

Insect Resistance Management and Refuge Requirements for Bt Corn

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Bt corn hybrids are genetically modified to contain a gene from the soil bacterium *Bacillus thuringiensis* (Bt). Many different strains of Bt have been identified and isolated as insecticide active ingredients, and each is specific for a different group of insects. One group of Bt corn hybrids offers protection against “caterpillar” pests such as European corn borer, stalk borer, and other select pests in the insect order Lepidoptera (see trait chart on back page). Another group of Bt corn hybrids offers protection against larval stages of corn rootworms.

Widespread farmer adoption of Bt corn hybrids has increased the number of acres where target insect pests are exposed to Bt active ingredients each growing season. The potential for target insect pests to develop resistance to Bt is more likely as the number of acres of Bt corn increases. Therefore an insect resistance management (IRM) plan becomes more important in preserving the usefulness of Bt traits.

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What is insect resistance management (IRM)?

The purpose of IRM is to maintain the effectiveness of Bt crops as an insect pest management tool by preventing or delaying development of insect resistance to Bt traits. The IRM plan is implemented by planting refuge corn acres on each farm where a Bt corn hybrid is planted. Refuge corn acres do not contain the Bt insect trait used in the Bt planting. The refuge must be planted to 20% of the corn acreage on each farm, and there are specific configuration and distance requirements.

Why is IRM important?

The aim of IRM is to maintain Bt susceptible insect populations by way of a refuge. A refuge provides a corn crop habitat that allows target pest insects to feed, mate and reproduce without being exposed to the Bt trait. Without a refuge, target insect populations that are exposed to Bt corn each growing season over multiple generations will eventually become resistant to Bt. Mating between Bt-susceptible insects from the refuge and potential resistant insects ensures that susceptibility to the Bt toxin is passed on to the next generation. These Bt-susceptible insects from the refuge decrease the odds that a resistant insect can emerge from a Bt corn field.

What happens if I don't plant a refuge?

Planting a refuge is required by law through the U.S. Environmental Protection Agency (EPA) as a condition of Bt corn hybrid registration and market

availability. At the time of purchase, farmers enter into a contractual agreement with the company supplying the Bt corn hybrid. The agreement obligates the farmer to plant the appropriate refuge. The first time a farmer is found noncompliant, a warning letter is issued by the company providing the Bt corn seed, followed by IRM compliance assessment the next year. Farmers who do not comply with the IRM refuge requirements in two consecutive years will be denied access to Bt corn the third year. If the EPA finds that farmers are largely noncompliant with the requirements of IRM, they have the authority to rescind registration of Bt traits.

Who checks for IRM compliance?

EPA requires the companies that register Bt corn traits to establish an industry compliance assurance program (CAP) to identify and address noncompliant farmers. Field and planting record inspections may be performed by seed companies through the EPA-mandated compliance assurance monitoring program. The purpose of CAP is to evaluate the extent of compliance among Bt corn growers, verify that IRM refuge acres are planted on-farm, and in the case of noncom-

pliance, bring growers back into compliance. CAP may use anonymous telephone surveys of Bt corn growers conducted by an independent third party, on-farm visits by trained seed company representatives to assess farmer compliance, and establish a mechanism for handling tips and complaints about farmers who may be out of compliance with their IRM obligations.

What are the refuge requirements for single Bt trait hybrids with Lepidoptera protection?

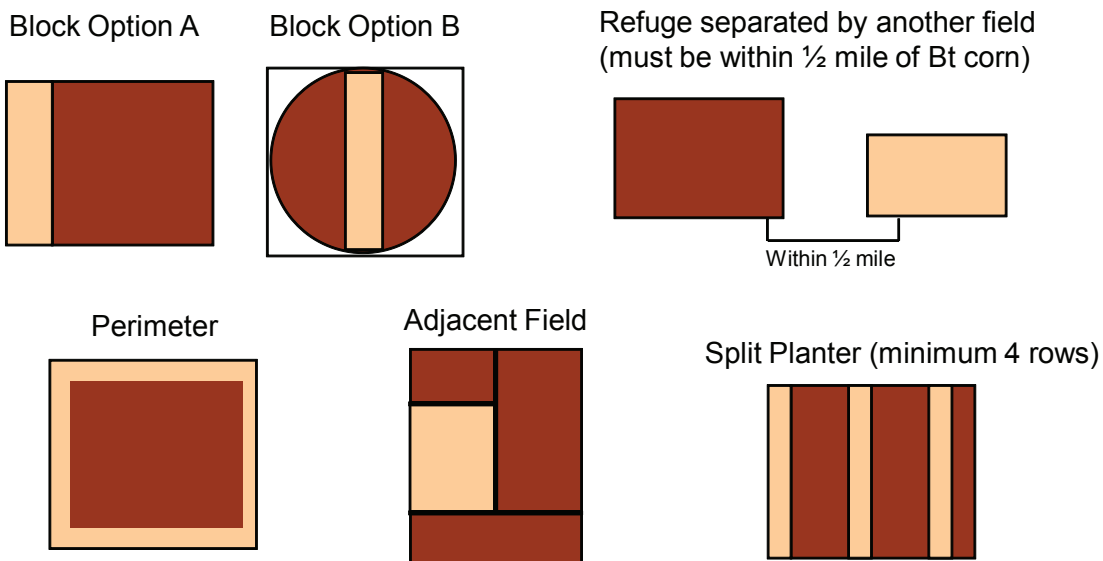
(see figure 1)

- No more than 80% of a farm's total corn acres may be planted with Bt Lepidoptera-protected hybrids.
- 20% of total corn acres (i.e., sum of Bt Lepidoptera-protected acres and Lepidoptera refuge acres) must be planted to a corn refuge that does not contain a Bt trait for control of any of the "caterpillar" pests.
- One type of Bt Lepidoptera-protected corn hybrid (e.g., YieldGard Corn Borer) cannot serve as a refuge for another (e.g., Herculex I or Agrisure CB).

1

Refuge Configuration Examples for Bt Corn Borer Corn* (single trait Bt corn hybrids with Lepidoptera protection)

■ = Bt Corn Borer Corn
 ■ = Corn Refuge



*Refuge configurations are representative examples and do not illustrate all possible configurations.

- The corn borer/Lepidoptera refuge may be a separate field within ½ mile, but must be on the same farm and managed by the same grower.
- The refuge may also be planted within the Bt corn field as a block, split planter to alternate four or more rows between Bt and refuge corn, or field perimeter planting to meet the 20% refuge requirement.
- Refuge corn can be treated with insecticide if insect pest pressure meets or exceeds economic threshold. Foliar Bt sprays cannot be applied in the refuge.

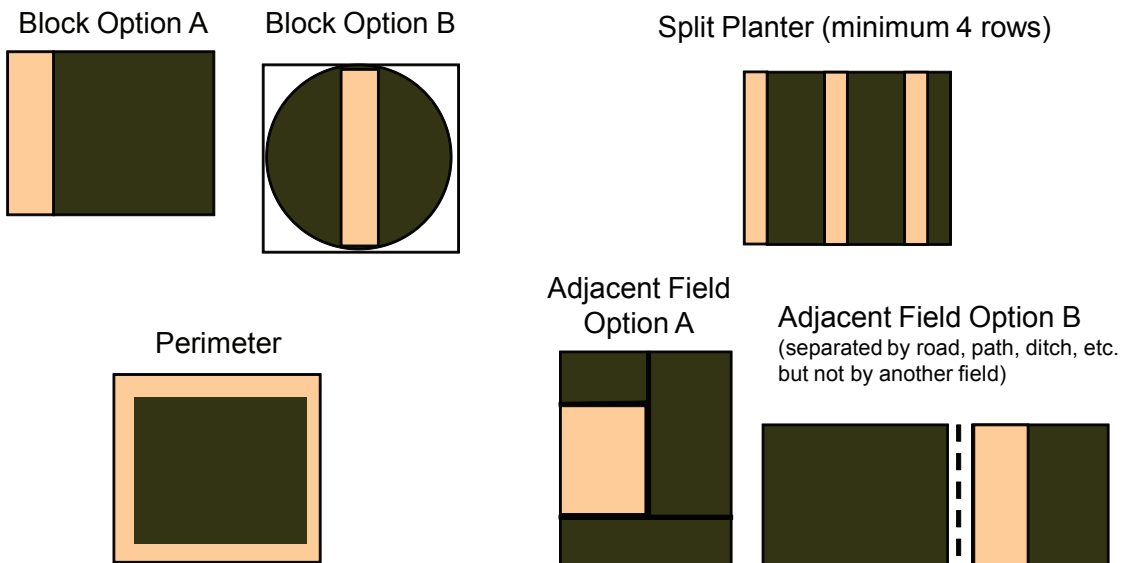
What are the refuge requirements for single Bt trait hybrids with corn rootworm protection? (see figure 2)

- No more than 80% of a farm’s total corn acres may be planted with Bt corn rootworm-protected hybrids.
 - 20% of total corn acres (i.e., sum of Bt rootworm-protected acres and corn rootworm refuge acres) must be planted to a corn refuge that does not contain a Bt trait for control of corn rootworms.
- One type of Bt corn rootworm-protected corn hybrid (e.g., Herculex RW) cannot serve as a refuge for another (e.g., Agrisure RW or YieldGard RW).
 - The corn rootworm refuge must be planted within or directly next to each Bt corn rootworm field. The corn rootworm refuge cannot be separated by another field.
 - The refuge can be planted as a block, split planter to alternate four or more rows between Bt and refuge corn, or field perimeter planting to meet the 20% refuge requirement for each field.
 - If the corn rootworm refuge is planted on rotated ground, then the Bt corn rootworm hybrid must also be planted on rotated ground.
 - If the corn rootworm refuge is planted on continuous corn ground, then the Bt corn rootworm hybrid may be planted on either continuous or rotated ground.
 - The corn rootworm refuge can be treated to control corn rootworm larvae and other soil insect pests with soil or seed-applied insecticides.

2

Refuge Configuration Examples for Bt Corn Rootworm Corn*
(single trait Bt corn hybrids with corn rootworm protection)

■ = Bt Rootworm Corn
■ = Corn Refuge



*Refuge configurations are representative examples and do not illustrate all possible configurations.

- The corn rootworm refuge can be treated with a non-Bt foliar insecticide to control late season pests such as corn borer or western bean cutworm, if pest pressure reaches economic threshold. However, if corn rootworm beetles are present at the time of foliar application, then the Bt corn rootworm field must be treated in a similar manner.

What are the refuge requirements for stacked Bt trait hybrids with both Lepidoptera and corn rootworm protection?

Bt corn hybrids with “stacked” insect traits contain two or more traits that offer protection from different target insect groups among Lepidoptera and corn rootworms. IRM requirements for hybrids with Lepidoptera and corn rootworm Bt traits must be met at the same time for BOTH insect pest groups.

Two different refuge planting options are allowed to meet the IRM requirements for stacked Bt trait corn hybrids. These options include one shared common refuge for both insect groups, or separate refuges for each insect group.

Common refuge for stacked Bt trait hybrids (see figure 3a)

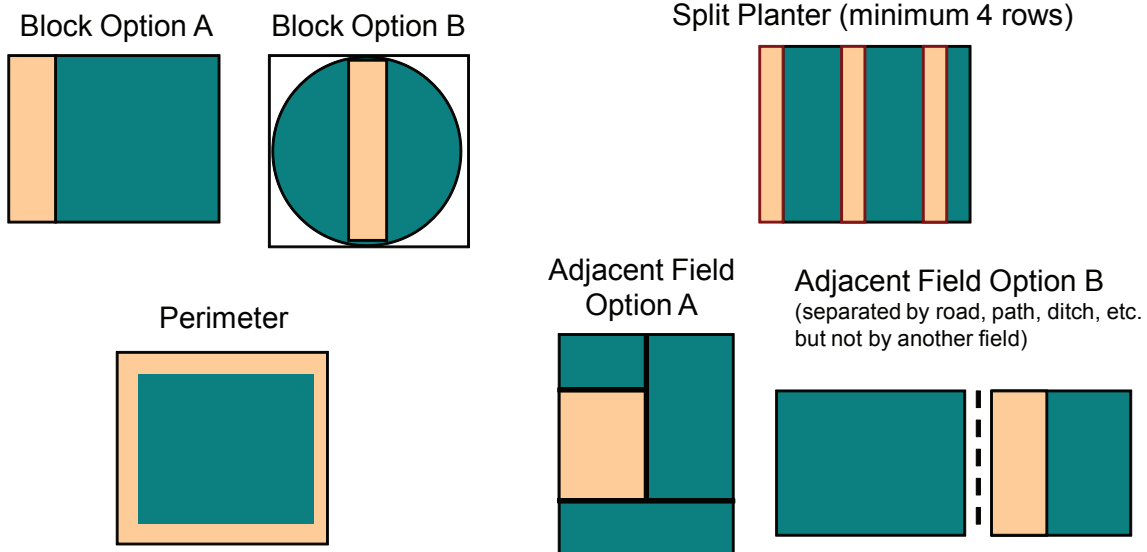
Plant one common refuge for Lepidopteran target pests (e.g., corn borer) and corn rootworms. The common refuge must be planted with a non-Bt corn hybrid (e.g., conventional corn or herbicide resistant trait only).

- Up to 80% of a farm’s total corn acres may be planted with a stacked Bt trait corn hybrid.
- The common refuge must represent at least 20% of the grower’s corn acres on each farm (i.e., sum of stacked Bt trait corn and refuge acres).
- The common refuge must be planted within or directly next to each stacked Bt trait corn field. The common refuge cannot be separated by another field.
- The refuge can be planted as a block, split planter to alternate four or more rows between stacked Bt trait corn and refuge corn, or field perimeter planting to meet the 20% refuge requirement for each field.

3a

Common Refuge Configuration Examples for Stacked Bt Trait Corn* (stacked Bt trait corn hybrids with Lepidoptera and corn rootworm protection)

- = Stacked Bt Trait Corn
- = Common Corn Refuge (e.g., Conventional Corn, or Herbicide Resistant Trait Only)



*Refuge configurations are representative examples and do not illustrate all possible configurations.

- If the common refuge is planted on rotated ground, then the stacked Bt trait hybrid must also be planted on rotated ground.
- If the common refuge is planted on continuous corn ground, then the stacked Bt trait hybrid may be planted on either continuous or rotated ground.
- The common refuge can be treated with a soil or seed-applied insecticide to control corn rootworm larvae and other soil insect pests.
- The common refuge can be treated with a non-Bt foliar insecticide for late season pests such as corn borer or western bean cutworm, if pest pressure reaches economic threshold. However, if corn rootworm beetles are present at the time of foliar application, then the stacked Bt corn field must be treated in a similar manner.

■ **Separate refuge for stacked Bt trait hybrids**
(see figure 3b)




Plant a separate refuge for Lepidopteran target pests (e.g., corn borer); and a separate refuge for corn rootworms.

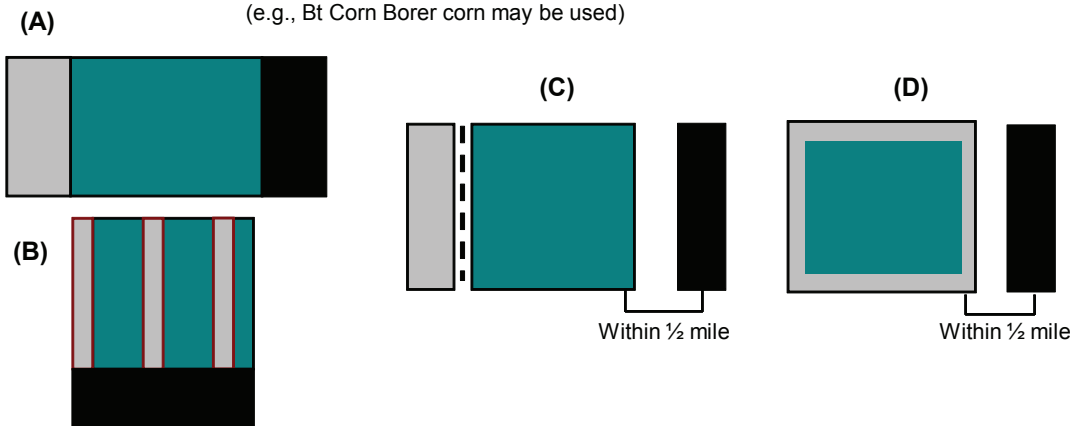
Corn rootworm separate refuge: Up to 80% of a farm's corn acres may be planted with Bt corn rootworm-protected hybrids.

- 20% of total corn acres (i.e., sum of Bt hybrids with rootworm protection and corn rootworm refuge corn) must be planted to a corn refuge that does not contain a Bt trait for control of corn rootworms.
- Any corn hybrid that does not contain a Bt trait to control corn rootworms can serve as a refuge for corn rootworm.
- Single Bt trait Lepidoptera (e.g., corn borer) corn may be planted in the corn rootworm refuge, but total Bt Lepidoptera-protected corn acres on the farm may not exceed 80%.

3b

Separate Refuge Configuration Examples for Stacked Bt Trait Corn*
(stacked Bt trait corn hybrids with Lepidoptera and corn rootworm protection)

-  = Stacked Bt Trait Corn
-  = Corn Borer (Lepidoptera) Refuge
(e.g., Bt Rootworm Corn may be used for within-field or adjacent configurations, (A) and (B). However, if Corn Borer refuge is in a separate field within ½ mile, then use Conventional Corn or Herbicide Resistant Trait only, (C) and (D).)
-  = Corn Rootworm Refuge
(e.g., Bt Corn Borer corn may be used)



(A) Corn borer and corn rootworm refuge blocks within the same field; and (B) Corn rootworm refuge strips (minimum 4 rows) and corn borer refuge block (e.g., 60% stacked Bt trait corn, 20% corn borer refuge, and 20% corn rootworm refuge). (C) Adjacent field corn rootworm refuge block and corn borer refuge within ½ mile of stacked Bt trait field; and (D) Perimeter corn rootworm refuge and corn borer refuge within ½ mile of stacked Bt trait field (e.g., 60% stacked Bt trait corn, 20% corn borer refuge, and 20% corn rootworm refuge).

*Refuge configurations are representative examples and do not illustrate all possible configurations.

- The corn rootworm refuge must be planted within or directly next to each stacked Bt trait corn field. It cannot be separated by another field.
- The corn rootworm refuge can be planted as a block, split planter to alternate four or more rows between stacked Bt trait corn and corn rootworm refuge corn, or field perimeter planting to meet the 20% refuge requirement for each field.
- If the corn rootworm refuge is planted on rotated ground, then the stacked Bt trait corn hybrid must also be planted on rotated ground.
- If the corn rootworm refuge is planted on continuous corn ground, then the stacked Bt trait corn hybrid may be planted on either continuous or rotated ground.
- The corn rootworm refuge can be managed for corn rootworm larvae and other soil insect pests using a soil or seed-applied insecticide.
- The corn rootworm refuge can be treated with a non-Bt foliar insecticide for control of late season pests such as corn borers if pest pressure reaches economic threshold. However, if rootworm adults are present at the time of foliar application, then the stacked Bt trait corn field must also be treated.
- The corn borer refuge can be treated with a non-Bt foliar insecticide if economic thresholds for late season pests such as corn borer or western bean cutworm are met; the stacked Bt corn hybrid would NOT have to be treated under this option.

How do you select the best Bt insect trait package? (see trait chart on back page)

Crop rotation sequence, insect field scouting records, state pest survey data, and historical insect problems on your farm should guide your decision when selecting corn hybrids with Bt traits. Bt corn hybrids expressing Lepidopteran protection may be suited for a wider range of corn growing scenarios (multiple pest targets, cyclic years of high pest pressure alternating with years of low pressure). By contrast, Bt corn rootworm hybrids are generally better suited for continuous corn fields, or any field in which corn rootworm beetle scouting counts from the previous season have reached economic threshold (e.g., corn following soybeans in regions affected by rotation-resistant western corn rootworm). Evaluate the cost of added protection with Bt stacked traits and decide if the cost is justified for your situation. Just because you can buy a trait doesn't mean you need that trait.

Corn borer/Lepidoptera separate refuge: Up to 80% of a farm's corn acres may be planted with Bt Lepidoptera-protected hybrids.

- 20% of total corn acres (i.e., sum of Bt hybrids with Lepidoptera protection and Lepidoptera refuge corn) must be planted to a corn refuge that does not contain a Bt trait for control of corn borers or other target "caterpillar" pests.
- Single Bt trait corn rootworm corn may be planted in the corn borer/Lepidoptera refuge, for within field or directly adjacent configurations, but total Bt corn rootworm-protected corn acres on the farm may not exceed 80%.
- The corn borer/Lepidoptera refuge must be planted within ½ -mile of the stacked Bt trait corn field, on the same farm and managed by the same grower.
- Within-field refuge configurations are also an option as described previously.

How long will Bt insect traits work?

The length of time a Bt insect trait will remain effective against a target insect pest depends upon a number of complex factors including genetic makeup of the target insect population and their exposure to Bt corn hybrids and non-Bt corn refuge areas over multiple generations (i.e., years). One way to prevent or delay resistance is to control selection pressure for development of insect resistance to the Bt trait. Compliance with IRM is mandated by law as a condition of EPA registration of Bt corn technology. As previously stated, a refuge provides a corn crop habitat that allows target insects to feed, mate and reproduce in the absence of selection pressure for resistance to the Bt trait. These Bt-susceptible insects decrease the odds that mating will occur between Bt-resistant insects. Mating between Bt-susceptible insects and potential resistant insects ensures that susceptibility to the Bt toxin is passed on to the next generation.

Where are Bt traits expressed in the corn plant? (see trait chart on back page)

Protection against Lepidopteran insect pests such as corn borer occurs in the above ground portion of the plant. The Bt protein is expressed in the leaves, stalks, ears and pollen where it can be ingested by the target insect pest. However, the Bt protein for protection against corn rootworm larvae is expressed primarily in corn roots. Consequently corn silks are not protected against feeding from corn rootworm beetles later in the growing season. If silk clipping reaches the economic threshold, a foliar insecticide application is justified to control rootworm beetles even if the corn is a Bt rootworm hybrid.

What if the Bt corn hybrid is not controlling the targeted insect?

If you suspect that your Bt corn is not controlling the target insect pest(s), first verify that a Bt corn hybrid was planted. Secondly, contact your seed supplier immediately to report any unexpected insect damage. Monitoring corn fields is an important part of IRM. This includes scouting refuge areas for the purpose of comparing target insect pest pressure and corn plant condition in the refuge areas to areas planted with Bt corn hybrids.



U.S. Environmental Protection Agency (U.S. EPA) References on Bt Corn and IRM

The U.S. Environmental Protection Agency has published detailed reports about each of the Bt corn products. Report titles identify products by their technical names rather than the commonly used trade names provided below.

Current & Previously Registered Section 3 PIP Registrations

http://www.epa.gov/oppbppd1/biopesticides/pips/pip_list.htm

Bt Plant-Incorporated Protectants relating to Bt Corn Borer Corn (e.g., YieldGard® Corn Borer)

http://www.epa.gov/oppbppd1/biopesticides/pips/bt_brad.htm

YieldGard® Rootworm Fact Sheet

http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006484.htm

YieldGard® Plus Fact Sheet

http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_006430-006484.htm

YieldGard® Plus/RR2 Fact Sheet

http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006430-006502.htm

Herculex I

http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006481.htm

Herculex Rootworm

http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006490.htm

&

http://www.epa.gov/oppbppd1/biopesticides/ingredients/tech_docs/brad_006490.pdf

Herculex XTRA

http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006481-006490.htm

Agrisure Rootworm

http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006509.htm

Bt Corn Trait Chart

Product	Bt type	Herbicide Resistance		Protection									Suppression (Lepidoptera)			
		Liberty link	European corn borer	Southwestern corn borer	Sugarcane corn borer	Southern corn stalk borer	Western bean cutworm	Black cutworm	Fall armyworm	Western corn rootworm	Northern corn rootworm	Mexican corn rootworm	Corn earworm	Fall armyworm	Stalk borer	
YieldGard Corn Borer	Cry1Ab		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
YieldGard Corn Borer/RR2	Cry1Ab	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
YieldGard Rootworm	Cry3Bb1												✓	✓	✓	✓
YieldGard Rootworm/RR2	Cry3Bb1	✓		✓									✓	✓	✓	✓
YieldGard VT Rootworm/RR2	Cry3Bb1	✓											✓	✓	✓	✓
YieldGard Plus	Cry1Ab + Cry3Bb1			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
YieldGard Plus/RR2	Cry1Ab + Cry3Bb1	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
YieldGard VT Triple	Cry1Ab + Cry3Bb1	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Herculex I	Cry1F			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Herculex I RR2	Cry1F	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Herculex RW	Cry34/35Ab1			✓									✓	✓	✓	✓
Herculex RW RR2	Cry34/35Ab1	✓		✓									✓	✓	✓	✓
Herculex XTRA	Cry1F + Cry34/35Ab1			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Herculex XTRA RR2	Cry1F + Cry34/35Ab1	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Agrisure CB/LL	Cry1Ab			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Agrisure RW	mCry3A												✓	✓	✓	✓
Agrisure GT/RW	mCry3A	✓											✓	✓	✓	✓
Agrisure GT/CB/LL	Cry1Ab	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Agrisure CB/LL/RW	Cry1Ab + mCry3A			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Agrisure GT/CB/LL/RW	Cry1Ab + mCry3A	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓