



MANAGING WESTERN CORN ROOTWORM RESISTANCE TO BT ON THE FRINGE

BRIEF HISTORY OF ROOTWORM BT CORN

The first Bt toxin for corn rootworm control, Cry3Bb1, was sold as Yieldgard Rootworm in 2003, then the same toxin was combined with a Bt trait targeting European corn borer 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 a seed mixture of Bt and non-Bt seeds, commonly referred to as “refuge in-the-bag.”

Performance problems with Cry3Bb1 (fields with excessive root damage and lodging) were first reported to the Environmental Protection Agency in 2004, but became more widespread and were brought to the attention of extension entomologists in 2009 in southern Minnesota and eastern Iowa when more than 30,000 acres of corn were affected. The number of acres affected was approximately the same in 2010 but then greatly increased in 2011 and 2012. Using a combination of field and laboratory studies over multiple field seasons, entomologists from Iowa State University demonstrated 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, and reports also came in from Colorado, Illinois, Kansas, Missouri, Nebraska, South Dakota, and Wisconsin.

Fig. 1. Aerial photos of Cry3Bb1 fields with unexpected rootworm damage – Minnesota, 2009. A) Twenty-row strips of Cry3Bb1 corn had significantly more lodging and root damage compared to 4-row refuge strips treated with soil insecticide. B) 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. (Photos from Ken Ostlie, Univ. of MN).



A. (Above), B. (Below)

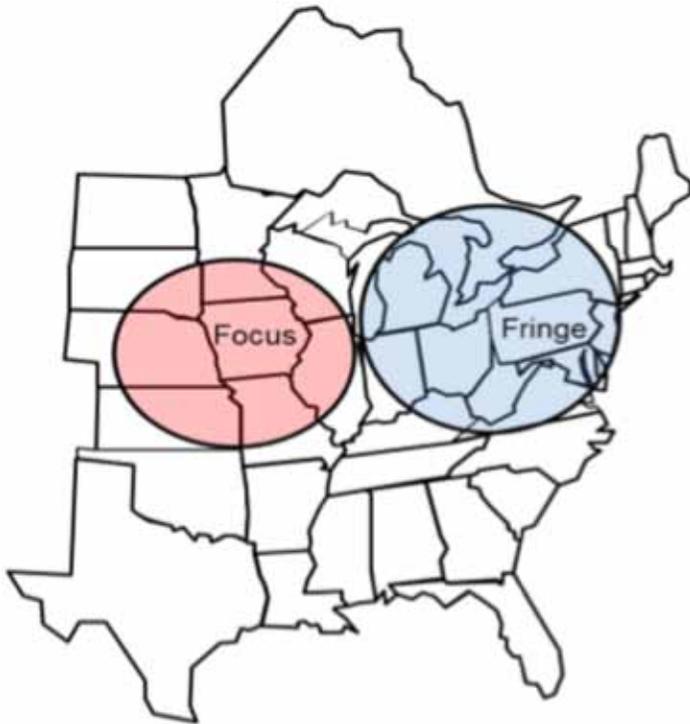


CORN BELT (FOCUS AREA)

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 (point sources). Problem fields share the following characteristics:

- Planting corn continuously for multiple years (typically more than four years)
- Using the same (Cry3Bb1) Bt trait year after year
- Refuge compliance was sometimes problematic (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 when control tactics are implemented because selection pressure is applied to a huge rootworm population over a wide area, year after year. Since genes for Cry3Bb1 resistance—even if rare—must have been present in rootworm populations across the Central Corn Belt, when strong selection pressure was imposed resistance evolved independently at multiple locations 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, where Bt-resistant rootworm populations have developed. The east has higher crop and landscape diversity, more crop rotation, lower levels of irrigated corn, and smaller field/farm sizes. Even in this different setting, however, we can assume that genes for resistance to Cry3Bb1 are present in rootworm populations; therefore, there is a similar potential for rootworms to develop resistance Bt rootworm trait in continuous corn fields. 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.

While the situation in the Central Corn Belt is already severe, entomologists in the Eastern Corn Belt believe that early-identification and elimination of point sources by crop rotation is the best approach to slowing the development and movement of resistance in the fringe. Given the speed with which Cry3Bb1 resistance evolved and spread in the west, it is common sense to take a strict, proactive approach in the Eastern Corn Belt, and rotate 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 at most risk for developing resistant rootworm populations. These fields should be targeted for

scouting during the field season. Contact your seed dealer and Penn State Extension immediately if you suspect a problem, so that the location can be sampled, documented, and tested when rootworms are still active. Below are some warning signs of potential rootworm resistance:

1. *Large number of beetles in the field, possibly leaf feeding and damaging silks, resulting in poor pollination.*

- Beetle numbers alone do not indicate resistance, but problem fields in the Central Corn Belt do tend to have large adult populations.

2. *Unexpected lodging and root damage that cannot be explained by an agronomic or environmental problem, or presence of another root-feeding pest.*

Fig. 2. Warning signs of rootworm populations that may be resistant to Bt varieties: A) Large numbers of adult beetles, damaging silks and leaves. B) Goosenecked or lodged corn plants; C) Extensive pruning of roots. (Photos from Chris DiFonzo, MSU)

C.. (Below)



A. (Above), B. (Below)



A key step to identifying whether or not a rootworm infestation may be due to resistant rootworm populations is confirming that plants are indeed expressing Bt toxin. This is done by grinding and testing leaf tissue to detect the specific type of Bt. Seed companies and field crop entomologists at Penn State usually have access to strips for testing. For final confirmation of resistance, beetles need to be collected for egg laying. Eggs then 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. However, this step is usually not completed before the next season.

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 is high, Bt 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 are:

1. CHECK nearby at-risk fields this year

If resistance is suspected in one field, it may also be occurring in similarly managed, nearby, continuous corn fields. Scout these nearby fields immediately (look for lodging, dig roots) to detect a problem, and handle them the same way as the original field.

2. ROTATE next year

Our sole recommendation for fields with suspected resistance is to rotate. Rotation can be to soybean or any other non-host crop (alfalfa, canola, snap beans, etc.). 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 is not present, making rotation the single, most-effective way to reduce the spread of resistance. The goal

is to eliminate point sources. In addition, as a precaution consider rotating nearby continuous corn fields. If this cannot be done, these fields should at least be monitored the following year, and rotated as soon as practical.

Note: In Pennsylvania and the rest of the Mid-Atlantic region, unlike the much of the Central Corn Belt, we have no evidence of rotational-resistant corn rootworms that lay eggs in soybeans.

3. 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 Penn State Agronomy Guide or work with an agricultural professional to develop a herbicide program for the next season in the rotational crop.

Best Management Practices to Reduce Risk of Resistance to Bt

Even before you detect a problem, you can help preserve the efficacy of Bt traits in corn by doing the following:

1. **Rotate your crops.** 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.
2. 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. Alternatively, plant a conventional hybrid with a soil insecticide.

Note: the use of a soil insecticide on top of a Bt hybrid is not recommended by corn entomologists. 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.

3. Detect problems early; **scout** continuous fields for beetles and damage in mid to late-July, and **report** problems immediately.

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