



2012 Guide to Bt Corn for Georgia

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What is Bt corn? Bt corn is defined as corn hybrids that contain one or more gene(s) from the bacterium *Bacillus thuringiensis* (designated Bt). These genes produce a toxin that controls a selected group of insect pests. Bt corn with single gene for corn borer and other caterpillar control have been available in Georgia since 1998. Bt corn is a preventive type of pest control so a decision concerning the value of this control must be made before planting without knowledge of whether you will have a serious pest infestation. The presence of one or more Bt genes in a corn hybrid will not increase yield. Instead, the gene(s) prevent the loss of yield from certain insects. Therefore, the most important thing to remember is that if the insect population in your field is high enough, the Bt corn will pay off. If the “insect pressure” is not there, then you may not see a benefit. Bt corn helps you manage the risk of losses from insect damage. The purpose of this information sheet is to describe the various traits and to suggest situations specific to Georgia where it may pay to plant Bt corn.

Different Bt genes are available. Bt traits targeting several different types of insects are now available. Some of the Bt genes protect against corn borers while other genes protect the roots from western corn rootworm. Still others help prevent leaf and ear damage from various caterpillars including corn earworm and fall armyworm. These genes often are bundled together in various combinations, with genes for tolerance to the herbicides glyphosate and/or glufosinate (Liberty- Link) resistance genes. This makes the selection of a Bt corn more complicated. Table 1 is a detailed list of brand names, traits and relative efficacy of different Bt products against insect pests in Georgia. Brief comments about each product or group of products with the same Bt traits follow:

YieldGard® Corn borer (YGCB), Agrisure® CB/LL can contain the same gene (Cry1Ab) with either the MON810 event or the Bt11 event. YGCB targets caterpillar pests including European and southwestern corn borers, fall armyworm, and other lepidopterans. The toxin is expressed season-long throughout the plant although expression may be limited in seedlings.

Herculex® I contains the gene Cry1F. It also targets caterpillar pests including European and southwestern corn borers, fall armyworm, and other lepidopterans. The toxin is expressed season-long throughout the plant. Activity in seedling and whorl-stage plants is greater than YGCB. Conversely Herculex I provides little protection in ears and kernels is against corn earworm damage.

Triple Stacked Traits: Many hybrids now contain Bt caterpillar trait, a Bt rootworm trait plus herbicide tolerance in a 3-way stack. Products with stalk protection, root protection and herbicide tolerance include Agrisure® 3000GT, Herculex® XTRA and YieldGard® VT Triple.

Genuity® VT Triple PRO™, **Genuity® VT Double PRO™** contain two traits for caterpillar control, the same one in YieldGard VT Triple plus a new trait (Cry2A). The combined traits provide good control of stalk borers and fall armyworm in the whorl, but also provides good levels of control of corn earworm in the ear. Triple PRO also contains a gene for rootworm control but Double PRO does not have rootworm control.

Genuity® SmartStax® and SmartStax® by Dow is an 8 gene combination and contains all the traits in Genuity VT Triple PRO plus all the traits in Herculex EXTRA. SmartStax provides good to excellent control of all target pests listed in Table 1.

Agrisure® Viptera™ is a new product series that contains a second new trait (Vip3A) for caterpillar especially corn earworm control. Specific Viptera products have a number designation which for southern hybrids will be 3110, 3111 and 3220. Depending on the product it also may be stacked with one or two traits for corn borer and corn rootworm control as well as tolerance to glyphosate and glufosinate herbicides.

Optimum® Intrasect™ by Pioneer is a new product for the southern U. S. It contains the two original corn borer proteins, in YieldGard-CB and Herculex 1, but does not contain a rootworm trait. This product provides very good to excellent control of corn borers and fall armyworm in the whorl. It also provides partial reduction in kernel damage by corn earworm similar to that of YieldGard-CB. Optimum® Intrasect™ XTRA also has the rootworm trait in Herculex XTRA.

Integrated or blend refuge-in-the-bag products. For 2012 there will be several Bt products marketed for the Midwest corn belt that have a reduced 5% or 10% non-Bt refuge that is mixed or blended in the bag of a Bt product. They include Genuity® SmartStax® RIB Complete, REFUGE ADVANCED Powered by SmartStax®, and Optimum® AcreMax® (several products). These products will not be marketed in cotton areas of the southern U.S., but if grown in cotton areas they will still require a 20% non-Bt structured refuge.

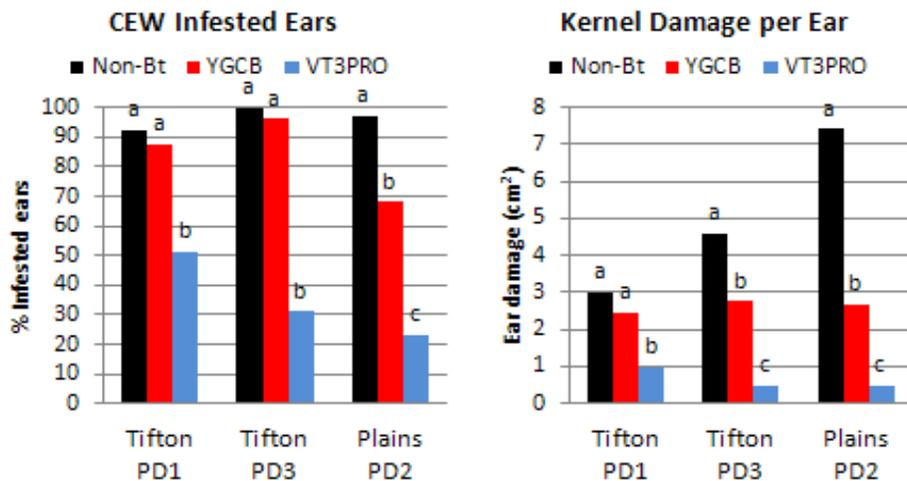
Bt Hybrids for Rootworm Control in Georgia. Bt rootworm traits target midseason rootworms. The only midseason rootworm species in Georgia is the western corn rootworm, and it currently is present in the northern two thirds of the state. Western corn rootworm is only a pest when corn is grown continuously in the same field for several years. Bt for rootworm control is NOT needed where corn is rotated annually with other crops. Therefore hybrids with a rootworm Bt trait should be considered for where corn is grown continuously, such as in dairy operations, and western corn rootworms were present in the corn the previous year. Several types of Bt rootworm products may be available. Each product contains a different Bt gene that is active against rootworm larvae. Rootworm Bt traits are not effective against wireworms, white grubs or southern corn rootworm in the seedling stage.

Efficacy of Bt traits for Corn Earworm Control. Newer Bt products have improved activity against corn earworm in the ears as compared with older single trait products. These include Agrisure® Viptera, Genuity® VT Triple PRO and Double PRO, and SmartStax® products. The additional genes allows for a reduced structured non-Bt refuge requirement of 20% compared with 50% for the older single gene products.

Efficacy of Genuity VT Triple PRO (GENVT3P) and SmartStax. I have conducted early and late planted trials at Tifton, Plains and Griffin, GA since 2009 comparing hybrids with GENVT3P or SmartStax to similar hybrids with YGCB or no Bt trait. Three trials with large

infestations from 2009 show how GENVT3P is more effective at preventing ear infestation and damage by corn earworm than the older YieldGard-CB. Pictures of representative ears also show how GENVT3P had significantly less ear damage than YGCB or a non-Bt corn. GENVT3P does not completely prevent ear infestation and damage but on average reduces corn earworm infestation in ears by about two-thirds and reduces kernel damage by 80 to 90%. More recent trials have found that corn earworm control and reduction in kernel damage by Genuity SmartStax and GENVT3P are similar.

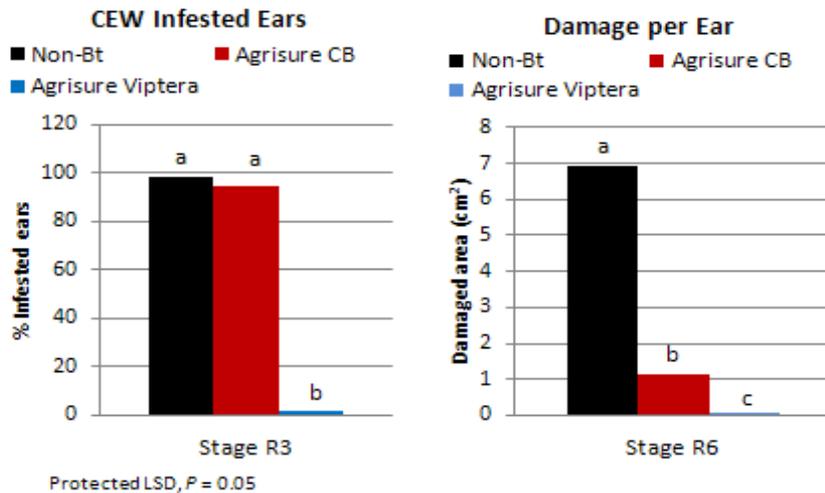
Corn Ear Infestation and Damage by Corn Earworm in Hybrids with YieldGard – CB (YGCB) and Genuity® VT3 PRO (VT3PRO) in three trial, GA in 2009



Examples of ears showing kernel damage by corn earworm in non-Bt (left), YieldGard® - CB (center), and Genuity® VT Triple PRO (right).

Efficacy of Agrisure® Viptera™. The Viptera trait provides excellent ear protection against corn earworm and prevents nearly all kernel damage by corn earworm. The Viptera trait does not provide control of corn borers thus must always be stacked with a corn borer trait like Bt11 which is in Agrisure® CB/LL. The Viptera trait also provides improved protection for whorl defoliation by fall armyworm as compared to the Bt11 protein alone. The figure shows the results of a trial from 2009 comparing Viptera to the older Agrisure CB/LL and non-Bt hybrid with similar base genetics. Representative pictures of ears from this trial also are shown.

Corn Earworm Infestation and Ear Damage to Corn Hybrids with Agrisure[®] CB/LL and Agrisure[®] Viptera[™] in GA in 2009



Examples of ears showing kernel damage by corn earworm in non-Bt (left), Agrisure[®] CB/LL (center), and Agrisure[®] Viptera (right).

Grain Yield and Quality. The yield return from Bt technology will depend primarily on how high the pressure is from corn earworm and fall armyworm. Field trials industry and university researchers from across the South have shown an **average 3 to 4 bushel per acre** yield difference between a hybrid with Genuity[®] VT3 PRO and its corresponding single Bt-trait isolate. In these trials with large corn earworm infestation, yield averaged about 6 bushel per acre over the single Bt-trait isolate. However, yield differences are rarely statistically significant. My trials in the Coastal Plain region of Georgia showed no significant differences between traits, but the Genuity[®] VT3 PRO averaged 3.0 bushels per acre more than the single trait Bt line. Similar yield trials with SmartStax[®] and Agrisure[®] Viptera are much more limited so yield comparisons are not available at this time.

Corn earworm control by Genuity[®] VT3 PRO also corresponded with better grain test weight. In my six trials in 2009, **test weight averaged 1.0 lb per bushel more** in hybrids with Genuity[®] VT3 PRO than hybrids with the single YGCB trait. Improved test weight is presumably due to less damaged or broken kernels and less secondary insect damage and fungal infection often associated with corn earworm damage. The economic benefit a better test weight is difficult to gauge, but it may reduce the risk of dockage for low test weight corn.



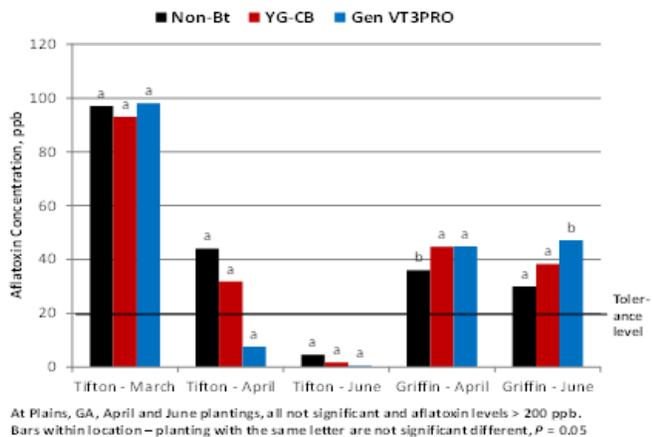
Corn ears of Genuity[®] VT3 PRO corn (top) showing reduced corn earworm damage and overall improvement in grain quality compared with non-Bt corn (bottom) from the same trial at Griffin, GA in 2008.

Corn earworm (photo by Xinzhi Ni, USDA-ARS)



Bt Corn and Aflatoxin Contamination. Aflatoxin is a highly toxic mycotoxin produced when kernels are infected by the fungus, *Aspergillus flavus*. Previous research has found that aflatoxin contamination is affected by many factors including heat and water stress, hybrid genetics, kernel hardness and integrity, ear drooping, husk coverage, and insect damage. This includes an association between ear/kernel damage by corn earworm and aflatoxin contamination. It has been suggested that improved ear/kernel protection for corn earworm by stacked Bt corn may help reduce corn grain aflatoxin contamination. The following chart shows aflatoxin levels in 5 trials at Tifton and Griffin, GA in 2009 that compared aflatoxin levels in grain of hybrids with the same based genetic and either YieldGard-corn borer, Genuity VT Triple PRO and a non-Bt hybrid. These results do not show a consistent trend in aflatoxin levels among entries. These data are representative of other trials in 2010 and 2011 showing no strong and consistent reduction in aflatoxin contamination associated from improved corn earworm control by newer stacked Bt products.

Corn grain aflatoxin concentration in hybrids with Bt traits in 5 trials in Georgia, 2009. (Each bar average of 2 hybrids).



When is Bt Technology Likely to Pay Off?

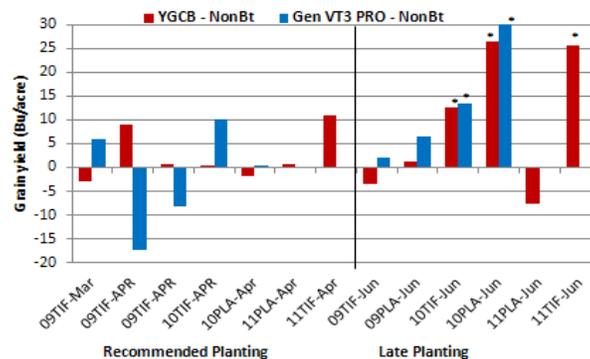
How much does Bt technology cost? The price of corn seed has risen dramatically in the past decade. This is because the price includes insecticide and fungicide seed treatments, as well as herbicide resistance and Bt traits. Generally the cost of transgenic traits for herbicide tolerance and Bt insect control are not itemized for corn seed. In general, the cost of Bt technology for older products such as YieldGard Corn Borer, Agrisure CB/LL, and Herculex I is about \$10 per bag (80,000 units) or less than \$4.00 per acre. The cost differential for the newer stacked products will be higher. Growers should compare the cost of a stacked Bt product to the cost of a hybrid with the similar based genetics and herbicide tolerance alone.

Will Bt Corn Pay Off in Recommended Time Plantings? Most corn in Georgia is planted at the recommended planting time of March through Mid-May depending on the region for the state. In most years this corn avoids serious insect damage. However, the main target pest in recommended plantings throughout the state is corn earworm, which often exceeds 50% infested ears. Fall armyworm damage to whorls usually is avoided in early plantings but it can be significant in outbreak years. In most years, the risk of damage by fall armyworm in recommended plantings is greatest in the southernmost tier of counties and in the southwest corner of Georgia. Growers must weigh the added cost of the Bt trait(s) being considered against the historical risk of serious whorl defoliation or ear damage by insects in on-time plantings.

There are three situations where planting hybrids containing Bt traits provides a clear benefit:

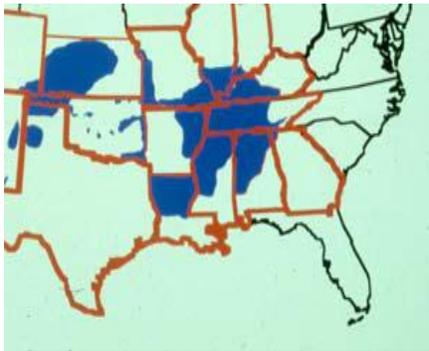
Situation 1. Corn statewide that will be planted after the recommended planting date. The risk of damage by fall armyworms, corn earworms and stalk borers increases the later you plant. Bt technology reduces the risk of insect damage thereby allowing for later plantings, although late plantings have lower yield potential and increased risk of damage by diseases. Studies in 2009-2011 compared the yield of hybrids with single trait YieldGard – corn borer and Genuity VT3 PRO to a similar non-Bt hybrid in trials planted at the recommended and late planting times at Plains and Tifton, GA. In trials at the recommended planting time, hybrids with Genuity VT3 PRO averaged 0.96 bu per acre more than the hybrids with YieldGard-CB and 2.35 bu per acre more than non-Bt hybrids. A more consistent response occurred in trials at later planting times where hybrids with Genuity VT3 PRO averaged 4.10 bu per acre more than hybrids with YieldGard – CB and 9.11 bu per acre more than non-Bt hybrids.

Corn Grain Yield of YieldGard – Corn Borer (YGCB) and Genuity VT3 PRO over non-Bt in GA trials in 2009 - 2011



*sign over Non-Bt, P = 0.05

Situation 2. Northwest Georgia including the Limestone Valley, which consistently high corn borer populations. Several species of corn borers occur in Georgia, but corn borers normally do not reach damaging levels throughout most of the state. The exception is northwest region Georgia including the Limestone Valley. In this area the Southwestern corn borer occurs and it usually is worse in corn after corn in later plantings but can damage rotated corn planted on time. While yield response varies with infestation level, trials near Calhoun, GA found a 5-15 bushel per acre response to YGCB Bt corn. More recent studies in northern Alabama found a 9 bu per acre advantage due to SW corn borer control (R. Duffield and K. Flanders, Auburn Univ.).



Southwestern corn borer and its distribution. (Photos courtesy of Frank Peairs, Colorado State Univ.)



Situation 3. Non-rotated (corn after corn) in the northern half of Georgia, where western corn rootworm can be a problem. This is a very uncommon situation. I have only seen a handful of fields with damaging infestations of western corn rootworm. All were dairy operations in the northern half of the state growing corn in the same fields for several years. Western corn rootworm larvae attack roots mid-season. It is only a pest of continuous corn and is controlled by rotation. As little as one year rotated out of corn every 3 or 4 years will control this insect in Georgia. Scout fields during pollination because adults are easily seen feeding on silks and tassels. Bt rootworm traits are very effective. To get rootworm traits you will need to plant a stacked product with a rootworm trait (see table below) Bt rootworm traits do not control wireworms, white grubs, or southern corn rootworm in the seedling stage.



Western corn rootworm adult and corn roots severely damage by larvae. (Photos courtesy of Marlin Rice and Iowa State University)

Bt Insect Resistance Management (IRM) and Refuge Requirements.

To help preserve the usefulness of Bt corn, the U.S. Environmental Protection Agency requires that non-Bt corn be planted on part of the corn acres on each farm as a refuge. The refuge requirement in cotton-growing areas, which includes all of Georgia, is 50% for all single-trait Bt corn borer and triple-stacked products. Products with two or more lepidopteran proteins, Agrisure Viptera 3110 and 3111, Genuity VT Triple Pro and Double Pro, Genuity SmartStax, Optimum Intrasect and SmartStax (Dow), have a 20% non-Bt corn refuge requirement. Table 1 lists the percentage for each product. The grower is ultimately responsible for the IRM / refuge compliance for Bt corn on their farm. This is stated in the agreement form that grower has to sign when they buy the seed. The dealer and seed company should provide information about refuge options for a given variety.

In 2012 the seed bag tag of most hybrids will display details about the IRM and refuge requirements for a particular Bt corn hybrid. This will be required starting in 2013. The National Corn Growers Association produced a very easy to use refuge configuration calculator that is downloaded to your computer. It covers Bt traits for all of the types of Bt corn sold in the U.S. and can be found at www.irmcalculator.com. You can look up the type of Bt product you have, the state, and can enter acreage and the program will tell you how many acres of Bt and refuge Non-Bt are needed and options for how it can be planted. Some general requirements are:

- For Bt corn products with above-ground traits only, the non-Bt corn refuge must be planted within ½ mile of the Bt corn.
- For Bt products for below ground containing a rootworm trait(s), the refuge must be planted in the same field or adjacent to the Bt corn.
- Bt and non-Bt corn can be planted as in-field strips of 4 or more consecutive rows. Strips of 1 to 3 rows are not allowed.
- Check with seed dealers, seed company or the [irmcalculator](http://www.irmcalculator.com) for complete Bt corn refuge requirements.

Table 1. Bt Corn Products for the Southeastern United States, version 2012

Product Trade Name (Abbreviation)	Bt protein(s)	Amount of Insect Control ¹						Herbicide tolerance	Refuge Require- ment in the South ⁵	Event(s)
		Corn Earworm (ear)	Fall army- worm (whorl)	Corn Borers ² (stalk)	Black Cutworm (seed- ling)	LCB ³ (seed -ling)	West. corn root- worm ⁴ (roots) In soil			
Agrisure Products										
Agrisure CB/LL	Cry1Ab	F	G	E	P	G	--	LL	50%	Bt11
Agrisure CB/LL/RW	Cry1Ab mCry3a	F	G	E	P	G	F-G	LL	50%	Bt11, MIR604
Agrisure 3000GT	Cry1Ab mCry3A	F	G	E	P	G	F-G	GT LL	50%	Bt11, MIR604, GA21
Agrisure Viptera 3110	Vip3Aa20 Cry1Ab	E	E	E	G	G	--	GT LL	20%	MIR162, Bt11, GA21
Agrisure Viptera 3111	Vip3Aa20 Cry1Ab mCry3A	E	E	E	G	G	F-G	GT LL	20%	MIR162, Bt11, MIR604, GA21
Agrisure Viptera 3220	Vip3Aa20 Cry1Ab Cry1F	E	E	E	VG	VG	--	GT LL	20%	MIR162, Bt11, TC 1507, GA21
Herculex Products										
Herculex I (HX1)	Cry1F	P	VG	E	G	G	--	LL	50%	TC 1507
Herculex RW (HXRW)	Cry34Ab1/Cry35Ab1	--	--	--	--	--	E	LL	20%	DAS-59122-7
Herculex XTRA (HXX)	Cry1F Cry34Ab1/Cry35Ab1	P	VG	E	G	G	E	LL	50%	TC 1507, DAS-59122-7
Optimum Products										
Optimum Intrasect	Cry1F Cry1Ab	F-G	VG	E	VG	VG	--	LL RR2	20%	TC 1507, MON810
Optimum Intrasect XTRA	Cry1F Cry1Ab Cry34Ab1/Cry35Ab1	F-G	VG	E	VG	VG	E	LL RR2	20%	TC 1507, MON810, DAS-59122-7
YieldGard Products										
YieldGard Corn Borer (YGCB)	Cry1Ab	F	G	E	P	G	--	--	50%	MON810
YieldGard VT Rootworm / RR2 (VTRR2)	Cry3Bb1	--	--	--	--	--	E	RR2	20%	MON88017
YieldGard VT Triple (VT3)	Cry1Ab Cry3Bb1	F	G	E	P	G	E	RR2	50%	MON810, MON88017
Genuity/SmartStax Products										
Genuity VT Double PRO (GENVT2P)	Cry1A.105 Cry2Ab2	G-VG	E	E	P	VG	--	RR2	20%	MON89034, NK603
Genuity VT Triple PRO (GENVT3P)	Cry1A.105 Cry2Ab2 Cry3Bb1	G-VG	E	E	P	VG	E	RR2	20%	MON89034, MON88017
SmartStax (SSX, Dow) or Genuity SmartStax (GENSS, Monsanto)	Cry1A.105 Cry2Ab2 Cry1F Cry3Bb1 Cry34Ab1/Cry35Ab1	VG	E	E	G	VG	E	LL RR2	20%	MON89034, TC 1507, MON88017, DAS-59122-7

¹ E = excellent, VG = very good, G = good, F = fair, P = poor. Excellent usually means better than 95 percent control. Poor means less than about 30% control;