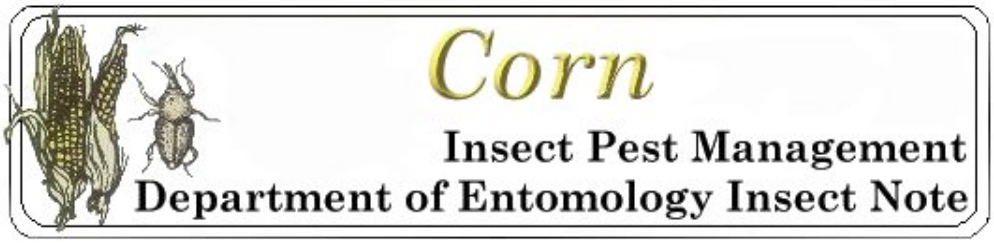

Transgenic Bt Corn, A Powerful Pest Management Tool

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Bt transgenic corn is normal corn that contains one or more genes from the soil bacterium *Bacillus thuringiensis*, or Bt as is commonly used. The gene(s) allow the bacterium to produce one or more toxins that are toxic to certain insects, but are not toxic to mammals, including humans. When the gene(s) are placed into a corn plant the plant produces the protein toxin internally. This makes the plant toxic to certain plant feeding caterpillars and / or beetles, or both, depending on how many genes, and what kind, are placed into the plant.

Types of Bt Corn: Many seed companies sell Bt corn from differing "transformation events". Each transformation event may contain a unique gene(s), gene promoter(s), or gene location(s) on a corn chromosome. These differences result in variation of toxin type(s), toxin expression, and insect control performance. The different types of Bt field corn are presented in Table 6.1. They include hybrids that are intended for the caterpillar complex alone, the rootworm complex alone, or are stacked toxin types that will control both caterpillars and rootworms. Also, additional Bt corn types are in development which contain multiple toxins for caterpillars and/or multiple toxins for corn rootworms. When available, the new multiple stacked hybrids will provide much higher levels of control of insects that are not well controlled by the current Bt types listed in Table 6.1, such as corn earworm, and will make it less likely for pest insects to develop resistance to the toxin(s). Additionally, future transgenic plants may have a multitude of traits for pest control (insects, weeds, pathogens) as well as other performance promotion factors (e.g. drought tolerance) or quality factors (e.g. improved protein or oil characteristics).

Table 6-1. Bt gene events developed for use in Bt field corn (As of 12/06/2007).

TOXIN(S)	DEVELOPER	HYBRID BRANDS*	TRADEMARKS
Cry1Ab	Monsanto	Syngenta NK	Agrisure CB, Yieldgard CB
Cry1Ab	Monsanto	Dekalb and many other brands	Yieldgard CB
Cry1F	Mycogen	Mycogen, Pioneer, others	Herculex I
Cry3Bb1	Monsanto	Dekalb and many other brands	Yieldgard VT Rootworm
Cry34/35Ab1	Dow	Mycogen, Pioneer, others	Herculex RW
Cry1AB + Cry3BB1	Monsanto	Dekalb and many other brands	Yieldgard VT PLUS Yieldgard VT TRIPLE
Cry1F + Cry34/35Ab1	Dow & Pioneer	Mycogen, Pioneer, others	Herculex EXTRA

* In a state of change and different seed companies may sell one or more genes in their hybrid selections. Check with the company representitive.

Target Pests of Bt Corn: The targets for Bt corn types in North Carolina are: (1) a complex of caterpillar pests and (2) a complex of corn rootworms. The complex of caterpillars, that may attack the stalk, root crown, and ear, primarily include European corn borer, southern cornstalk borer, stalk borer, and corn earworm, however others may become important at certain times and places (e.g. fall armyworm, armyworm, lesser cornstalk borer, and cutworms). Corn in our state is primarily infested by these caterpillars following pollen shed, although 1st generation European corn borer, armyworms, stalk borer, and lesser cornstalk borer can be economic pests of seedlings and whorl stage plants. The corn rootworm complex is composed of western corn rootworm, northern corn rootworm, and southern corn rootworm with western corn rootworm as the dominant species. In total, these pests may cause direct loss by eating seedlings, leaf tissue, vascular tissue, roots and grain. Indirect damage may result from increasing the risk of stalk rots, ear rots, grain mycotoxins, lodging, and ear drop. The Yieldgard CB hybrids may also give some reduction of stored grain moths, such as the Indian meal moth and the angoumois grain moth in stored corn. Table 6.2 presents target insect pests for six different Bt corn types.

Table 6-2. Some characteristics and performance aspects of Bt gene events used in Bt field corn.

SUBJECT	Yieldgard CB	Herculex I	Yieldgard VT Rootworm	Herculex RW	Yieldgard VT PLUS	Herculex EXTRA	Yieldgard VT PLUS	Herculex EXTRA
Toxin type	Cry1A(b)	Cry1F	Cry3Bb1	Cry34/35Ab1	Cry1Ab + Cry3Bb1	Cry1F + Cry 34/35Ab1	Cry1Ab + Cry3Bb1	Cry1F + Cry 34/35Ab1
Effect vs.1st gen. ECB*	High	High	None	None	High	High	High	High
Effect vs. 2nd gen. ECB*	High	High	None	None	High	High	High	High
Effect Vs. 3rd gen. ECB *	High	High	None	None	High	High	High	High
Effect vs. ECB* in the ear	High	High	None	None	High	High	High	High
Effect vs. SCB* in stalk	High	High	None	None	High	High	High	High
Effect vs. CEW* in ear	Mod	Low	None	None	Mod	Low	Mod	Low
Effect vs. WCR	None	None	Mod**	Mod**	Mod**	Mod**	Mod**	Mod**
Effect vs. NCR	None	None	Mod**	Mod**	Mod**	Mod**	Mod**	Mod**
Effect vs. SCR	None	None	Mod**	Mod**	Mod**	Mod**	Mod**	Mod**
Season long performance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

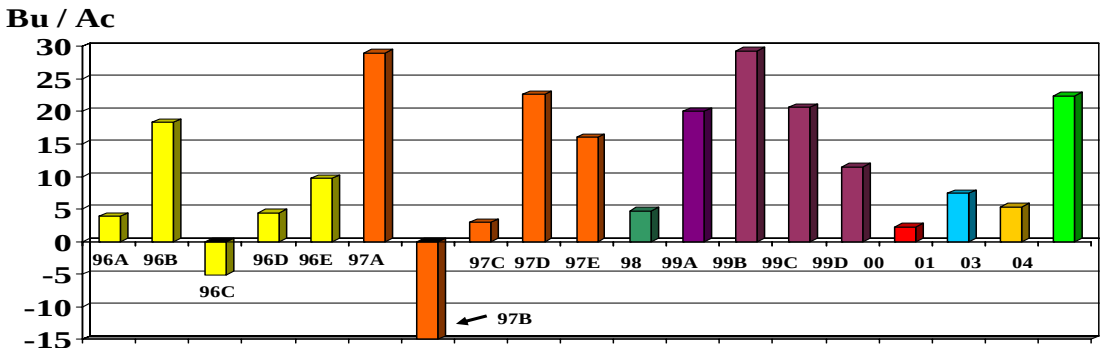
* ECB = European corn borer, SCB = southern cornstalk borer, CEW = corn earworm, NCR = northern corn rootworm, SCR = southern corn rootworm, and WCR = western corn rootworm
** Equal or better than the best available soil insecticide but will not remove all rootworms from the field.

Bt Performance in North Carolina: Research conducted in North Carolina has shown high performance against all generations of European corn borer, the most important stalk boring pest, with corn hybrids expressing Yieldgard CB and Herculex I Bt hybrids. Over a period of eight seasons, starting in 1996 and including 19 independent replicated trials comparing near-isogenic hybrid pairs (with and without Bt), the average yield advantage for Yieldgard CB corn equaled 11.09 bushels / acre or a gross dollar advantage of approximately $33.27 per acre (@ $3.00 / bushel selling price), an advantage well

above the technology fee for the Bt trait. Across the 19 trials only two gave no yield increase for the Bt versus the non-Bt near-isoline of the same hybrid. There was an increase of 5 bushels or more in 12 of the 19 tests, or 63%. Figure 6.1 presents the results. Other tests have shown that Herculex I Bt corn hybrids give approximately the same level of performance versus European corn borer and southern cornstalk borer as Yieldgard CB. Herculex I is more active against black cutworm on seedlings and less active against corn earworm in the ear.

Corn rootworm active Bt corn has been widely researched across the Corn Belt with less testing in North Carolina, as only corn in the Piedmont and mountains experience losses to corn rootworms in our state. Damage from corn rootworms is mainly limited to corn-after-corn situations and most often involves only western corn rootworm. Southern corn rootworm can frequently be a problem on seedlings, especially in no-tillage situations, but seed coating insecticides (e.g. Poncho and Cruiser) or other soil insecticides efficiently address this problem, removing the justification for Bt corn, in many situations. However, western and northern corn rootworm eggs hatch after corn seedlings have grown-off and soil insecticides, especially seed treatments, do not provide enough residual control to fully address larvae feeding on later stages of corn. Table 6.3., from Iowa State University, presents information from western / northern corn rootworm infested corn grown for grain and indicates a clear benefit for Yieldgard Rootworm Bt corn in situations were these pests are abundant. Table 6.4 shows data from a silage production situation in Iredell County, NC and again shows a clear benefit. Although not shown in the tables, Herculex RW should be expected to perform similarly to that shown in for Yieldgard Rootworm.

Figure 6.1. Yield gain of Yieldgard CB Vs. non-Bt Corn in comparisons of near-Isogenic hybrid pairs. 1996 – 2004. Northeastren N.C.



Bars depict bu / acre gain per each test location conducted over an 8 season period in northeastern North Carolina. Overall benefit = 11.09 bu / acre or $33.27 / acre gross @ $3.00 /bu corn.

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Table 6.3. Three-year summary (2003-2005) of corn rootworm control products. Iowa State University (7 locations). From: "Three-year summary of corn rootworm control products" by Marlin E. Rice and Jim D. Oleson, Iowa State University (found at http://www.ipm.iastate.edu/ipm/icm/2005/12-12/rootworm.html).

Treatment	Placement[1]	Node-Injury [2,3,4]	Product Consistency[2,4,5]	Percent Lodging[4,6]	Stand Count[7,8]	Yield (Bu/Acre)[4,9]
YieldGard RW	Transgenic	0.03 a	99 a	1 a	27.44	183 a
Aztec 2.1G	Furrow	0.24 ab	82 b	0 a	28.14	159 b
Aztec 4.67G	Furrow SB	0.28 bc	78 b	1 a	28.28	157 b
Force 3G	T-band	0.29 bc	76 bc	0 a	27.54	162 b
Aztec 2.1G	T-band	0.30 bc	75 bc	0 a	27.90	151 bc
Force 3G	Furrow	0.35 bcd	72 bc	0 a	28.02	159 b
Fortress 2.5G	Furrow	0.49 cd	68 bc	10 a	27.84	153 bc
Fortress 5G	Furrow SB	0.57 de	61 c	4 a	27.62	155 b
Lorsban 15G	T-band	0.80 ef	44 d	6 a	28.10	150 bc
Capture 2EC	T-band	0.80 ef	42 d	7 a	27.96	151 bc
Poncho ST	ST	0.98 f	21 e	6 a	27.24	158 b
Cruiser ST	ST	1.53 g	8 ef	31 b	27.71	152 bc
CHECK	--	2.00 h	2 f	40 c	27.38	130 c

[1]T-band and Furrow = insecticide applied at planting time; SB = SmartBox application; ST = seed treatment (1.25 mg/seed).
[2]Means based on 218 observations; replications with insufficient larval feeding pressure to challenge a product's performance (CHECK rep mean < 0.75 of a node injured) were deleted from the analysis (27 of 28 replications).
[3]Iowa State Node-Injury Scale (0-3). Number of full or partial nodes completely eaten.
[4]Means sharing a common letter do not differ significantly according to Ryan's Q Test ($P < 0.05$).
[5]Product consistency = percentage of times nodal injury was 0.25 (1/4 node eaten) or less.
[6]Means based on 50 observations (plants lodged in 17.5 row-ft).
[7]Means based on 50 observations (number of plants in 17.5 row-ft).
[8]No significant differences between means (ANOVA, $P < 0.05$).
[9]Means based on 27 observations. The summary had 3 sites in 2003, and 2 sites in both 2004 and 2005. All plots were machine harvested except one 2003 test; 2-row trt, approx. 90 ft in length, with 4 replications.

Table 6.4. At-planting insecticides and Yieldgard Rootworm Bt corn performance versus corn rootworm in a corn-after-corn, silage production system and with high numbers of western corn rootworm. Iredell Co., NC. 2005.

Treatment[1]	Plant Population[2]	Seedling Damage[2]	Silage Tons/acre	Increase over UTC[3]
Untreated	23011 b	7.5 a	16.97 b	NA
Force 3G	23905 ab	0.7 a	16.50 b	- $13/Ac
Poncho @ 1.25 mg/ker	23905 ab	0.7 a	18.07 ab	+ $31/Ac
Cruiser @ 1.25 mg/ker	25979 a	0.0 a	19.20 ab	+ $63/Ac
Yieldgard Rootworm + Poncho @ 0.25 mg/ker	25549 ab	1.0 a	22.07 a	+ $143/Ac

1. Force 3G applied in-furrow; Cruiser and Poncho = seed treatments.
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2. On 5/17/05 and damaged plant counts done on 200 row feet.
3. At $28 per ton

Regulatory Status and Current Sales Restrictions: In the United States transgenic plants containing an insecticide may fall under the jurisdictions of three federal agencies, the EPA, USDA, and FDA. The EPA has jurisdiction over pesticides and dictates the labeling requirements for these products, including transgenic insecticidal plants. USDA regulates movement, importation, and release into the environment of any organism that may pose environmental danger. FDA has oversight in matters that involve foods developed from new crop varieties.

Bt corn may express the toxin within the plant for the entire season and throughout the plant. Thus, several generations of pests may be exposed to the toxin. Conventional insecticides last for days or weeks. Due to this increased exposure, the risk of resistance development in insects is predicted to be much greater with Bt transgenic plants. EPA has expressed significant concern that insect resistance may rapidly develop and has required companies to include an insect resistance management (IRM) plan as a product label specification. IRM labels for Bt gene events used in corn hybrids are approved by EPA and must be periodically re-approved pending new information that may impact IRM. Due to the perceived high risk of resistance development in corn earworm (aka bollworm) in cotton growing states, EPA has chosen to increase the national structured refuge size of 20%, in areas that do not grow cotton, to 50% in states that do grow cotton, including NC. This has been a controversial issue, especially to corn growers who feel they are being penalized. This is especially true since Bollgard II and Widestrike stacked Bt cotton varieties have been approved for zero structured refuge due to the abundance of corn earworm moths, that serve refuge purposes, that come from other crops and wild hosts; corn is one of the main producers of these moths. However, as new Bt genes (e.g. Syngenta's VIP) and new stacked types of Bt corn are developed and approved, it is likely refuge reductions for Bt corn will be approved (e.g. to the national norm of 20%).

Insect Resistance Management in Bt Corn: The goal of an insect resistance management (IRM) plan is to delay resistance so that the effectiveness of each Bt toxin, including similar toxins in corn and cotton, are sustained for at least 10 years. All crop IRM plans include the requirement for a structured IRM refuge, except Bollgard II and Widestrike cottons, which depend upon natural refuge. A "structured refuge" is one that the grower must plant for IRM to supply corn earworm moths as opposed to moths that may come from a "natural refuge" (weeds and crops not planted for IRM purposes). For corn, the structured refuge is the non-Bt corn that the farmer planting his normal operation. The non-Bt corn provides non-selected insects for breeding with those few survivors from the Bt corn. This greatly helps to delay resistance development. An effective refuge must both supply adequate numbers of non-selected moths and be close enough so that the moths inter-breed. Thus, non-Bt corn structured refuge(s) must consist of 50% of the corn grown on each farm that must be planted within, adjacent to, or near each Bt cornfield; within ½ mile of the Bt corn. If a within-field strip-planted arrangement is used to establish the non-Bt refuge corn, strips created must be at least

four rows wide to minimize the risk of corn borer larvae movement from non-Bt to Bt plants (an event that is believed to enhance resistance development). Each farmer must maintain an independent refuge, a neighbor's non-Bt corn cannot serve as a refuge. The refuge corn cannot be treated with Bt-based insecticides but can be treated with other insecticides. Farmers that grow Bt corn are legally obligated, by the terms of the label and grower agreement, to follow the IRM conditions. The penalty for non-compliance, if for two consecutive seasons, is refusal of the company, who's technology was involved, to deny selling Bt traits in corn and cotton to the offending party. This was experienced by several southeast farmers in 2007.