

What is Bt and What is the Risk of Insects Becoming Resistant to Bt Transgenic Plants?

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One of agriculture's best defenses against plant-eating insects is Bt, which either can be sprayed on the surfaces of crops to provide temporary protection or can be genetically engineered into the crops to protect against insects throughout the lifespan of the plants. Bt has allowed growers to avoid applying large quantities of potentially toxic insecticides. However, the widespread use of Bt has prompted concerns that insects might someday become resistant to this important treatment. This is a valid concern that has engaged agricultural researchers before Bt crops reached the marketplace.

Question: What is Bt?

Answer: Bt is short for *Bacillus thuringiensis*, a natural bacterium in the genus *Bacillus*. This diverse genus also includes more than 20 other *Bacillus* species and hundreds of different subspecies. Members of the genus *Bacillus* are generally considered soil bacteria, and Bt is common in terrestrial habitats including soil, living and dead insects, insect feces, granaries, and on the surfaces of plants. Bt occurs in nature predominantly as spores that can disseminate widely throughout the environment. Bt is very safe to humans and the environment. In fact there have not been any reports of harm to humans in the nearly 50 years it has been used as an insecticide.

A unique feature of Bt is that the bacterium produces protein crystalline structures, and these proteins have activity against some insect species. Bt was first isolated about 100 years ago in Japan from silkworm larvae. For over 50 years, Bt has been applied to crops in spray form as an insecticide, containing a mixture of spores and the associated protein crystals. Rachel Carson promoted Bt as a natural insecticide in her book, *Silent Spring*, published in 1962. By 1995, 182 Bt-based products were registered by the United States Environmental Protection Agency (EPA). However, by 1999 the total sales of Bt formulations constituted less than 1 percent of the total sales of all insecticides. Bt lacked performance compared to many other available insecticides, so it was not widely used. However, organic farmers rely on it as one of their main controls for caterpillar pests.

Q: How does Bt kill insects?

A: The main insecticidal effect of Bt comes from insecticidal crystal proteins (ICPs) produced during the bacterium's sporulation phase. Different ICPs work against particular insect types — caterpillars, for example, or certain species of beetles. Key agricultural pests currently targeted with Bt insecticides include bollworms, stem borers, budworms, and leaf worms in field crops and grains; the gypsy moth and spruce budworm in forests; and the cabbage looper and

diamondback moth in vegetable crops. Mosquitoes and black flies are also controlled with Bt sprays or treatment of water breeding sites with Bt.

Bt insecticides, whether in the form of a spray or in a Bt-engineered crop, do not function on contact as most insecticides do. Rather, the ICPs must be ingested by the target organism to be effective. The process takes hours or even days — much longer than is required for most synthetic insecticides to kill insects. The active ICP binds to specific receptors on the midgut of the stomach, forming pores and leading to leakage of the midgut contents, paralysis, and death of the insect. Only some insect species have such receptors in the gut; humans, mammals and most other organisms do not.

Q: What are Bt plants?

A: Bt plants have genes from the Bt bacterium engineered into them so that the plants produce an ICP toxic to the pest species of concern. As the insect feeds on the plant, it ingests the ICP and suffers the same fate as if it ingested leaf tissue sprayed with Bt. There are only two Bt crops presently registered in the United States — Bt corn and Bt cotton. Many other Bt crops are being developed including rice, eggplant, cabbage and cauliflower.

Q: How do Bt-engineered plants compare with foliar sprays of Bt?

A: There are some advantages to the use of Bt-engineered plants compared with foliar sprays of Bt, and some disadvantages. The chief advantages to Bt plants are that the pests hiding inside plant parts (stem borers, for example) can now be controlled effectively; multiple sprays are not needed; and the dose of Bt can be more effectively regulated. A disadvantage of Bt plants is that insect-specific ICPs cannot be changed during a growing season.

Q: What is resistance?

A: Resistance is a genetic change in an organism — in this case, the insect pest — that allows it to avoid harm from another organism or chemical product. Insect pests can develop resistance to synthetic, organic and biological (such as Bt) insecticides. Developed resistance can impair the performance of insecticides in the field. A survey found that more than 500 species of arthropods have developed strains that are resistant to one or more of the five principal classes of insecticides.

Q: So, what are the chances that insects will develop resistance to Bt plants?

A: There are only two insect species that have developed resistance to Bt foliar sprays under commercial situations — the diamondback moth and the cabbage looper. In several places in the world, some populations of these insects have developed resistance to foliar sprays of Bt. This warns us that some insect species have the capacity to develop resistance to an ICP. However, after 12 years of large-scale plantings of Bt crops, there has only been a single report of an insect species having developed resistance to a Bt plant. Although this was a very isolated instance, the sale of Bt plants in that area was suspended. In 2006, there were nearly 80 million acres of Bt crops grown in 19 countries.

The important question is: Why have we not seen wide-spread resistance to Bt plants, especially since resistance to other types of insecticides generally occurs in 3–5 years? Although there are no definite answers, there are some interesting speculations. One likely answer is that the high and consistent levels of ICP production in the plant make them much less favorable for the development of resistance, compared to the variable and constantly changing dose when Bt is sprayed on the plant. In scientific language, the dose of the ICP in the plant was designed to be sufficiently high enough to kill the SS and RS insect genotypes, and such a dose is impossible to maintain with foliar sprays. Perhaps most importantly, Bt plants are more strictly regulated in the field than are foliar sprays of Bt. Every grower who plants a field of Bt plants also must plant an adjacent field of the same crop that does not contain Bt. This separate planting is called a “refuge” and it preserves Bt-susceptible genes in the general population of insects. The size of the refuge may be 5–20 percent the size of the Bt crop. No other insecticides, including foliar sprays of Bt, have such a requirement for resistance management.

Q: What’s the bottom line?

A: It has only been since the genes for production of Bt ICPs were engineered into plants that Bt really became a major insecticide. Its now widespread use has provided strong economic and environmental benefits. However, with its more widespread use there is increased risk of resistance development to Bt plants. What is remarkable is that there has only been a single case of resistance to Bt plants in 12 years of use, while resistance to conventional insecticides often develops in as few as 3 years. It is also important to remember that when resistance to an ICP occurs, it is to a single type of ICP and other Bt ICPs may still provide control. It is also important to remember that in the years prior to the development of resistance to a specific ICP, substantial environmental and human health benefits would have accumulated compared to the use of more toxic insecticides. For example, the use of Bt cotton has reduced the use of traditional insecticides by 207,900,000 lbs of active ingredient of insecticide and resulted in a 24 percent benefit to the environment, as well as reduced pesticide poisoning to humans (Brookes and Barfoot, 2006).

References and further reading

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