

European corn borer larvae infected with *Bacillus thuringiensis*.

Courtesy Nova Nordisk Entotech, Inc.

Bacteria

Over 90 species of naturally occurring, insect-specific (entomopathogenic) bacteria have been isolated from insects, plants, and the soil, but only a few have been studied intensively. Much attention has been given to *Bacillus thuringiensis*, a species that has been developed as a microbial insecticide.

Primary hosts: caterpillars; some beetle and fly larvae

- Key characters: larvae stop eating, become limp and shrunken, die and decompose
- Crops: many
- Commercially available: yes -- several species and varieties

Bacillus thuringiensis (Bt) occurs naturally in the soil and on plants. Different varieties of this bacterium produce a crystal protein that is toxic to specific groups of insects. Bt has been available in North America as a commercial microbial insecticide since the 1960s and is sold under various trade names. These products have an excellent safety record and can be used on crops until close to the day of harvest. Bt can be applied using conventional spray equipment but, because the bacteria must be eaten to be effective, good spray coverage is essential.

Habitat (Crops)

Many, including vegetables, cotton, tobacco, tree crops, forest crops, landscaping.

Pests Attacked

Numerous moth and butterfly larvae and some beetle and fly larvae are susceptible to infection. Formulations of Bt variety *kurstaki* are available for the control of many caterpillar pests including imported cabbageworm, cabbage looper, hornworms, European corn borer, cutworms, some armyworms, diamondback moth, spruce budworm, bagworms, tent caterpillars, gypsy moth caterpillars and other forest caterpillars, and Indianmeal moth larvae in stored grain. Less well controlled are corn earworm on corn, codling moth, peach tree and squash vine borers.

Formulations of Bt variety *tenebrionis* and variety *san diego* are registered for use against larvae of Colorado potato beetle larvae and elm leaf beetle adults and larvae.

Bt variety *israelensis* is marketed for use against black flies and mosquitoes, fungus gnats, although unless used on a community-wide basis, it is probably more effective to eliminate standing water and control weeds at the edges of ponds. Bt variety *aizawai* is used to control wax moth larvae in bee hives and various caterpillars. It is important for control of diamondback moth caterpillar which has developed resistance to Bt variety *kurstaki* in some areas.

Some commercially available Bt varieties and target pests:

- *Bacillus thuringiensis*
 - var. *tenebrionis* - Colorado potato beetle and elm leaf beetle larvae
 - var. *kurstaki* - caterpillars
 - var. *israelensis* - mosquito, black fly, and fungus gnat larvae
 - var. *aizawai* - wax moth larvae and various caterpillars, especially the diamondback moth caterpillar

Some commercial products may mix varieties or contain additional varieties. Check the label.

Mode of Action

The toxic crystal Bt protein in commercial formulations is only effective when eaten by insects with a specific (usually alkaline) gut pH and the specific gut membrane structures required to bind the toxin. Not only must the insect have the correct physiology and be at a susceptible stage of development, but the bacterium must be eaten in sufficient quantity. When ingested by a susceptible insect, the protein toxin damages the gut lining, leading to gut paralysis. Affected insects stop feeding and die from the combined effects of starvation and tissue damage. Bt spores do not usually spread to other insects or cause disease outbreaks on their own as occurs with many pathogens.

Action of *Bacillus thuringiensis* var. *kurstaki* on caterpillars

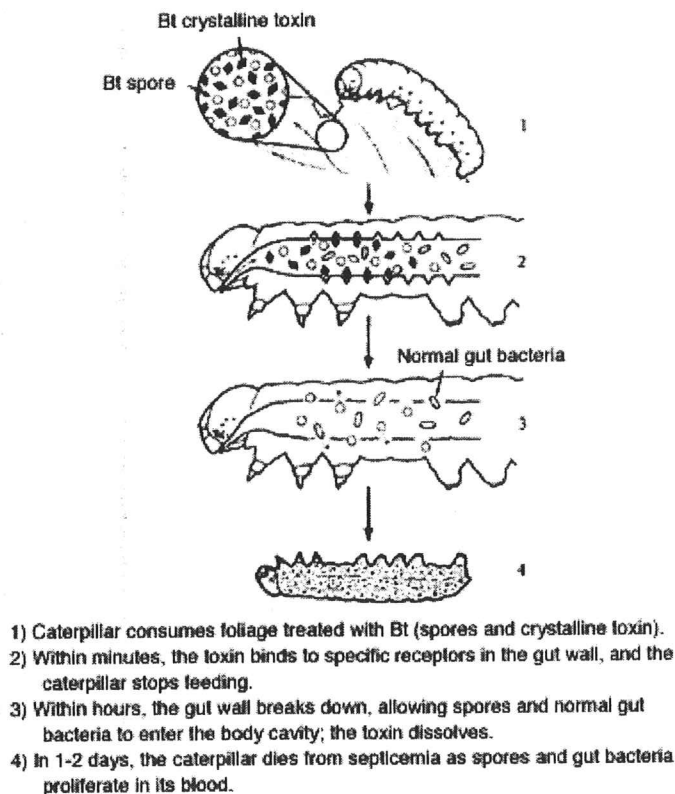


Diagram courtesy of Abbott Laboratories.

Bt genes have been transferred into other microorganisms to produce more active formulations, some of which are commercially available. Additionally, researchers have genetically engineered varieties of several plant species to express the Bt toxin as part of the plant's normal development. This has led to the production of "insect-resistant" Bt-transformed lines of tobacco, cotton, corn, tomatoes, potatoes, and others. The evaluation and development of management systems for these new plant lines are the subject of considerable research.

Symptoms

Larvae affected by Bt become inactive, stop feeding, and may regurgitate or have watery excrement. The head capsule may appear to be overly large for the body size. The larva becomes flaccid and dies, usually within days or a week. The body contents turn brownish-black as they decompose. Other bacteria may turn the host body red or yellow.

Relative Effectiveness

Some naturally occurring bacteria can cause epizootics, especially if the pest population is under stress from lack of food, overcrowding, or cold weather. These epizootics are not as common as those caused by other naturally occurring pathogens. Commercial formulations of *Bacillus thuringiensis*, however, are widely used. Greenhouses, tree and field crops, waterways and thousands of acres of forests are sprayed annually with commercial Bt products.

Successful use of these Bt formulations requires application to the correct target species at a susceptible stage of development, in the right concentration, at the correct temperature (warm enough for the insects to be actively feeding), and before the insect pests bore into the crop plant or fruit where they are protected. Young larvae are usually most susceptible. Caterpillar growth may be retarded even if less than a lethal dose is eaten. Determining when most of the pest population is at a susceptible stage is key to optimizing the use of this microbial insecticide.

Not all caterpillar pests are equally susceptible to Bt. Beet armyworm has proven difficult to control, and some moth species, including some populations of diamondback moth, a major worldwide pest of cole crops, have evolved resistance to the Bt variety *kurstaki* toxins. Corn earworm, squash vine borer larvae, and codling moth larvae are susceptible, but field control is difficult because they rapidly bore into and are protected by plant tissue. Bt is effective against European corn borer if it is applied just as the larvae are hatching. Bt formulations for use against Colorado potato beetle may vary in effectiveness.

Bt formulations may be deactivated in sunlight and may be effective for only one to three days. Rain or overhead irrigation can also reduce effectiveness by washing Bt from crop foliage. Some formulations, such as those involving the genetic engineering of the Bt toxin, aim to overcome these problems.

Bacillus popilliae* and *Bacillus lentimorbus

are related, naturally occurring bacteria that have been mass-produced for the control of Japanese beetle larvae in turf since the 1940s. Several commercial products are available. The bacteria, usually applied to the soil, cause "milky disease." Milky disease spores may reproduce within the beetle larvae and establish a resident population capable of causing mortality over several seasons if the soil is sufficiently warm and moist through the summer months. It may take several seasons for the disease to control the pest, and it is preferable to treat a broad area to reduce the impact of immigrating healthy beetles.

Symptoms:

Beetle larvae killed by *Bacillus popilliae* and *B. lentimorbus* may turn white, hence the name "milky disease."

Taken from:

Hoffmann, M.P. and Frodsham, A.C. (1993) Natural Enemies of Vegetable Insect Pests. Cooperative Extension, Cornell University, Ithaca, NY. 63 pp.

Additional References

Tanada, Y., and Kaya, H.K. (1993) Insect Pathology. Academic Press, Inc., San Diego. 666 pp.

Weinzierl, R., and Henn, Tess. (1989) Alternatives in insect management: Microbial insecticides. Cooperative Extension, University of Illinois, Circular 1295. 12 pp.

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