Bacillus thuringiensis (*Bt*) in Genetically Modified Crops Fact Sheet

Bacillus thuringiensis (*Bt*) is a naturally occurring soil bacterium that is used for its insecticidal action. When the *Bt* bacterium produces spores, it also creates protein crystals which it releases with the spores. The crystals and spores settle on surfaces in the environment such as plant leaves. The crystals dissolve in the insect's gut when it eats them. This activates the proteins. The proteins destroy the insect's gut cells and kill the insect. The spores germinate into new bacteria, which feed on the dead insect.[1]

This fact sheet describes *Bt* genes specifically used in genetically modified crops. These crops are also known as transgenic or **bioengineered** crops. For more information about *Bt* used on its own as an insecticide, please refer to our fact sheet on ***Bacillus thuringiensis (Bt)***.

What are genetically modified crops and plant-incorporated protectants?

corn field, photo credit: pxhere.com

Genetically modified crops have a gene inserted into the crop plant. The gene is usually from another organism. This is frequently done to make the plant resistant to insects, herbicides, or both.[2] Some crops have been genetically modified to produce the substances found in *Bt* that are toxic to insects.

Plant-incorporated protectants, or PIPs, are one form of genetically modified crops.[3] The plants have bits of *Bt* DNA inserted into their own DNA so that they make the *Bt* toxins in their own cells.[4] The *Bt* toxin kills the insect when it feeds on the plant. Crops that have been genetically modified with Bt include corn, cotton, potatoes, and soybeans. The U.S. Environmental Protection Agency (U.S. EPA) regulates the proteins of the *Bt* toxin and the genes that help the plant produce the toxins. They do not regulate the modified plants.[5]

The part of the plant that produces the *Bt* toxins depends on two factors. First, it depends on where scientists insert the *Bt* gene into the plant's DNA. This is called the insertion event. Second, it depends on the promoter, or "genetic switch" scientists use. This affects where and how much *Bt* toxin will be made. Different combinations of insertion events and promoters create different varieties of *Bt* plants.[6] Plant leaves, pollen, and root tissue may create *Bt* toxins.[6,7,8]

The first genetically modified crops with *Bt* were registered by the U.S. EPA in 1995. Genetically modified crops may include more than one *Bt* toxin. This helps prevent insects from developing resistance to the *Bt* toxins.[9] These crops may also have more than one trait inserted into them. For example, a crop may be both resistant to herbicides and contain genes for *Bt* toxins as well.[10]

What happens to *Bacillus thuringiensis* (*Bt*) crops when they enter the body?

The U.S. EPA **evaluated potential risks** to human health. They concluded that eating crops that have been genetically modified to create *Bt* toxins is not expected to be harmful to people. This is because *Bt* toxins are proteins, and humans digest proteins quickly. Normal food processing also breaks down proteins.[11,12] In addition, the toxins are activated when eaten by insects, which have alkaline guts with a pH of 9.0-10.5.[13] Humans and other mammals have much more acidic conditions in their stomachs. Acid destroys the toxins.[14]

The U.S. EPA requires data from manufacturers to show that the *Bt* proteins are not likely to act as a food allergen. Studies also show that *Bt* proteins do not cause toxicity even when fed to test animals at very high doses. The information is meant to show that the *Bt* toxins will act like any other dietary protein.[11]

Scientists have exposed mice to very high doses of different *Bt* toxins in many different studies. The scientists saw no effects in mice that ate 576 to over 5000 mg/kg *Bt* toxins. The amount the mice ate depended on the specific study and *Bt* toxins used.[15] **See the text box about mg/kg.**

What is milligrams per kilogram (mg/kg)?

"Mg/kg" is a way to measure a chemical dose. This can tell us how toxic a chemical is. "Mg" means milligrams of a chemical. "Kg" means one kilogram of an animal's body weight. Something that is highly toxic may kill a person with a very small amount of chemical. If something is very low in toxicity, it may take much more for that same person to become very sick or die.

Scientists fed dairy cows a diet with 35% *Bt* corn for five weeks. They did not find the toxin proteins from the *Bt* corn in the muscles, milk, liver, or blood of the cows.[16]

Are children more sensitive to *Bt* than adults?

Children may be especially sensitive to pesticides compared to adults. However, there are currently no data showing that children are at increased risk specifically to *Bt*.[11]

Is consuming *Bt* crops likely to contribute to the development of cancer?

The toxin produced by *Bt* is a protein. Research has shown that eating proteins has not led to cancer, genetic mutations, or birth defects.[15]

Has anyone studied non-cancer effects from long-term exposure to eating crops that have been genetically modified to contain *Bt*?

Overall, there is no evidence that eating *Bt* crops has led to negative health effects in either test animals or humans.

Scientists reviewed studies that had exposed animals to *Bt* crops in their food for over 90 days or across generations. No effects were found in dairy cows, sheep, chickens, rats, or mice.[17]

Scientists have examined the effects of feeding *Bt* corn to pigs. Most studies on pigs found that *Bt* corn had no effects on them.[18,19,20,21]

- Scientists fed sows diets of 86% *Bt* corn through pregnancy until their piglets weaned at 28 days. The sows and their piglets weighed the same as sows and piglets eating non-*Bt* corn diets.[19]
- Mother pigs fed 75-87% *Bt* corn had piglets that in turn were fed *Bt* corn in their diets for 115 days. The piglets were as healthy and heavy as piglets raised on non-*Bt* corn.[21]
- Other scientists fed *Bt* corn to pigs for up to 110 days and found no effects on the pigs.[20]
- In another study, pigs that ate 39% *Bt* corn in their diets for one month needed more food than pigs who ate non-*Bt* corn. The pigs also gained less weight.[18]

Studies on rodents fed *Bt* corn found no effects on their health or reproduction. However, some studies showed small effects on the rodents' kidneys, livers, or body weight.[22,23]

- Scientists fed rats diets with no corn, 20% non-*Bt* corn, or 20% *Bt* corn for three generations. They did not see any effects in any of the newborn rats in each generation. The rats' behavior, health, and reproduction were the same among groups. The scientists saw some small differences in the kidneys and livers of rats fed the corn diets. The livers of rats fed the *Bt* corn were more affected.[22]
- Other scientists fed mice diets with either 68% *Bt* corn or non-*Bt* corn for five generations. The *Bt* corn diet did not affect growth, weight, lifespan, or reproduction in the mice. Mice in each generation weighed less than in previous generations no matter which type of corn they ate. Scientists thought that this was from the large amount of corn in their diets.[23]

Scientists fed four Holstein cows with 35% *Bt* corn for 5 weeks. They found no differences in milk yield, health, or the cows' rumens (their largest stomachs) compared to cows fed non-*Bt* corn.[16]

Chickens ate diets with 61% *Bt* corn for 12 weeks. Organ weights, body weights, organ health, and egg laying were not affected compared to hens who ate non-*Bt* corn.[24]

No scientific studies were found that examined the effects on human health from eating *Bt* crops. No other reports of negative effects from eating *Bt* crops were found.

What happens to *Bt* crops in the environment?

Bt is a naturally occurring soil bacterium, and its spores and the toxic proteins are already found in **soils**.

Bt crops and non-*Bt* crops take the same amount of time to break down in the **environment**.[25] Environmental conditions such as rain, temperature, and contact with soil degrade crop residue. Crop residue includes the leaves, stems, and other plant matter remaining after harvest. Environmental factors were more important in how fast corn residue degraded rather than the presence of the *Bt* protein.[26] For example, there was no difference in the breakdown of *Bt* corn and non-*Bt* corn in streams near corn fields.[27]

Farming practices after harvest affect how quickly *Bt* corn residue breaks down on the soil surface. How much crop residue was left also mattered.[26] In one study, scientists measured toxins from *Bt* corn crop residue in soil in Switzerland. *Bt* toxins broke down slowly. The breakdown speed depended on temperature. *Bt* toxins did not break down in winter. After 200 days, in June, less than 1% of the *Bt* toxin remained in crop residues. In the first month after harvest, the *Bt* toxins degraded more rapidly when crop residues were left on the soil surface than when they were tilled into the soil.[28]

In a second study, scientists found that *Bt* toxins broke down most quickly when the crop residues were incorporated into the soil. They planted a *Bt* corn variety active against European corn borers. After harvest, they compared crop residue treatments such as no-till and tilling the field. The scientists fed crop residues to the European corn borer larvae 0-24 weeks after harvest. Larvae were 31-48% smaller than larvae eating crop residues from non-*Bt* corn. Crop residue from *Bt* corn that was tilled under the soil surface affected the larvae the least.[26]

Although *Bt* crops can release *Bt* toxic proteins from their roots, effects to the soil microbiome seem to be limited.

- In one study, scientists found that the bacteria in the soil around the plant roots were more affected by the plants' ages and field conditions than by the presence of *Bt* crops.[29]
- In another study, scientists found that the soil bacteria were affected by *Bt* cotton compared to non-*Bt* cotton and wheat. The soil bacteria community overall did not change in abundance. However, the types of bacteria did change relative to each other. This also changed soil functions.[30]
- Studies have concluded that the toxic proteins produced by *Bt* crops did not affect soil microorganisms, including protozoa, fungi, bacteria, or larger organisms such as earthworms and nematodes. Farming practices themselves may have large impacts on soil and soil microbial communities.[11]

Can *Bt* crops affect birds, fish, and other wildlife?

Although some laboratory studies suggest *Bt* crops might have negative impacts on non-target insects that are closely related to the target pest, most field studies have not shown effects.[31] Scientists reviewed studies looking at the effects of *Bt* plants on insects, microbes, and worms. Most studies they reviewed did not find any effects on non-target organisms unless the non-target organisms were closely related to the pest controlled by the *Bt* toxins.[32,33]

The U.S. EPA concluded that published studies and data submitted by manufacturers showed "minimal to undetectable changes" to non-target insect populations, including **beneficial insects**.[11]

Butterflies

At first some scientists were worried that monarch butterfly larvae could be harmed by *Bt* corn pollen. They concluded in the same study that the risk of exposure to *Bt* pollen was low for black swallowtail butterflies, another endangered species. However, the scientists thought that other endangered butterflies that are sensitive to *Bt* and exposed to *Bt* pollen could be impacted.[8] Other scientists determined that the actual risks to monarch butterflies were low because the butterflies would not be likely to encounter the pollen and that current corn hybrids are low in toxicity to the monarch butterflies.[34] One type of *Bt* corn that scientists found may harm monarch butterflies[35] is no longer sold.[5]

Honeybees

Scientists reviewed 64 published studies, and 18 unpublished studies provided to the U.S. EPA. These studies looked at the risk to honeybees from pollen and nectar of *Bt* crops. The scientists concluded that *Bt* crops should not affect honeybees.[36]

Parasitic wasps

Scientists studied whether parasitoid wasps were affected by preying on host insect larvae that ate *Bt* plants. Parasitic wasps lay their eggs on their host insects. When the eggs hatch, they eat the host. Most studies found no effects. Other scientists in one study found that the wasps did not develop well in hosts that fed on *Bt* plants. They thought this was because the hosts were not healthy rather than an effect of the *Bt* toxins on the wasp larvae.[8] Another study looked at a parasitic wasp that feeds on southern armyworms. The wasps were not affected when the armyworm larvae ate *Bt* soy plants.[37]

Predatory insects

Many scientists have asked whether *Bt* crops affected predatory insects. Very few studies have shown negative effects.

One scientist reviewed many studies to determine whether *Bt* crops affected non-target insects such as the predators of pest insects. The scientist found that predatory insects were harmed if a *Bt* crop was used to control their prey. If the prey insect was not controlled by the *Bt* crop, the predator was not affected. The review concluded that the predators were not harmed by the *Bt* toxins directly, but through the loss of their prey.[31]

One study reported that more ladybug larvae died when they ate prey eggs sprayed with *Bt* toxins than larvae who ate unsprayed eggs.[38] However, another group of scientists fed ladybug larvae with spider mites that had been raised either on *Bt* corn, regular corn, or sugar spiked with the *Bt* toxins. *Bt* corn or sugar did not harm the ladybug larvae. The scientists thought that the previous study had design problems because ladybug larvae do not usually eat the shells of eggs.[33]

Aquatic insects

Overall, there is little evidence that *Bt* toxins from crop residue could harm aquatic insects.

Crop residue and pollen from *Bt* corn crops can be found in streams, where aquatic insects may eat them. Scientists used toxicity data and environmental fate data to model the likelihood that *Bt* toxins from crops would harm aquatic insects. Even when they modeled worst-case concentrations of *Bt* toxins in aquatic systems, they found that "there is a reasonable certainty of no harm" in 99% of cases for sensitive species.[39] A second risk assessment by other scientists modeling worst-case conditions also concluded that the exposure risks were very low.[40]

Scientists studied caddisflies in the laboratory and in streams. Caddisflies are aquatic insects whose larvae shred leaves or scrape rocks. Most studies found no effects from *Bt* crop residue.

- Scientists fed *Bt* corn crop residue to caddisfly larvae in the laboratory. They grew more slowly than insects fed non-*Bt* corn crop residue.[27] However, the study was criticized because the scientists did not use proper controls.[41]
- Other scientists who exposed aquatic insects to *Bt* corn residue did not find effects to the insects from eating the *Bt* toxins in the residue. The researchers in that study used a better control treatment. Although this study showed negative effects in the insects, the scientists involved felt that other factors were responsible.[42]
- Caddisflies that shred leaves were not affected by *Bt* corn residue in streams in *Bt* corn fields versus non-*Bt* corn fields. The scientists thought that other environmental factors were more important.[43] Another species of caddisfly that scrapes algae from rocks was tested in the laboratory. It was not affected by *Bt* toxins at levels that were found in streams.[27]

Earthworms

Earthworms ate *Bt* corn crop residue for 200 days in the laboratory and in the field. Juvenile worms in the field were not affected. Adult worms in the laboratory gained less weight than control worms after 160 days. The scientists thought that either food quality was lower or that the *Bt* toxin was finally affecting the worms after they grew up being exposed to it.[44]

Birds

Japanese quail ate feed with 40-50% *Bt* corn for 10 generations. Scientists did not see any effects on health, meat or egg quality, laying performance, or egg hatching in any of the generations.[45] Another 10-generation feeding study of Japanese quail compared diets of *Bt* corn, soybeans modified to resist herbicide, and conventional soybeans and corn. The researchers found no differences in hatching, survival, or body weight in quail across treatments. Quail fed *Bt* corn had slightly heavier breast muscle. More quail in the *Bt* corn group laid eggs.[46]

Fish

A review of several studies concluded that *Bt* corn fed to fish had no effects on development, growth, or survival although some individual fish in the *Bt* corn groups showed slight signs of stress in their enzymes and blood.[47]

- A study using Atlantic salmon studied health effects of using *Bt* maize in the fish's diet. Growth rates among all fish did not differ. The fish fed *Bt* maize showed changes in white blood cells that may have indicated an immune response.[48]
- Scientists exposed zebrafish embryos to two different *Bt* toxins. The *Bt* toxins did not affect egg hatch rates, development, or body length at hatching.[49]
- Other scientists fed zebrafish diets including *Bt* corn for two generations. Half of the offspring were fed *Bt* corn, and the other half were fed non-*Bt* corn. Fish in the first generation were not affected by the *Bt* corn. If both generations of fish ate *Bt* corn, the second generation grew faster.[50]
- Researchers tested both soy and *Bt* corn diets on the growth and development of young Atlantic salmon. They fed the fish these diets for 99 days and tested the fish throughout. Fish had minor changes in their intestine function. The researchers concluded that there were no effects of *Bt* corn on the general health of the fish.[51]

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Where can I get more information?

For more detailed information about *Bt* in Genetically Modified Crops, please visit the list of referenced resources below, call us Monday - Friday, between 8:00am and 12:00pm PT (11:00am to 3:00pm ET) at 800-858-7378, email us at npic@oregonstate.edu, or visit us on the web at npic.orst.edu. NPIC provides objective, science-based answers to questions about pesticides.

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