What the heck is Bt? The Agricultural and Ecological Credentials of a Bacterial Bug Beater

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Introduction

Bacillus thuringiensis (pronounced as bah-sill-us thur-in-jee-en'-sis) is a living bacterium that has been used by organic growers, non-organic growers and in genetically modified crops to control a plethora of insect pests. *Bt* is a naturally occurring biological organism that is considered to be remarkably safe for both humans and the environment, due to its specificity against target insects and limited persistence in the environment. *Bt* products have had widespread, versatile and long-term use and are commonly promoted as an environmentally safe pesticide alternative.

History

Bt was initially discovery in Japan in 1901 from the larvae of diseased silkworm. *Bt* products were first marketed and available in France during the 1930's, however, it was not until 1954 that the insecticidal activity of *Bt* was understood. Researchers discovered that the insecticidal action of *Bt* against Lepidoteran (butterflies and moths) insects was due to the presence of crystal-like proteins.

Bt was used commercially in 1958 and was registered by EPA (Environmental Protection Agency) as a pesticide in 1961. In 1983, the first genetic modification of plants was reported and in 1987 researchers studying *Bt* successfully isolated and cloned the *Bt* crystal protein gene. Nine years later, in 1996, large-scale corn crops containing *Bt* transgenic genes were planted. *Bt* transgenic crop production rapidly increased to more than 14 million hectares grown worldwide in 2002. The cumulative area of *Bt* crops grown from 1996 to 2002 was estimated to be 62 million hectares (James 2002).

Mode of Action

The insecticidal nature of *Bt* is attributed to crystal-like proteins that are produced by *Bt* cells during the spore-forming stage of its life cycle. The crystal protein in *Bt* kills insects by binding to and disrupting the midgut (stomach) membranes. Susceptible insects will stop feeding within hours of ingesting *Bt* and will generally die within 2-5 days. The specificity of *Bt* lies in the fact that particular stomach enzymes (present only in certain insects) must activate the crystal proteins before they are considered toxic. Under normal conditions the crystal protein is insoluble (not active) and is therefore safe to humans, mammals and the majority of insects. The *Bt* toxin is most effective against young insect larvae, which are more susceptible because they are relatively small. Once in the environment, the insecticidal protein of *Bt* degrades quickly (1-4 days) following exposure to sunlight and microorganisms.

There are numerous strains of *Bt*, which may exhibit different toxicity to various organisms. In Canada, three subspecies are registered for use. *Bt* subspecies *Kurstaki* (*BT*K) is effective against a wide range of Lepidopteran species (see Table #1). *Bt* subspecies *Israelensis* (*BT*I) is used for controlling the larvae of mosquitoes and blackflies and *Bt* subspecies *Tenebrionis* (*BT*T) is registered for use against Coleoptera (beetles) like the Colorado potato beetle.

Two Main Types of *BT*

Bt is used in two main ways, either as a spray formulation or it is genetically modified into crops. The sprayable forms of *Bt* can be applied directly to plants (as a liquid, powder, dust or granule), or it can be applied to surface waters, furthermore, it can be used in the watering lines of greenhouses. For many years, both organic and non-organic farms throughout the world have used *Bt* sprays to control target pests. *Bt* suitability for organic production is currently being reviewed because some products are prohibited by organic certifying agencies because they contain inert ingredients, which are prohibited (Boiteau 2004).

Genetic modification is a relatively new tool used by scientists to add desirable traits to a plant or crop. The process involves physically removing the DNA from one organism and

transferring the genes into another organism. For *Bt*-transgenic crops, a modified version of the *Bt* insecticidal gene is incorporated into the plants DNA. *Bt* crops are currently engineered to produce a single activated insecticidal crystal protein throughout all parts of the plant and they expose insect populations to *Bt* toxins throughout all stages of the growing season, thereby creating a much higher probability that target insects will develop resistance.

Health Canada has classified genetically modified foods as novel foods (Health Canada 2004). Novel foods are products that have never previously been used as a food; foods that result from a process that has not previously been used for food; or, foods that have been modified by genetic manipulation. There are currently over 60 genetically modified food items that have been approved for sale in Canada. Canadian approved novel foods that contain *Bt* include corn (*BT*K), potatoes (*BT*T), tomatoes (*BT*T) and cottonseed oil from cotton lines (*BT*K).

_Bt_ Products Registered in Canada

The Pest Management Regulatory Agency (PMRA) is the government body that is in charge of approving all pest control products prior to their use in Canada. Of the 34 *Bt* products currently registered by the PMRA, 3 are marketed for domestic use, 7 for formulation use, 11 for commercial use and 14 for restricted use (PMRA 2004). Label directions should be followed closely to ensure proper application techniques and rates.

Can insects become resistant to _BT_?

Although researchers initially believed that insects would not develop resistance to biological insecticides, they soon discovered that biological sprays were not exempt. Insect resistance to *Bt*-sprays has been reported in both laboratory and field research. Field-evolved resistance to transgenic *Bt* crops has yet to be documented, however, evidence from *Bt*-spray research and the widespread use of transgenic *Bt* crops has raised concerns about future resistance developments (Tabashnik and Carriere 2004). There are currently no published reports of field-evolved resistance to *Bt* crops (Tabashnik 2004).

Is _Bt_ safe for humans and the environment?

Bt is considered to be a remarkably safe alternative pesticide due to its specificity against target insects and limited persistence in the environment. This is demonstrated by the fact that *Bt* is the only insecticide for which there are no mandated residue limits on foods, however, the unprecedented adoption of transgenic crops has raised several concerns among the public. Concern over genetically engineered foods has tended to focus on the unknown health and environmental effects. Some apprehensions include potential ecological consequences of gene flow to non-engineered crops and wild relatives, possible effects on non-target organisms, and concerns of putting new things into the human diet that have not been eaten before. To alleviate public concerns, further research is required for both the short and long-term effects of genetically modified organisms in our environment and our food.

The specific nature of *Bt* proteins limits its toxic effects to only certain insects. Unfortunately, some beneficial insects can be affected. A controversial article published in *Nature* in 1999, indicated increased monarch butterfly mortality following the ingestion of pollen from *Bt*-transgenic corn crops. This report prompted further studies with different *Bt* varieties of transgenic corn and indicated that the actual risk to monarch butterflies was negligible. Researchers found that only one variety of Bt was especially damaging to the monarchs and has since been withdrawn from the U.S. market. Furthermore, studies indicated that the amount and distribution of corn pollen on the monarch's host plant, milkweed, was very low. Ongoing Bt research seeks to discover new, more specific varieties that do not hurt beneficial insects.

Although concerns have been raised about *Bt*-transgenic crops and more recently about the use of *Bt* for organic farms, the ecological impacts of *Bt* are generally less than chemical pest controls. Furthermore, farm workers have benefited from using *Bt* sprays in place of hazardous insecticides. Yet *Bt* like its synthetic competitors, Bt is still an insecticide and should be used with care, and only after trying cultural and physical insect control methods.

Table #1 - *Bt* target insect pests, Canadian registered domestic and commercial products and allowable organic *Bt* products

***B.t.* Subspecies**	**Insect Pests Affected**	**Domestic and Commercial *Bt* Products Currently Registered in Canada**	**ACORN Directory of Allowable *BT* Organic Inputs**
B.t. var. *Kurstaki* (*BT*K)	Caterpillars including: - Cabbage loopers - Codling moth larvae - Diamondback moths - Douglas fir tussock moth - Gypsy moths - Imported cabbageworms - Spruce budworm - Tomato hornworms And others…consult label for the complete list of susceptible insects.	Bioprotec CAF Aqueous Biological Insecticide (AEF Global, Inc.) Bioprotec ECO (AEF Global, Inc.) Bioprotec 3P Dry Flowable Biological Insecticide (AEF Global, Inc.) DiPeL® WP (Valent Biosciences Corporation) Dipel* 176 (Abbott Laboratories) DiPeL ® 2X DF (Valent Biosciences Corporation) Foray® 48 BA Low Volume Aqueous Concentrate (Valent Biosciences Corporation) Thuricide® -HPC High Potency Acueous Concentrate (Ceris USA) Safer's® Biological Insecticide (Woodstream Canada Corporation)	Bioprotec ECO (AEF Global, Inc.) DiPeL ® 2X DF (Valent Biosciences Corporation) Safer's® Biological Insecticide (Woodstream Canada Corporation)
B.t. var. *israelensis* (*BT*I)	Fly larvae including: - Blackflies - Fungus gnats - Midge and filter fly - Mosquitoes	Aquabac Biological Larvicide (10/14) and (5/8) (AFA Environment INC.) Aquabac II XT Biological Larvicide (AFA Environment INC.) VectoBac® Biological Larvicide (200g and 600L) (Valent Biosciences Corporation)	No products allowed
B.t. var. *tenebrionis (or san diego)*	Beetle small larvae including: - Black vine weevils - Boll weevils - Colorado potato beetles - Elm leaf beetles	Novador® Flowable Concentrate (Valent Biosciences Corporation)	No products allowed

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