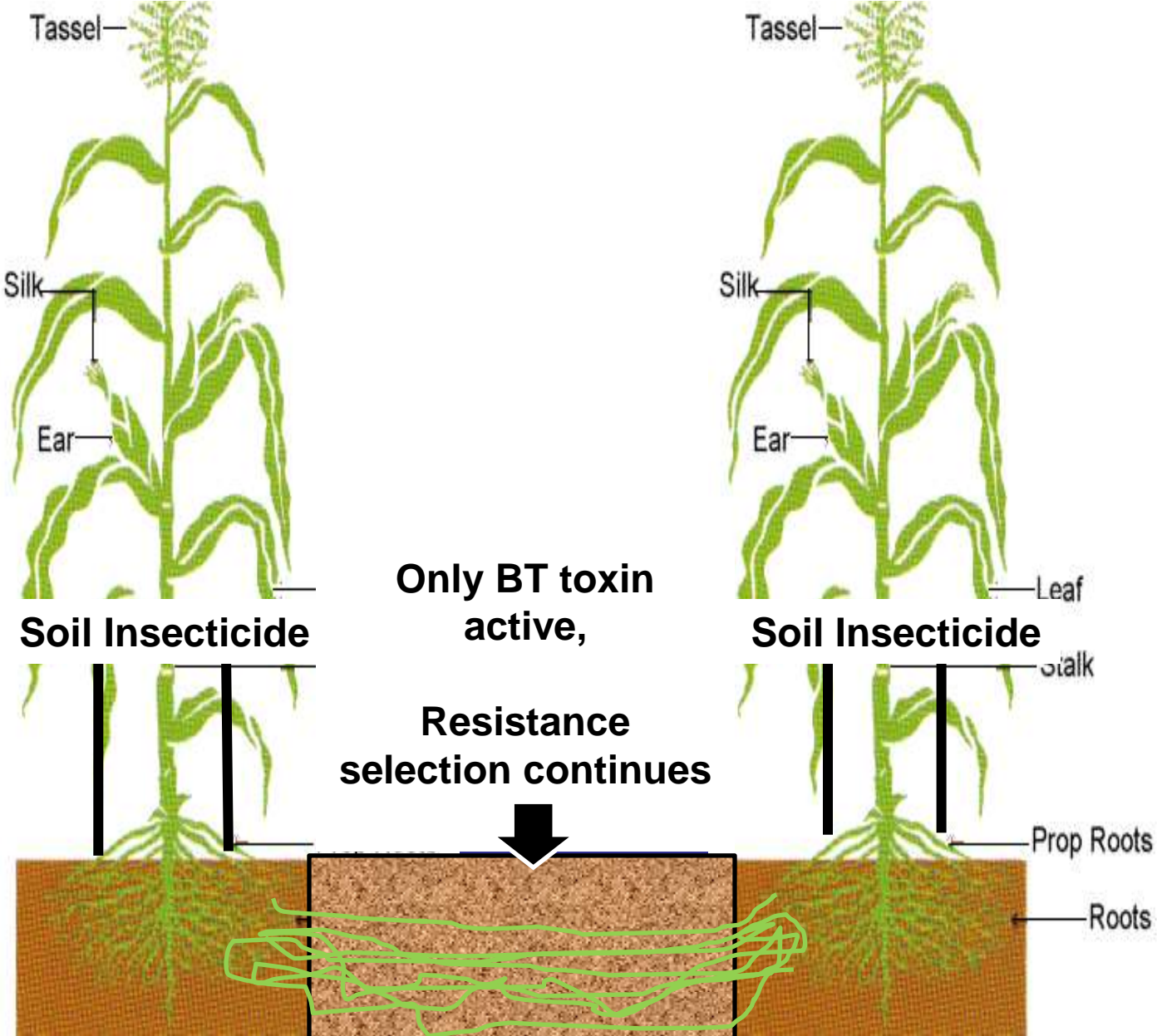
ROTATE! ROTATE! ROTATE!

DO NOT PLANT SMART STAK!

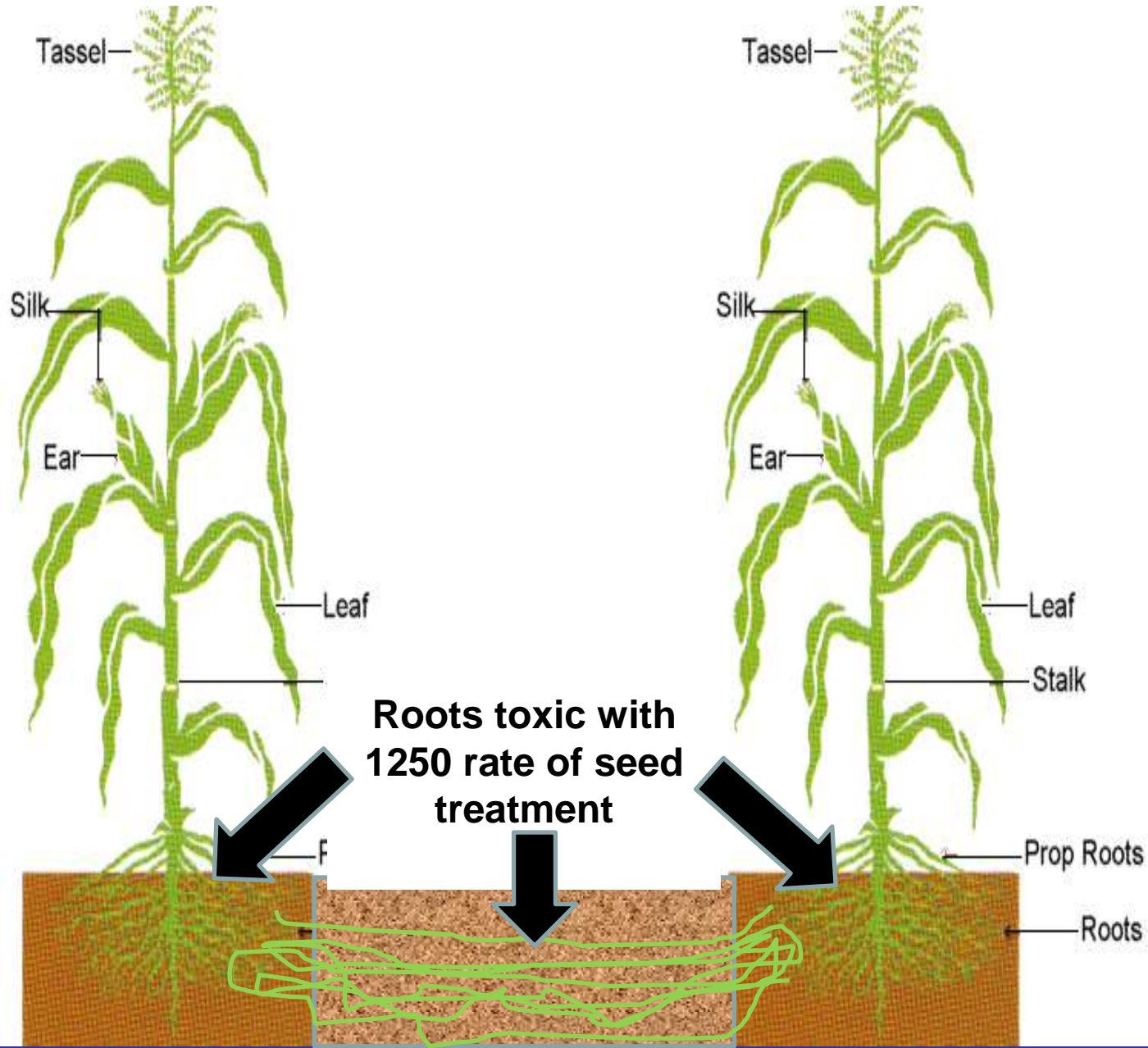
(5% refuge, only 1 toxin working)

**Do Not Layer a soil insecticide
over a failing BT event**

Layering Soil Insecticide Over a BT Toxin



1250 Seed Treatment layered over BT Toxin



Fields with Control Problems

If corn needs to be planted:

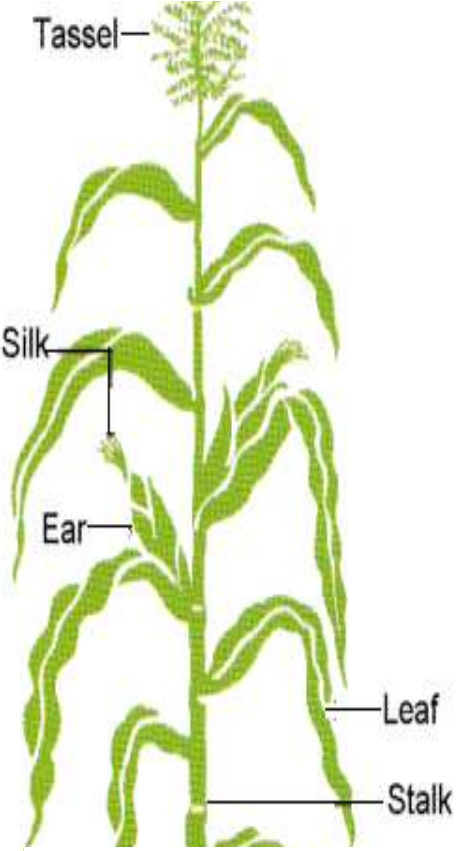
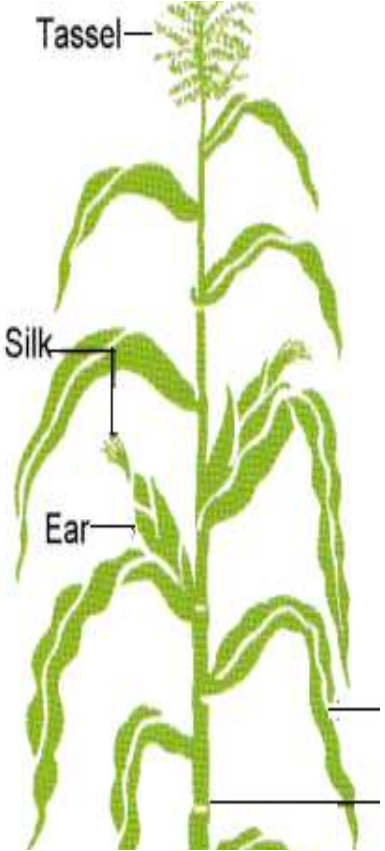
Conventional corn + insecticide

(1250 seed treatment or soil insecticide)

Herculex-Rootworm (Cry 34/35)

with 10% RIB (Refuge in a Bag)

Soil Insecticide Over Conventional Corn

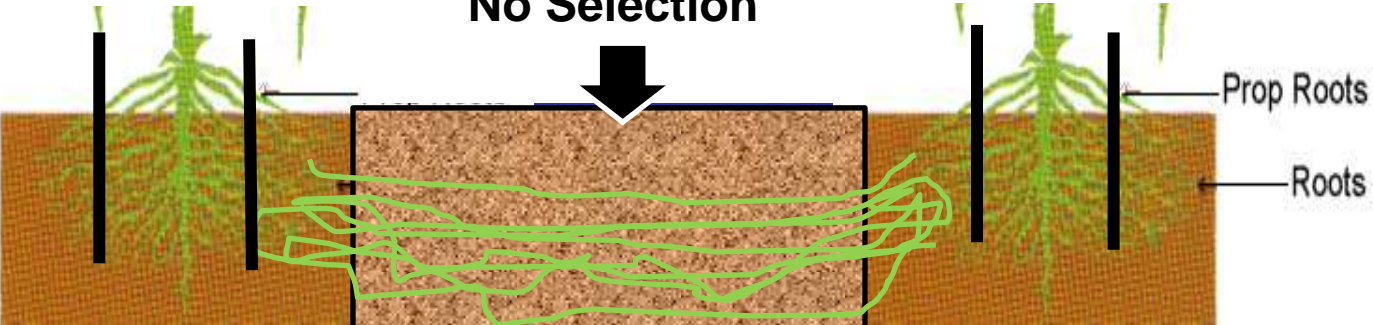


Soil Insecticide
Refuge

Soil Insecticide

Soil Insecticide

No Selection



Corn Rootworm Damage

**Year of
Corn Production**

**% Acreage over
Threshold**

1

0

2

25-35%

3

50-70%

4 +

80-100%

Strategies to Prevent Resistance

1st Year Corn: No action necessary

**2nd year Corn: High Rate of Seed
Treatment (Cruiser 1.25, Poncho 1250)**

3rd - 4th + year Corn:

1) High Rate of Seed Treatment

2) BT – Rootworm Corn

(Herculex, YieldGard)

Questions?

Discussion?