Seeds of Change: Can Mutant Rootworms Defeat Our Current Efforts to Control Them with Bt Corn?

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Background

- Host plant resistance has always been considered one of the foundations of IPM
- Transgenic insecticidal corn allows us to achieve some of our traditional goals
- The problem is that stakeholders must wisely and rationally use Bt corn

New Strategies

- Blocks of single-toxin Bt and non-toxic seed have been planted by growers for several years

- Now growers and seed companies are about to experiment with two-toxin pyramids and seed mixtures.

Background

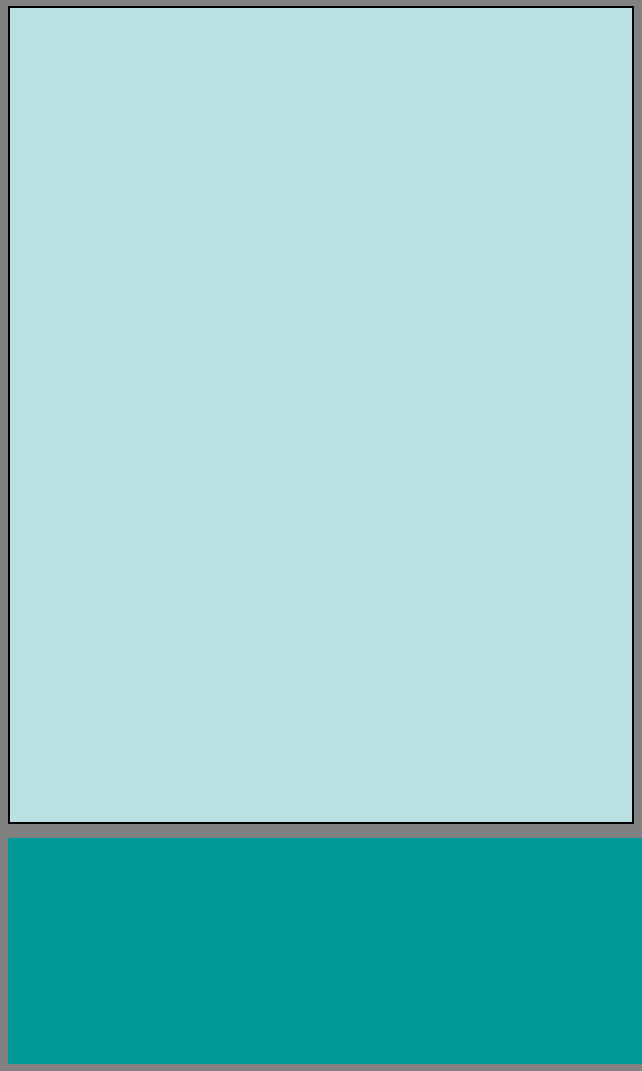
- WCR has evolved resistance to chemical insecticides and to crop rotation.
- The more effective the pest control, the greater the probability of resistance evolution
- Don’t bet against the rootworm!

Background

- Since 2001, Onstad has modeled and analyzed WCR IRM using both block and seed-blend refuges in areas with and without rotation-resistant WCR.
- Now SmartStax double-toxin corn has been approved by EPA (with block refuge) and seed blends of single-toxin corn have been proposed by Pioneer Hi-Bred.

Objectives

- Analyze models of WCR that will infest approved and proposed transgenic insecticidal corn hybrids
- Evaluate resistance management (IRM) strategies for delaying evolution of resistance to Bt corn



First Model

- Corn with two insecticidal traits (pyramid)

(some corn may be older hybrids with single toxin)

Refuge varies from 5% currently approved for Monsanto/Dow SmartStax to

20% currently required for single trait corn

(Refuge has no Bt toxin in plants)

First Model Assumptions

USEPA estimates of Bt mortality for SS

Cry34/35Ab1 0.9420-0.9918,

Cry3Bb1 is 0.962 - 0.9996,

both traits 0.9822-0.9997.

Thus we modeled SS|SS mortality as the maximum of two in pyramid and made each 0.999

Why don’t toxins work independently and completely?

- Interference during expression in plant?
- Inadequate energy in plant?

- Interference of one toxin with another in insect?
- Limited target sites in insect?

Assumptions of First Model

- Initial resistance-allele frequency=0.0001
- Resistance confers 100% survival on Bt corn
- Insecticide mortality is 70% if used
- 100% compliance with refuge requirements
- Uniform distribution of adult beetles in every block of corn (either Bt corn or refuge)
- Female beetles mate before they disperse
- Female beetles disperse to lay eggs

Single-Trait Bt Corn

- Years to 50% R-allele frequency with block refuges
-

	Dominance of R allele	
Refuge	0.01	0.5
No insecticide use in refuge		
5%	35	4
10%	38	5
20%	43	6
Insecticide use every year		
5%	18	4
10%	34	4
20%	43	5

Pyramided Bt Corn

- Years to 50% R-allele frequency with block refuges
- Dominance is always 0.5 (additive)
-
- No insecticide use in refuge
- 5% 12
- 20% 15

- Insecticide use
- 5% 8 same as sequential use
- 20% 14

Pyramided Bt Corn Independent Toxins

- Years to 50% R-allele frequency with block refuges
- Dominance is always 0.5 (additive)
-
- No insecticide use in refuge
- 5% 18 instead of 12
- 20% 23 instead of 15

- Insecticide use
- 5% 11 instead of 8
- 20% 22 instead of14

Pyramided and Single Trait Bt Corn in Landscape

- Years to 50% R-allele frequency with block refuges
- Dominance is always 0.5 (additive)
- Half of cornfields remain single-trait

Pyramid refuge	Single-trait refuge	Years to resistance
20%	20%	15 and 8
5%	20%	14 and 7

- Faster evolution with inadequate compliance

Conclusions from First Model

- We must understand dominance of resistance as well as the mortality caused by more than one toxin trait in Bt corn.
- Insecticide use in refuges becomes more important as refuge size decreases.
- It is possible sequential use of Bt toxins over years may be just as good for IRM as pyramiding toxin traits.

Conclusions from First Model

- Planting significant amounts of single-trait Bt corn (expressing one of pyramided toxins) in same region as pyramided Bt corn, may reduce durability of pyramided corn.
- Rootworm evolves resistance to single-trait first then only must overcome second trait to defeat pyramid.

Second Model

- Created by Pioneer Hi-Bred team that included Onstad as consultant. (Pan, Stanley, Flexner et al.)
- Seed blend of single-toxin corn (Cry34Ab1/Cry35Ab1) mixed with refuge seed.
- Comparisons to block refuge scenarios

Second Model

- Model of WCR differs from First Model by explicitly modeling adult dispersal and daily emergence and behavior of beetles.

- This model was used to evaluate management of single resistance gene with major effect (gene confers 100% survival)

Second Model Assumptions

- Mortality of susceptible WCR=0.9875
- Dominance of resistance allele=0.05
- Initial resistance-allele frequency=0.001
- Female beetles mate before they disperse
- Female beetles disperse to lay eggs
- 0.75% of seeds in Bt cornfield are not Bt

Results of Second Model

- Resistance – Number of years until 50% R allele frequency in WCR population

Refuge type	Compliance	
5% blended refuge,	100%	10 years
20% block moved annually,	70%	7 years
No refuge,	0%	5 years

Results of Second Model

- Results are sensitive to refuge location and farmer compliance
- 20% Block refuge, Compliance
- Fixed 100% >20 years
- Fixed 70% 10 years
- Moved every 2 years, 100% 9 years
- Moved annually 100% 8 years

- Note male dispersal is greater in these simulations than in standard simulations

Conclusions of Second Model

- Based on the results produced by the Pioneer/Onstad team, we concluded that a 5% seed blend (refuge-in-the-bag) was just as good if not better than a 20% block refuge for delaying resistance to single-toxin (Cry34Ab1/Cry35Ab1) corn.

- Compliance by growers and dispersal of beetles across cornfields are important.

Summary

- Seed blend simplifies compliance and equalizes quality of refuge and Bt corn plants.
- 5% refuge is reasonable given typical insensitivity of WCR evolution to refuge levels.
- Block refuge location and insecticide use in block refuges remain important issues for WCR IRM.

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