Managing Western Corn Rootworm Resistance to Bt on the Fringe

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*** These recommendations were developed jointly with field crop extension entomologists from Michigan, Ohio, Ontario, New York and Pennsylvania**

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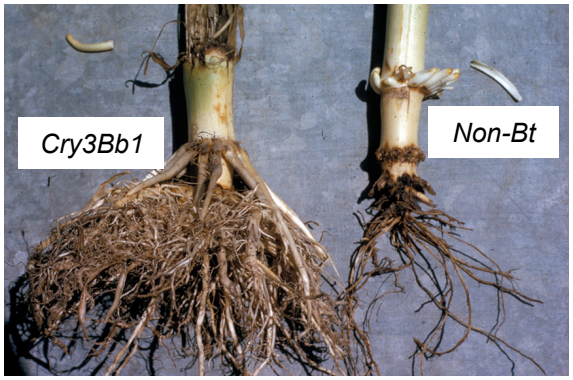
Brief History of Rootworm Bt Corn

The first Bt toxin for rootworm control, Cry3Bb1, was sold in Yieldgard Rootworm hybrids in 2003, then combined with corn borer Bt traits and/or herbicide tolerance genes in YieldGard Plus, VT Triple, and Genuity VT TriplePro. By 2010, Cry3Bb1 was part of a multi-trait pyramid in SmartStax (with Cry34/35Ab1) for rootworm control. The approval of pyramids led to a reduction in refuge from 20% to 5%. EPA also approved refuges in-the-bag for some traits.



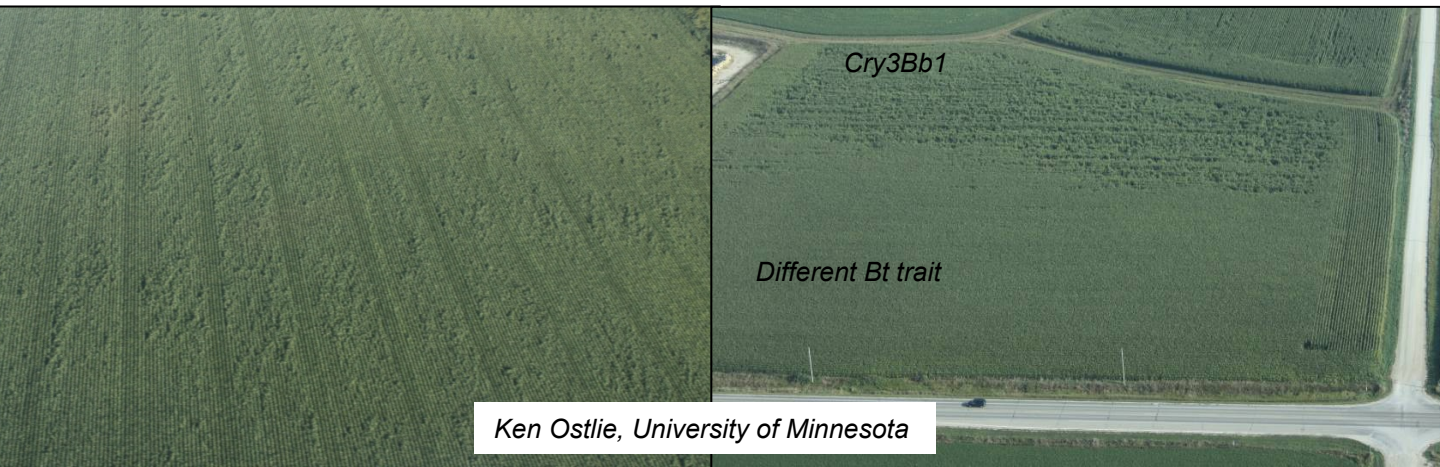
Cry3Bb1 corn root compared to heavily damaged conventional non-treated corn roots from a continuous corn field. In Indiana, Cry3Bb1 typically provides equal or better protection of roots compared to an insecticide.

Performance problems with Cry3Bb1 (fields with excessive root damage and lodging) were first reported in southern Minnesota and eastern Iowa in 2009. The number of problem fields increased in 2010 and 2011. Using a combination of field and laboratory studies over multiple field seasons, entomologists from Iowa State University showed that western corn rootworm larvae from problem fields in Iowa survived better on Cry3Bb1 corn than larvae from fields without performance problems. Corn entomologists in the Midwest now agree that this is evidence of field-evolved resistance to Cry3Bb1 by western corn rootworm. ***In 2012, the number of fields with suspected resistance increased in Iowa and Minnesota, with additional reports from fields in Colorado, Illinois, Kansas, Missouri, Nebraska, South Dakota, and Wisconsin.***

Aerial photos of Cry3Bb1 fields with unexpected rootworm damage – Minnesota, 2009

20-row strips of Cry3Bb1 had significantly more lodging and root damage compared to 4-row refuge strips treated with soil insecticide.

The portion of a field with Cry3Bb1 corn was heavily lodged compared to the rest of the field planted to a different type of rootworm Bt.



Ken Ostlie, University of Minnesota

Development and Management of Resistance in the Focus Area

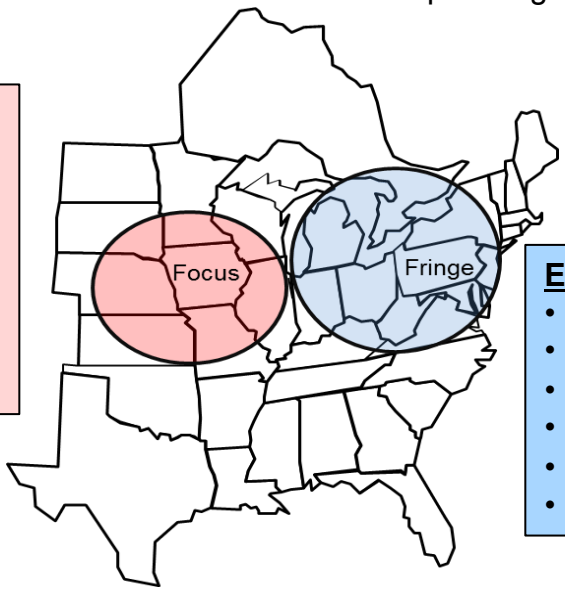
Agricultural production in the central corn belt is characterized by intensive corn cultivation coupled with low crop and landscape diversity. ***Rootworm resistance in this area appears to have arisen independently in single fields.*** All problem fields reported so far share the following common characteristics:

- planting **multiple years** of **continuous corn**
- using the **same (Cry3Bb1) Bt trait** year-after-year

Refuge compliance was sometimes also a problem (no/not enough refuge, or refuge too far from the Bt field) on farms with unexpected damage.

Continuous corn fields typically have high rootworm pressure, which maximizes resistance development because selection pressure is applied to large rootworm populations over a wide area, year-after-year. Since any genes for Cry3Bb1 resistance - even if rare - were likely present in rootworm populations across the Corn Belt, it was possible for resistance to evolve independently, at multiple locations, and across several states (as opposed to spreading from a single point-source). The pattern of problem fields suggests that this is happening in the central Corn Belt in a focus area with intensive production of continuous corn expressing Cry3Bb1.

Central Corn Belt (Focus)
- Intensive corn production
- Low crop diversity
- Low landscape diversity
- Less crop rotation
- Large fields/ farms
- *Numerous reports of problem fields*



Eastern Corn Belt (Fringe)
- Higher crop diversity
- Greater landscape diversity
- More crop rotation
- Less irrigated corn
- Smaller fields/ farms
- *Few reports of problem fields*

Status of Resistance in the Fringe Area

In the Eastern Corn Belt, agricultural production differs in important ways from the central U.S. The east has higher crop and landscape diversity, more crop rotation, lower levels of irrigated corn, and smaller field sizes. However, we can assume that the genetic basis for Cry3Bb1 resistance is present in rootworm populations in this area, so there is the potential for developing resistance in fields planted to continuous corn with the same Bt rootworm trait. Thus far, rootworm resistance to Bt corn in this 'fringe' area (Indiana, Michigan, New York, Pennsylvania, Ohio, Ontario) is rare. To our knowledge, only a handful of performance problems have been reported.

The situation in the Central Corn Belt is already severe. But entomologists in the Eastern Corn Belt believe that early-identification and elimination of point sources by crop rotation may slow the development and movement of resistance in the fringe. ***Given the speed with which Cry3Bb1 resistance has evolved and spread in the west, it makes sense to take a stricter, proactive approach in Indiana and surrounding states, starting with rotation when a problem is first detected.***

Our goal is to preserve the usefulness of Cry3Bb1 and other Bt rootworm traits for as long as possible.

Signs of a Potential Resistance Problem in Bt Corn

You, or your family, neighbors, or employees will likely be the first to see or hear about a potential problem field. Farms with continuous corn production, and specifically fields planted to the same Bt year-after-year, are most at-risk for developing a resistant population and should be targeted for scouting during the field season. Below are some warning signs of potential rootworm resistance. Contact your seed dealer and Purdue Extension immediately if you suspect a problem, so that the location can be sampled, documented, and tested when rootworms are still active.

Large number of WCR beetles in the field do not indicate resistance, but problem fields in the west often have large adult populations.

A key initial step is to confirm that plants are indeed expressing Bt toxins targeting rootworms. This is done by grinding and testing leaf tissue to detect the specific type of Bt protein. A positive test is indicated by two lines appearing on the strip. Seed company personnel usually have access to strips for testing.

For confirmation of resistance, beetles are sometimes collected for egg laying. Eggs must be held under cold conditions for several months before they hatch. Larvae can then be placed on Bt plants in a greenhouse to determine survival compared to a susceptible lab population. These steps usually take several months to complete.

A positive test for Cry3Bb

Managing Suspected Western Corn Rootworm Resistance in Bt Corn

After you report a problem field, it is important to document the field history, level of rootworm damage, and beetle population and to confirm Bt expression. If the beetle pressure and damage are high, a rootworm-specific Bt toxin is present in plants, and there is no other explanation for the failure of the hybrid, resistance is suspected. **Our best recommendations for this situation is below:**

CHECK nearby at-risk fields this year: If resistance is suspected in one field, it may also be occurring in nearby corn fields. Scout these nearby fields immediately (look for lodging and dig/inspect roots in June-July) to detect a problem, and handle them the same way as the original field.

ROTATE next year: **Our sole recommendation for fields with suspected resistance is crop rotation.** Rotation can be to soybean or any other non-host crop (dry beans, alfalfa, wheat). If this cannot be accomplished on-farm, consider working with a neighbor or renter to trade ground for a season. ***All rootworm eggs that hatch the following year will die if corn isn't present, making rotation the single, most-effective way to reduce the spread of resistance.*** The goal is to eliminate point sources before they can spread. In addition, consider rotating nearby continuous corn fields as a precaution. If this cannot be done, these fields should at least be monitored the following year, and rotated as soon as practical as a precautionary step.

Note that in some parts of Indiana, rotation-resistant ("variant") corn rootworms may lay eggs in soybeans, resulting in some damage in first-year corn. This does not change our recommendation. Rotation to a non-host crop is still the single most powerful way to reduce rootworms over a large area. Rootworm larvae cannot survive and develop without corn in the field.

ELIMINATE volunteer corn next year: For rotation to be effective, there must be early and complete control of volunteer corn the next year. Use the Weed Control Guide for Ohio and Indiana (WS16) or work with an ag professional to develop a herbicide program for the next season in the rotational crop.

Best Management Practices to Reduce Risk of Resistance to Bt

- **Keep crop rotation in your system**. If you plant continuous corn, make it a point to rotate fields on a schedule every 3 to 4 years. Rotation not only eliminates that rootworm population the following season, but it has many agronomic benefits.
- If you must grow continuous corn, **rotate modes of action,** just as you would with herbicides. Avoid using the same Bt year-after-year by planting a hybrid with a different Bt trait, or multiple Bt traits, for rootworm. If possible, plant a conventional hybrid with an insecticide to avoid Bt toxins entirely for a year.
- Note that the **use of a soil insecticide on top of a Bt hybrid is not recommended** by corn entomologists in the Midwest. Research trials in other states show little or no yield benefit from applying soil insecticides to Bt corn. Insecticides may also mask a problem with the Bt hybrid.
- Detect problems early; **scout** continuous fields for beetles and damage in mid
- to late-July, and **report** problems immediately.