Managing Corn Pests with Bt Corn: Some Questions and Answers
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Introduction

New technology now allows us to improve crop varieties by adding genes from other species. This allows us to add new traits to a variety, such as insect resistance, that might not exist in the crop species, or that might be difficult to transfer within the crop species using classical plant breeding methods. One successful application of this new technology has been the development of corn hybrids that are resistant to certain insect pests because of the addition of a gene from a natural soil bacterium.

Although these corn hybrids are highly effective in controlling insect pests, their use has raised a number of concerns. The following series of questions and answers provides an overview of these insect-resistant corn hybrids and their use in pest management. A second fact sheet, *Bt Corn: Health and Environmental Questions and Answers*, addresses what bacteria are involved, the insecticidal toxins they produce, crop transformation, and health and environmental issues that have arisen over the use of this technology.

Quick Facts

Bacillus thuringiensis (Bt) is a soil bacterium that produces insecticidal toxins.

Genes from Bt can be inserted into crop plants to make them capable of producing an insecticidal toxin and therefore resistant to certain pests.

Corn hybrids with a Bt gene (Bt corn) are resistant to some important pests.

Bt corn hybrids are a highly effective and economical alternative to conventional insecticide treatments, if targeted pest activity is at economically significant levels.

Marketing grain from Bt corn may be difficult in some foreign markets, but it is readily accepted in US markets.

Certain precautions are required of US corn producers to help avoid the development of pest populations that can overcome the resistance in Bt corn.

Questions and Answers

1. ***What is Bt?***

Bt is shorthand for a common soil-inhabiting bacteria called *Bacillus thuringiensis*. Bt also refers to insecticide products made from the bacteria.

1. ***What does Bt have to do with insect pests?***

Some strains of Bt kill insects with toxins called *insecticidal crystal proteins* or *delta endotoxins*. This group of toxins is considered to be relatively harmless to humans and most non-pest species. However, other toxins produced by Bt have a broader spectrum of toxicity.

2. ***What is Bt corn?***

Production of delta endotoxin is controlled by a single gene in the bacteria. A modified version of this gene can be put in corn. Corn plants containing the gene can produce delta endotoxin and therefore be toxic to insects that are susceptible to that form of the protein.

3. ***Why use the Bt gene in corn?***

Delta endotoxins sprayed on plants break down quickly when exposed to UV light. Delta endotoxins produced in the plant are protected from UV light. Also, several of the major pests of corn are difficult and expensive to control with conventional insecticides, but are susceptible to delta endotoxins produced in plant tissues. Finally, the biotechnology to insert the toxin producing Bt gene into corn is available.

4. ***Is the entire Bt corn plant toxic?***

It depends. Where delta endotoxins are produced in the plant and in what amounts is controlled by two factors, the *event* and the *promoter*. Different seed companies use different *events* and *promoters,* so their hybrids will also be different in what plant tissues produce delta endotoxins.

The insertion *event* is the physical act of putting the Bt gene into corn plant genetic material. This is when the physical location of the Bt gene is determined (which chromosome, what part of the chromosome, etc). Gene location affects where in the plant delta endotoxins are produced and how much delta endotoxin is produced. Currently, we do not have the technology to control Bt gene location, so each *event* results in plants that differ in where and in how much delta endotoxin is produced.

The *promoter* is a genetic switch that tells the inserted Bt gene when and where to produce delta endotoxins . Several different *promoters* are available and the choice of promoter also affects where and how much delta endotoxin is produced in the corn plant, leading to differences among hybrids.

11. ***How many kinds of Bt corn are there?***

There are many different Bt corn hybrids available, however, each contains only one of the events in the following table:

Bt Event	**Commercial Sources**	**Delta endotoxin**
176*	KnockOut (Novartis), NaturGard (Mycogen)	Cry 1A(b)
Bt11	YieldGard (Novartis)	Cry 1A(b)

Bt Event	Commercial Sources	Delta endotoxin
Mon810	YieldGard (Monsanto - marketed by Cargill, DeKalb,Golden Harvest, Pioneer, and others)	Cry 1A(b)
DBT418*	Bt-Xtra (DeKalb)	Cry 1A(c)
CBH351*	StarLink (Aventis marketed by AgriPro, Garst, others)	Cry 9C
TC1507	Herculex 1 (Mycogen, Pioneer)	Cry1F
MON863**	YieldGard Rootworm (Monsanto)	Cry3Bb
149B1**	pending (Pioneer)	Cry 34Ab1, Cry 35Ab1

*No longer available in US corn hybrids.
**Targets corn rootworm larvae.

12. ***Will all Bt corn hybrids give the same level of control?***

Events and *promoters* also affect how much and what kind of delta endotoxins are produced in each tissue, so

hybrids are expected to provide different levels of control of targeted pests and to control different spectrums of pests. It is better to compare insect control by event. For example, corn borer control will be similar in hybrids containing Mon810, which will be better than in hybrids containing 176.

Select hybrids that will do well in your area and ask for insect control data that are specific for the events that these hybrids contain.

13. ***Will Bt corn do well in my area?***

The Bt trait should not affect hybrid performance. If the conventional version of the hybrid does well, the Bt version should do well.

14. ***Is Bt the only trait that has been genetically engineered into corn?***

Other hybrids with genetically engineered traits, such as herbicide resistance, are available. Many other traits are in development and will become available sometime in the future.

15. ***Is corn the only crop that has been genetically engineered with Bt?***

No, several other crops have been modified to produce delta endotoxins. However, corn and cotton make up most of the commercial use.

16. ***What kind of European corn borer control can I expect from Bt corn?***

Control of first generation is expected to be excellent. Control of second generation European corn borer varies with the event. In Colorado State University tests, the better events have provided excellent control of both generations of European corn borer. Control has been somewhat better than what we generally achieve with a single well-timed insecticide treatment.

17. ***Are there other advantages to using Bt corn instead of an insecticide to control corn borers?***

Bt corn will control corn borers without affecting predators and other beneficial insects. This should make management of other pests such as spider mites easier, although there are no field data to support this claim.

18. ***Are there disadvantages to using Bt corn compared to conventional corn borer control?***

There will be an additional cost to Bt corn seed regardless of whether there is an economic corn borer infestation. Conventional chemical control allows you to wait and see if an infestation develops before investing in insect management.

Also, there may be difficulty in marketing Bt corn destined for international markets. Imports are generally approved by event or event combination. For example, the MON 810/Liberty Link combination is not currently (as of June, 2001) approved for export to Europe. Remember that even if a Bt event is approved, the other traits (e.g. herbicide resistance) that it is stacked with may not be. The international marketing situation changes rapidly, so it is impossible to know how the rules might change between hybrid selection and harvest.

19. ***What about the other corn pests that I have to deal with every year?***

Until recently, commercially available Bt corn hybrids have targeted corn borers (European and southwestern). In Colorado State University tests, these Bt corn hybrids did not control corn rootworm beetles, corn rootworm larvae, spider mites, or western bean cutworm. The Bt corn hybrids that target corn borers provide some control of corn earworm and fall armyworm.

Starting in 2003, Bt corn hybrids that control corn rootworm larvae will be available.

20. ***What kind of corn rootworm control can I expect from Bt corn?***

Control of corn rootworm larvae is expected to be excellent compared to the control provided by soil insecticides.

21. ***Are there other advantages to using Bt corn instead of a soil insecticide to control rootworms?***

Bt corn would eliminate the need for the specialized equipment needed to apply soil insecticides and the need to handle these chemicals.

22. ***Are there disadvantages to using Bt corn compared to corn rootworm control with soil insecticides?***

There may be difficulty in marketing Bt corn destined for international markets. The international marketing situation changes rapidly, so it is impossible to know how the rules might change between hybrid selection and harvest. As of spring, 2003, event MON863 for corn rootworm control had been fully approved for food and feed use in the U.S., Canada, and Japan.

If European corn borer is a problem in your area you would lose the benefits of Bt corn for this pest until hybrids are available that contain events that target both pests.

23. ***What will be the additional cost for Bt corn seed?***

It should cost from $5 (dryland) to $10 (irrigated) per acre to use Bt corn, depending on seeding rates. There may be additional costs for other traits. In some hybrids, the Bt trait is only available in combination (stacked traits) with other traits such as herbicide resistance.

24. ***Can I plant Bt corn and forget about insects and mites?***

No, Bt corn will not let you forget completely about insect pests. Scouting and management will still be necessary for some pests. The table below gives the major corn pests and the expected (not all the necessary research has been done) effect on them by Bt corn hybrids effective against corn borers. Predictions for the PHI8999 event (Herculex), which seems to have a broader spectrum of activity than those currently on the market are not included. Bt corn hybrids that target rootworm are not effective against any other pests.

CORN PEST	EFFECT OF BT CORN	COMMENTS
Armyworm	Not controlled	Some effect on growth rates, some control may occur if infestation starts with small larvae. Potential for control with other delta endotoxin forms
Corn rootworm adults	Not controlled	
Corn rootworm larvae	Not controlled by the events that control corn borers	Hybrids with delta endotoxins (3Bb) toxic to rootworm larvae are available on a limited basis in 2003.
Corn leaf aphid	Not controlled	Less insecticide use for corn borers could make aphid less of a problem since outbreaks may be triggered by chemical control of other pests.
Corn earworm	Some control with some events.	Mon810 and Bt11 are moderately effective. Will not control late season infestations. Will control larvae that feed in whorl early in season (not common).
Cutworms	Not controlled	Some control may be obtained with other delta endotoxins such as Cry 1F.

CORN PEST	EFFECT OF BT CORN	COMMENTS
European corn borer	Controlled	Main target of Bt corn. Research results indicate 100% control of first generation and slightly lower control of second generation. Events 176 and DBT418 not as effective against second generation.
Fall armyworm	Not controlled	Some control may be obtained with other delta endotoxins such as Cry 1F.
Grasshoppers	Not controlled	
Southwestern corn borer	Controlled	Not tested as much as European corn borer, but results by event have been comparable.
Spider mites	Not controlled	Less insecticide use for corn borers could lower spider mites risk since outbreaks may be triggered by chemical control of other pests.
Western bean cutworm	Not controlled	Some control may be obtained with other delta endotoxins such as Cry 1F.
Wireworms	Not controlled	

25. ***Where should I use Bt corn to control corn borers in my operation?***

Bt corn should be used only where the risk of European or southwestern corn borer infestation is high. Colorado State University Cooperative Extension entomologists recognize the following European corn borer risk areas within the Golden Plains area (Kit Carson, Phillips, Washington and Yuma Counties) based on more than a decade of pest survey information. Pest survey data are insufficient to characterize European corn borer risk for other parts of the state:

Zone 1 (Burlington, Bonny Dam, Kirk) is characterized by heavy soils and consistently low insect light trap catches. Areas in this zone generally are not expected to have economic European corn borer infestations, although growers in the Kirk area experience occasional problems. Growers in Zone 1 should select well-adapted non-Bt corn hybrids, scout for insect pest problems and apply appropriate insecticides if justified. The exception might be the Kirk area because it has a long (4 to 5 week) 2nd generation flight in some years, increasing the probability that late planted or late maturing varieties will experience economic infestation. Bt corn hybrids might be an appropriate choice for these situations.

Zone 2 (Yuma, Clarkville, Holyoke) has a high probability of late planting or late maturing varieties due to heavy soils. These areas also have a consistent history of a prolonged second generation flight that result in economic infestations. The Bt trait would be an appropriate choice for late planted or late maturing hybrids in these areas. The prolonged flight makes treatment decisions very difficult. The infestations accumulated over the season are economically significant, but not enough of the infestation occurs in any two week period to justify the use of an insecticide. The first generation flight is consistent enough in these areas that Bt hybrids might also be considered for early planting situations. Although there is not a consistent need for Bt hybrids in this zone, it will be important to consider resistance management requirements when selecting hybrids and their acreage allocation.

Zone 3 (Eckley, Wray, Wauneta – north of Hwy 34 and east of Yuma) is characterized by light soils, relatively uniform crop maturity, and consistently large 1st and 2nd generation European corn borer flights. Also, 2nd generation flights typically extend over long periods of time. Economic infestations from either generation are likely and often both generations have to be treated in the same field. In addition, it frequently has been difficult to obtain adequate second generation control with a single insecticide application. The use of Bt corn hybrids are recommended for this area, regardless of planting date or maturity.

26. ***If I am not in one of these corn borer risk areas, how can I justify switching to Bt corn?***

Take a look at your average expenditures for corn borer management (scouting, insecticides, application) and your average losses to corn borers over the last 5 years. Your annual total of management costs and crop value lost should be similar to the cost of switching to Bt corn.

27. ***How can I justify switching to Bt corn for rootworm control?***

If you currently use a soil insecticide or control adult rootworms to prevent egg laying, you are likely justified in using Bt corn for rootworm control.

28. ***Should I plant all of my corn acreage to Bt corn?***

No! EPA has published guidelines on resistance management (refuge strategy) that affect how much you can plant! Details on these guidelines can be found in the EPA document *Biopesticides Registration Action Document - Bacillus thuringiensis Plant-Incorporated Protectants* (http://www.epa.gov/pesticides/biopesticides/pips/bt_brad.htm). Also, how much you do plant also depends a lot on how severe and consistent your corn borer or rootworm problems are (see preceding questions). Your average annual total of management costs and crop value lost to these insects over the last 5 years should give you a rough idea of how much to spend on Bt corn seed premiums. Use this seed in situations with higher pest risk (with European corn borer, for example, in the earliest and latest planted fields).

29. ***Will corn borers or rootworms eventually overcome the delta endotoxins produced by Bt corn, as greenbugs do to the resistance in sorghum hybrids?***

Insects can develop resistance to delta endotoxins. Resistance in diamondback moth and other vegetable pests to commercial Bt insecticides has developed in several parts of the world. This is also a major concern for all Bt-modified crops because they put so much selective pressure on the pest. However, no cases of resistance in any corn or cotton pests have been documented since 1996 when Bt crops first were grown extensively in the United States.

30. ***What is being done to avoid corn borers and rootworms becoming resistant to Bt corn?***

University researchers, the seed industry, and EPA are working together to develop resistance management plans that are effective and practical. They are based on the high dose strategy and the refuge strategy.

31. ***What is the high dose strategy?***

The idea is to use Bt corn hybrids that produce enough delta endotoxin to kill even partially resistant corn borers or rootworms. Killing partially resistant insects and thereby preventing their mating greatly delays the development of resistance.

32. ***How does this strategy affect producers?***

Some events are not as high dose as others and some areas are considered to be more likely to develop insect resistance than others. EPA may prohibit the sale of certain events in certain regions. In the past, sales of two events were prohibited in some SE Colorado counties.

33. ***What is the refuge strategy?***

If a certain acreage (refuge) is planted to non-Bt hybrids then any corn borers or rootworms coming out of these areas will be susceptible to Bt. They will mate with any survivors from the Bt corn and preserve the genetic susceptibility of the overall population.

34. ***How does the refuge strategy affect producers?***

Current EPA policy restricts growers to 80% Bt corn acreage for either rootworm or corn borer control. This

figure eventually may be lowered to 60% in eastern Colorado because of our relatively intense insecticide use patterns (meaning that fewer pest insects would be expected to survive in refuge areas).

35. ***Can I plant my refuge in the same field as the Bt corn?***

Yes, EPA allows the non-Bt corn refuge to be planted as strips running the length of the field. The strips need to be at least 6-12 rows wide.

36. ***How is the refuge strategy for Bt corn hybrids for rootworm control different from the strategy for corn borer hybrids?***

See the following table for a comparison.

	Corn Borers	**Rootworms**
Refuge size	20%	20%
Grower agreement	Required	Required
Location of external refuges	Within ½ mile, ¼ mile if refuge will likely be sprayed	Adjacent
Size of internal refuges	6 row minimum width	6 row minimum width, 12 rows preferred
Treat refuge for target pest(s)	OK, but not with conventional Bt insecticides	OK for larval treatments. If adults are treated, Bt hybrid must be treated as well
Treat refuge for other pests	OK	OK, but Bt crop must be treated in same manner if rootworm adults are present

37. ***What can I, as a grower, do to help avoid the development of pests that are resistant to Bt corn?***

Follow the resistance management recommendations provided by Cooperative Extension specialists, your seed company and EPA. Use good agronomic practices to avoid unneeded crop stress. Report any suspected failures to the seed company and to local Cooperative Extension entomologists as soon as possible.

38. ***How do I tell if I have a Bt corn failure?***

Identifying resistance to Bt corn is a complicated process. A few damaged plants in a field may not be a sign that resistance has developed. For example, the occasional susceptible plant may get into a field either from the seed source or as volunteer plants. If frequency of damaged plants seems unusually high, however, it should be reported.

39. ***Are there ways to make future Bt corn hybrids less prone to resistance development?***

Some future hybrids will have combinations of different delta endotoxin forms that should have fewer problems with resistance development. Others may have different genes that produce different toxins, such as scorpion venom. Hybrids with toxin combinations should be less likely to have problems with resistance development in pest insects.

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