Have you ever seen a leaf eaten off by plant pests? What about an entire harvest destroyed by insects? Plant pests cause a lot of problems to farmers and home gardeners alike. Because of this, they have had very little recourse other than to continually spray their plants with pesticides. Unfortunately, some of these pesticides pose health risks to people who are exposed to them.

It is for this reason that scientists are constantly looking for alternative ways of dealing with plant pests.

The Bt Organism

Bt stands for *Bacillus thuringiensis* (Bt) a common soil bacterium so called because it was first isolated in the Thuringia region of Germany.

Bt produces a protein that paralyzes the larvae of some harmful insects, including the cotton bollworm and the Asian and European corn borers, all of which are common plant pests whose infestations produce devastating effects on important crops.

Mode of Action

USDA PHOTO

Cotton Bollworm

When ingested by the larva of the target insect, the Bt protein is activated in the gut's alkaline condition and punctures the mid-gut leaving the insect unable to eat. The insect dies within a few days.

It is because of its ability to produce the insecticidal protein that much research is being done to exploit the organism's agronomic value. To date, there are more than 200 types of Bt proteins identified with varying degrees of toxicity to some insects.

Earlier Bt Technology

Bt is easily cultured by fermentation. Thus, over the last 50 years, Bt has been used as an insecticide by farmers worldwide. Organic farming in particular has benefited from Bt insecticide, as it is one of the very few pesticides permitted by organic standards. The insecticide is applied either as a spray, or as ground application. It comes in both granules and liquefied form.

The efficiency of both applications is quite limited, as target organisms often do not come in contact with the insecticide as they are found on the underside of leaves or have already penetrated into the plant. Scientists are working to overcome this problem through the use of modern biotechnology.

Modern Bt Technology

Scientists have taken the Bt gene responsible for the production of the insecticidal protein from the bacterium and incorporated it into the genome of plants. Thus, these plants have a built-in mechanism of protection against targeted pests. The protein produced by the plants does not get washed away, nor is it destroyed by sunlight. The plant is thus protected from bollworm or corn borer round the clock regardless of the situation.

USDA PHOTO

Conclusion

Bt crops are an addition to our GM product arsenal against plant pests. With an increasing population and decreasing arable land, it is necessary to exploit all options with as little compromise to produce more crops. When used side by side with proper agricultural practices, Bt insect resistance technology can bring many benefits to crops, farmers, and consumers alike.

OSCAR GUTIERREZ PHOTO

References

1. 2004. Essential Biosafety. Agriculture and Biotechnology Strategies, Inc.
2. Donegan, K.K., C.J. Palm, V.J. Fieland, L.A. Porteous, L.M. Ganio, D.L. Schaller, L.Q. Bucao, and R.J. Seidler. 1995. Changes in levels, Species and DNA Fingerprints of Soil Microorganisms Associated with Cotton expressing the *Bacillus thuringiensis* var. kurstaki endotoxin. Applied Soil Ecology 2:111-124.
3. Donegan, K.K., D.L. Schaller, J.K. Stone, L.M. Ganio, G. Reed, P.B. Hamm, and R.J. Seidler. 1996. Microbial Populations, Fungal Species Diversity and Plant Pathogen Levels in Field Plots of Potato Plants Expressing the *Bacillus thuringiensis* var. tenebrionis Endotoxin. Transgenic Research 5:25-35.
4. The Council for Biotechnology Information. 2001. Bt Protein in Soil. http://www.whybiotech.com/pdf/Bt_Protein_in_Soil.pdf
5. Environmental Protection Agency. 1999. EPA and USDA Position Paper on Insect Resistance Management in Bt Crops. http://www.epa.gov/pesticides/biopesticides/otherdocs/bt_position_paper_618.htm
6. Extension Toxicology Network. 1996. Pesticide Information Profile, *Bacillus thuringiensis*.
7. Sears, M., R. Hellmich, S. Stanley-Horn, K. Onerhauser, J. Pleasants, H. Mattila, B. Siegfried, G. Dively. 2001. Impact of Bt Corn Pollen on Monarch Butterfly Populations: A Risk Assessment. PNAS 98(21): 11937-11942.
8. ISAAA. 2018. Global Status of Commercialized Biotech/GM Crops: 2018. ISAAA Brief No. 54. ISAAA: Ithaca, NY.
9. Brookes, G. and P. Barfoot. 2018. GM Crops: Global Socio-economic and Environmental Impacts 1996-2016. PG Economics Ltd, UK. pp 1-204.

Pocket Ks are Pockets of Knowledge, packaged information on crop biotechnology products and related issues available at your fingertips. They are produced by the Global Knowledge Center on Crop Biotechnology (http://www.isaaa.org/kc). For more information, please contact the International Service for the Acquisition of Agri-biotech Applications (ISAAA) SE*Asia*Center c/o IRRI, Los Baños, Laguna, 4031 Philippines.
Telefax: +63 49 5367216
E-mail: knowledge.center@isaaa.org

Updated March 2020 (No. 6)

ISAAA
INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS

Safety Aspects of *Bt* Technology

Effects on Human Health

So how safe is the Bt protein to non-target organisms? The specificity of Bt for its target insects is one of the characteristics that make it an ideal method of biological pest control. In fact, different strains of Bt have specific toxicity to certain target insects. The specificity rests on the fact that the toxicity of the Bt protein is receptor-mediated. This means that for an insect to be affected by the Bt protein, it must have specific receptor sites in its gut where the proteins can bind. Fortunately, humans and majority of beneficial insects do not have these receptors.

ISAAA PHOTO

Before Bt crops are placed on the market, they must pass very stringent regulatory tests, including those for toxicity and allergenicity.

The U.S. Environmental Protection Agency (US-EPA) has already administered toxicology assessments, and Bt proteins have already been tested even at relatively higher dosages. According to the Extension Toxicology Network (Extoxnet), a pesticide information project of several universities in the US, “no complaints were made after 18 humans ate one gram of commercial Bt preparation daily for five days, on alternate days. Humans who ate one gram per day for three consecutive days were not poisoned or infected.” Furthermore, the protein was shown to be degraded rapidly by human gastric fluid in vitro (Extoxnet, 1996).

Effects on the Environment

Soil ecosystems and groundwater

The Bt protein is moderately persistent in soil and is classified as immobile, as it does not move, or leach, with groundwater. It does not particularly persist in acidic soil conditions and, when exposed to sunlight, is rapidly destroyed due to UV radiation.

Independent experts have conducted studies to investigate the impact of Bt crops on soil organisms and other insect species that are considered beneficial in agriculture. No adverse effects have been found on non-target soil organisms, even when these organisms were exposed to quantities of Bt far higher than what would actually occur under natural crop-growing conditions. Likewise, research done by the US-EPA revealed no changes in the soil microbiota in fields with Bt plant material or conventional plant material (Donegan, et al., 1995), or between fields of Bt and non-Bt crops (Donegan, et al., 1996).

Animals and insects

USDA PHOTO

Monarch Caterpillar

On tests conducted on dogs, guinea pigs, rats, fish, frogs, salamanders, and even birds, the Bt protein was found not to have any harmful effects. It is also noteworthy that no toxic effects were found on beneficial or predatory insects, such as honeybees and lady beetles (Extoxnet, 1996).

In 1999, it was reported that pollen from Bt corn had a negative impact on Monarch butterfly larvae. This report raised concerns and questions about the risks of Bt crops on non-target organisms. Recent studies, however, show that Bt corn poses “negligible” threat to Monarch butterflies in the field. A collaborative research effort by scientists in the US and in Canada has produced information to develop a formal risk assessment of the impact of Bt corn on Monarch butterfly populations. They concluded that in most commercial hybrids, Bt expression in pollen is low, and laboratory and field studies show no acute toxic effects at any pollen density that would be encountered in the field.

Advantages of *Bt* Crops

Improved pest management. Insect-protected Bt crops provide the farmer with season-long protection against several damaging insect pests, and reduce or eliminate the need for insecticide sprays. This eliminates the yield loss that results from less than optimal pest control by applied farm insecticides, and it allows the farmer more time for other farm management duties.

Reduction in insecticide use. A study by the US Department of Agriculture reported that 8.2 million pounds of pesticide active ingredients were eliminated by farmers who planted Bt crops in 1998. Significant reductions have also been reported in China and Argentina, where the use of Bt cotton resulted in a 60-70% reduction in pesticide use.

Greater net return. Lower input costs often contribute to a higher net return compared to conventional crops. Bt cotton farmers in the US earned an incremental $99 million as a result of decreased pesticide costs and/or increased yields. Similarly, Bt cotton farmers in Argentina reported that Bt cotton generated an average incremental benefit of $65.05/ha.

Improved conditions for non-target organisms. Since Bt crops are able to defend themselves against pests, the use of chemical insecticides is significantly reduced, thereby encouraging the proliferation of beneficial organisms. These beneficial organisms can help control other secondary pests, which can often become a problem when predator and parasite populations are reduced by conventional broad-spectrum insecticides.

Less mycotoxin in corn. Aside from being effective against insect pests, Bt crops have lower incidences of opportunistic microbial pathogens, such as the fungus Fusarium. This fungus produces mycotoxins that can be deadly to livestock and also cause cancer in humans.

Insect Resistance Management

Since Bt crops are capable of season long expression of the Bt protein, precautionary steps have to be taken in order to avoid the development of insect resistance. In the US, for example, the EPA usually requires a “buffer zone,” or a structured refuge of non-Bt crops that is planted in close proximity to the Bt crops. Insect resistance management (IRM) is said to be the key to sustainable use of the insecticide in both genetically modified crops and Bt microbial spray formulations.

USDA PHOTO

Corn Borer

Current Status of Bt Technology

At the end of 2018, an estimated 23.7 million hectares of land were planted with crops containing the Bt gene. The following table shows the countries that have commercialized Bt crops (with single and stacked genes) and its products, from 1996 to 2019.

Bt Crop	Countries
Cotton	Argentina, Australia, Brazil, Burkina Faso, Canada, China, Colombia, Costa Rica, eSwatini, Ethiopia, European Union, India, Japan, Malaysia, Mexico, Myanmar, New Zealand, Nigeria, Pakistan, Paraguay, Philippines, Singapore, South Africa, South Korea, Sudan, Taiwan,USA
Cowpea	Nigeria
Eggplant	Bangladesh
Maize	Argentina, Australia, Brazil, Canada, Chile, China, Colombia, Egypt, EU, Honduras, Indonesia, Japan, Malaysia, Mexico, New Zealand, Nigeria, Pakistan, Panama, Paraguay, Philippines, Russian Federation, Singapore, South Africa, South Korea, Switzerland, Taiwan, Thailand, Turkey, USA, Uruguay, Vietnam, Zambia
Poplar	China
Potato	Australia, Canada, Japan, Mexico, New Zealand, Philippines, Russian Federation, South Korea, USA
Rice	China, Iran, USA
Soybean	Argentina, Australia, Brazil, Canada, China, Colombia, EU, India, Indonesia, Iran, Japan, Malaysia, Mexico, New Zealand, Paraguay, Philippines, Russian Federation, Singapore, South Africa, South Korea, Taiwan, Thailand, Turkey, USA, Uruguay, Vietnam
Sugarcane	Brazil, Canada, USA
Tomato	Canada, USA

Source: ISAAA GM Approval Database (http://www.isaaa.org/gmapprovaldatabase/)

For the first 22 years of commercialization (1996-2016), benefits from IR crops are valued at US$97.4 billion, 52.3% of the global value of biotech crops of US$186.1 billion; and for 2016 alone at US$9.73 billion, 53.4% of the global value of biotech crops of US$18.2 billion.