

Insect Resistance Management and Bt Corn in the U.S.

Summary

- Pioneer now offers several types of hybrids with Bt traits:
 - Hybrids with the Herculex[®] I (HX1) or YieldGard[®] Corn Borer (YGCB) trait for controlling *corn borers* (HX1 also controls several other insect pests).
 - Hybrids with the Herculex RW (HXRW) or YieldGard Rootworm (YGRW) trait for *corn rootworm* control.
 - Hybrids with the *stacked* Bt traits of HX1 and HXRW that control corn borer and corn rootworm within the same plant. This stack is called Herculex XTRA (HXX).
 - Hybrids with the *stacked* Bt traits of YGCB and YGRW that control corn borer and corn rootworm within the same plant. This stack is called YieldGard Plus (YGPL).
- Growers using these technologies must plant a *refuge*. A refuge is an important component of Insect Resistance Management (IRM) plans to help deter development of resistance to Bt traits by target insects.
- Complying with EPA-mandated IRM requirements is a regulatory and stewardship obligation. Failure to do so can result in growers losing access to Bt technology.
- Although the EPA has tried to keep refuge requirements as similar as possible, there are refuge differences between Bt hybrids for corn borer, corn rootworm and both (stacks).
- This article explains the concepts of insect resistance management, how to establish an effective refuge, and the importance of monitoring fields and reporting damage.



Corn borer (left) and corn rootworm (right) are two devastating pests of corn now controlled by Bt traits¹.

Hybrids with Bt traits have proven very effective for managing their targeted insect pests. However, insects are notorious for population changes that ultimately overcome their intended control measures. To reduce the probability of insects developing resistance to Bt technology, the Environmental Protection Agency (EPA) has mandated that certain provisions be placed on the use of Bt corn products. One of

the most important EPA requirements is that growers implement an IRM program, including planting a refuge.

In addition to IRM requirements for growers, the EPA requires companies selling Bt technology to educate their sales force and customers in meeting IRM guidelines, and to assess IRM compliance by its customers. These companies must also conduct research on IRM and closely monitor and report any development of resistant insect populations.

IRM Requirements

Pioneer requires that all growers purchasing hybrids with a Bt trait sign a *Pioneer Hi-Bred Technology Agreement*. By signing it, the grower agrees to implement an IRM program as specified in the Product Use Guide (PUG). The IRM program includes planting a corn refuge, following EPA-mandated use requirements and other steps outlined in the PUG. Failure to follow these IRM requirements can result in the grower losing access to Bt technology.

IRM Compliance Assurance Program (CAP)

Complying with IRM requirements is a regulatory and stewardship obligation critical to preserving the longevity and effectiveness of Bt corn technology. The EPA requires Bt corn seed providers to conduct random on-farm visits as part of a comprehensive Compliance Assurance Program (CAP) to assess whether growers are following the IRM requirements.

The CAP also outlines consistent standards developed by EPA and Bt corn registrants to respond to growers who have not followed the IRM requirements to bring them into full compliance. These responses include:

- Notifying the grower by letter of IRM compliance deviations.
- Conducting a compliance assistance visit with the grower prior to planting to assist the grower in planning and implementing a proper IRM program.
- Conducting a compliance assessment visit with the grower the following growing season to assess IRM compliance.
- Providing the grower additional IRM educational materials.
- Denying access of Bt corn to growers who have been out of compliance in two consecutive years.

Establishing an Effective Refuge

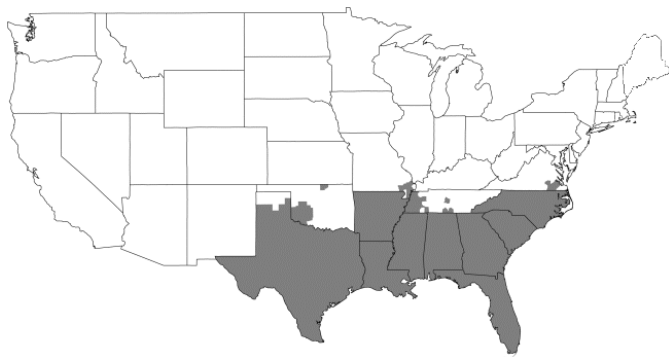
The goal of a refuge is to ensure that susceptible insects are available in sufficient numbers to mate with any resistant survivors from Bt fields. Susceptible by resistant matings result in susceptible offspring and reduce the probability of the

buildup of resistant insect populations. To be effective, the refuge must be the correct size and distance from the Bt field, and be planted with a similar hybrid under similar management practices.

Refuge Requirements

In **non-cotton** growing areas, the refuge requirements for corn borer-Bt and corn rootworm-Bt products are both 20% of corn acres planted. In **cotton** growing areas, the refuge requirements for corn borer-Bt products are 50% and for corn rootworm-Bt products are 20%.

% Refuge Requirement for YGCB or HX1 Hybrids*



Refuge Requirement:

- 20% for corn borer and CRW
- 50% for corn borer and 20% for CRW

*Not all products are approved in all geographies.

Refuge Placement

Appropriate refuges must be planted on every farm with a field that contains Bt corn – that is, you cannot use a neighbor’s field to satisfy the refuge requirements.

Select Similar Hybrid for Refuge

One key to establishing an effective refuge is selecting an appropriate hybrid. Insect behavior requires that the refuge hybrid be agronomically similar to the Bt hybrid. This helps ensure that the refuge hybrid attracts adult insects to the same extent as the Bt field.

To ensure similar growth and development, choose a refuge hybrid that is as similar as possible to the Bt hybrid. The refuge hybrid should match the Bt hybrid in maturity (especially silk CRM), early vigor and plant height.

Manage Refuge the Same as Bt Hybrid

Management practices in the refuge acres and Bt corn acres should be as similar as possible to promote parallel hybrid

development. Planting the refuge at the same time as the Bt hybrid is the best way to coordinate initial development. Fertility programs, including starter and sidedress, should be similar. The tillage system should also be very much the same in the Bt field and the refuge. Different tillage operations may result in dissimilar residue levels on the soil surface. Soil temperature differences could then lead to dramatic early development differences between the Bt field and the refuge. Reducing inputs on the refuge or planting it on marginal land also decreases the effectiveness of the refuge.



Refuges produce populations of susceptible insects to mate with any resistant survivors from Bt fields¹.

Refuge Layouts

Because Bt corn growers use different management practices, considerable flexibility is allowed in laying out the refuge. Several of these refuge patterns are described below:

Refuge within the Bt field:

- Block
- Perimeter or Border
- Split Planter

Refuge separate from Bt field:

- For corn borer-Bt products, a separate field planted within 1/2 mile of each Bt corn field (and preferably within 1/4 mile).
- For corn rootworm-Bt products, a separate field adjacent to Bt hybrids. Can be separated by a ditch or a road, but not by another field.

(Surveys indicate that most farmers plant the refuge within the Bt field. This closer proximity increases the effectiveness of the refuge.)

Seed mixtures are not approved for use with any Bt hybrids to satisfy grower refuge requirements.

Common and Separate Options for Stacked Bt Refuge

For stacked trait Bt products such as HXX, two different refuge options exist. A **common refuge** is designed to address both corn borers and corn rootworms with one refuge. A **separate refuge** is designed to work independently for each insect, thus a refuge exists for corn borers and another refuge exists for corn rootworms.





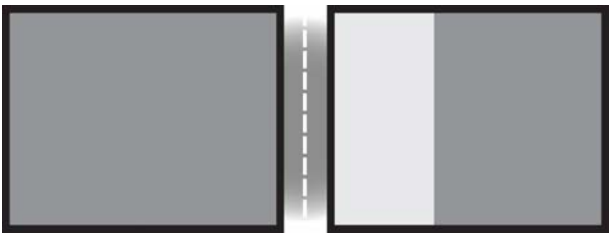
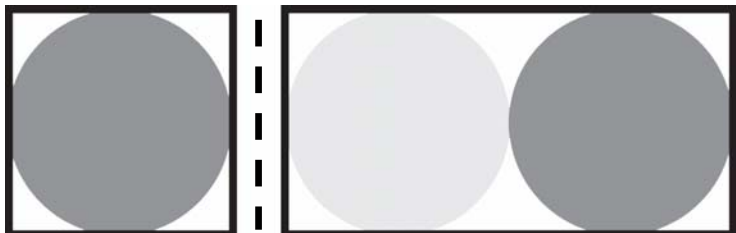
There are some important differences between the two kinds of Bt traits that provide protection of corn borer and corn rootworm. Table 1 shows specific refuge requirements for both Bt technologies on their own and as a stacked trait.

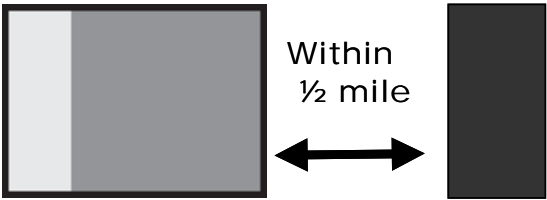
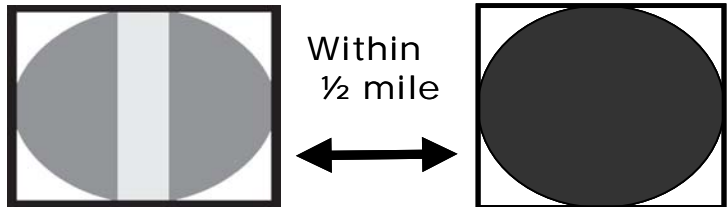
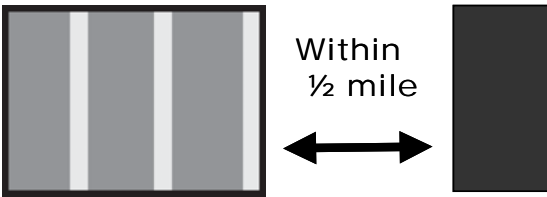

Table 1. Refuge requirements for corn insect-resistant technologies in the U.S.

	Corn Borer-Bt (HX1, YGCB)	Corn Rootworm-Bt (HXRW, YGRW)	Stacked* Bt Common Refuge (HXX or YGPL)	Stacked* Bt Separate Refuge (HXX or YGPL)
Refuge % Non-Cotton Areas	20% of corn acres planted.	20% of corn acres planted.	20% of corn acres planted.	20% of corn acres planted.
Refuge % Cotton Areas	50% of corn acres planted.	20% of corn acres planted.	50% of corn acres planted.	Corn borer refuge: 50% of corn acres planted. Corn rootworm refuge: 20% of corn acres planted.
Distance Requirement	Within 1/2 mile (and preferably within 1/4 mile) of the Bt field.	In same field as or adjacent to Bt hybrids. Can be separated by a ditch or a road, but not by another field.	In same field as or adjacent to Bt hybrids. Can be separated by a ditch or a road, but not by another field.	Corn borer refuge: Within 1/2 mile (and preferably within 1/4 mile) of the Bt field. Corn rootworm refuge: In same field as or adjacent to Bt hybrids. Can be separated by a ditch or a road, but not by another field.
Strip Width Requirements	At least <u>4</u> rows wide (<u>6</u> rows preferred).	For HXRW at least <u>4</u> rows wide (<u>6</u> rows preferred). For YGRW at least <u>6</u> rows wide (<u>12</u> rows preferred).	For HXX at least <u>4</u> rows wide (<u>6</u> rows preferred). For YGPL at least <u>6</u> rows wide (<u>12</u> rows preferred).	Corn borer refuge: At least <u>4</u> rows wide. Corn rootworm refuge: For HXRW at least <u>4</u> rows wide (<u>6</u> rows preferred). For YGRW at least <u>6</u> rows wide (<u>12</u> rows preferred).
Insecticide Use Within Refuge	Allowed if economic thresholds are met for any target pests. Non-Bt insecticides (e.g., Dipel) must <u>not</u> be used.	Soil-, seed- or foliar-applied insecticides for control of CRW larvae and other soil pests are allowed. Non-Bt insecticides for late-season pests (e.g., corn borer) allowed under certain conditions. See Product Use Guide for further details.	Soil-, seed- or foliar-applied insecticides for control of CRW larvae and other soil pests are allowed. Non-Bt insecticides for late-season pests (e.g., corn borer) allowed under certain conditions. See Product Use Guide for further details.	Corn borer refuge: Allowed if economic thresholds are met for any target pests. But, the HXX- or YGPL-protected Bt corn <u>does NOT</u> have to be treated. Microbial Bt insecticides (e.g., Dipel) must <u>not</u> be used. Corn rootworm refuge: Soil-, seed- or foliar-applied insecticides for control of CRW larvae and other soil pests are allowed. Non-Bt insecticides for late-season pests (e.g., corn borer) allowed under certain conditions See Product Use Guide for further details.
Refuge Hybrid Requirements	<u>Cannot</u> contain a Bt trait that controls corn borers (HX1 or YGCB). <u>Can</u> contain a Bt trait that controls corn rootworms (HXRW or YGRW).	<u>Cannot</u> contain a Bt trait that controls corn rootworms (HXRW or YGRW). <u>Can</u> contain a Bt trait for corn borers (HX1 or YGCB).	<u>Cannot</u> contain a Bt trait that controls corn borers (HX1 or YGCB) or corn rootworms (HXRW or YGRW).	Corn borer refuge: <u>Cannot</u> contain a Bt trait that controls corn borers (HX1 or YGCB). <u>Can</u> contain a Bt trait that controls corn rootworms (HXRW or YGRW). Corn rootworm refuge: <u>Cannot</u> contain a Bt trait that controls corn rootworms (HXRW or YGRW). <u>Can</u> contain a Bt trait for corn borers (HX1 or YGCB).

Refuge designs for corn borer *only* and corn rootworm *only* hybrids are not shown here but are available in the Product Use Guides (PUGs) available at <http://www.pioneer.com/biotech/irm/default.htm>. Because of the complexity of the HXX and YGPL IRM refuge requirements, these refuge configuration examples are shown below:

Refuge Examples for HXX and YGPL in the U.S.

Common Refuge Configurations			
■ HXX or YGPL		□ Refuge (e.g. conventional corn)	
			
Block Option A	Block Option B	Split-planter strips minimum rows/preferred rows: HXX 4/6	Perimeter minimum rows/preferred rows: YGPL 6/12
			
Adjacent Option A. Separated by road, path, ditch, etc., but not by another field of corn.		Adjacent Option B.	

Separate Refuge Configurations			
■ Herculex XTRA or YieldGard Plus			
■ Corn Borer Refuge - must be within ½ mile (¼ mile preferred) of HXX or YGPL and minimum of 20% non-Bt corn borer corn (in cotton-growing areas refuge must be a minimum of 50% non-Bt corn borer corn)			
□ Corn Rootworm Refuge - must be adjacent to HXX or YGPL and minimum of 20% non-Bt corn rootworm corn.			
	Block Option A		Block Option B
	Split-Planter (Strips) minimum rows/preferred rows: HXX 4/6 YGPL 6/12		Adjacent

Monitoring Fields for Resistance Development

Monitoring Bt fields for insect resistance development is an integral part of an IRM plan. If resistant populations are detected early, alternative control measures can be quickly implemented to eradicate the population and halt the spread of resistance. Because of its importance to maintain the effectiveness of Bt technology, the EPA mandates monitoring activities as a condition of registration of Bt products. Pioneer instructs customers to monitor Bt fields as they would any other field and report unexpected levels of damage to a Pioneer representative. Acres planted to Bt hybrids should be correctly marked at planting to prevent confusion when monitoring.

Unexpected damage is to be reported to the Pioneer representative, who must forward this information immediately to the Pioneer agronomist. The agronomist will view the problem area and assess the cause of the damage.

More Information

[Insect Resistance Management Online Course](#). Pioneer Hi-Bred and National Corn Growers Association.

[Product Use Guides for Pioneer Hybrids with Herculex or YieldGard Technologies](#). Pioneer Hi-Bred, Johnston, IA.

Herculex Insect Protection technologies by Dow AgroSciences and Pioneer Hi-Bred. ®Herculex is a registered trademark of Dow AgroSciences LLC.

®YieldGard is a registered trademark of Monsanto Company.

¹ Image of western corn rootworm larvae and beetle courtesy of Jim Kalisch, University of Nebraska. Image of northern corn rootworm beetle and European corn borer moth courtesy of Donald Specker, Pioneer Hi-Bred.

