Bt (*Bacillus thuringiensis*),

A Microbial Insecticide

Synthetic chemical insecticides provide many benefits to food production and human health, but they also pose some hazards. In many instances, alternative methods of insect management offer adequate levels of pest control and pose fewer hazards. One such alternative is the use of microbial insecticides--insecticides that contain microorganisms or their by-products. Microbial insecticides are especially valuable because their toxicity to non-target animals and humans is extremely low. Compared to other commonly used insecticides, they are safe for both the pesticide user and consumers of treated crops. Microbial insecticides also are known as biological pathogens, and biological control agents.

Advantages of Microbial Insecticides

Individual products differ in important ways, but the following list of beneficial characteristics applies to microbial insecticides in general.

- The organisms used in microbial insecticides are essentially nontoxic and nonpathogenic to wildlife, humans, and other organisms not closely related to the target pest. The safety offered by microbial insecticides is their greatest strength.
- The toxic action of microbial insecticides is often specific to a single group or species of insects, and this specificity means that most microbial insecticides do not directly affect beneficial insects (including predators or parasites of pests) in treated areas.
- Because their residues present no hazards to humans or other animals, microbial insecticides can be applied even when a crop is almost ready for harvest.

Disadvantages of Microbial Insecticides

The limitations or disadvantages listed below do not prevent the successful use of microbial insecticides. Understanding how these limitations affect specific microorganisms will help users to choose effective products and take necessary steps to achieve successful results.

- Because a single microbial insecticide is toxic to only a specific species or group of insects, each application may control only a portion of the pests present in a field, garden, or lawn. If other types of pests are present in the treated area, they will survive and may continue to cause damage. Conventional insecticides are subject to similar limitations because they too are not equally effective against all pests. Nonetheless, the negative aspect of selectivity is often more noticeable for microbials.
- Heat, desiccation (drying out), or exposure to ultraviolet radiation reduces the effectiveness of several types of microbial insecticides. Consequently, proper timing and application procedures are especially important for some products.
- Special formulation and storage procedures are necessary for some microbial pesticides. Although these procedures may complicate the production and distribution of certain

products, storage requirements do not seriously limit the handling of microbial insecticides that are widely available. (Store all pesticides, including microbial insecticides, according to label directions.)

This publication has been developed to help readers make the most effective use of the microbial insecticide *Bt* (*Bacillus thuringiensis*). It summarizes the strengths and weaknesses of products available commercially and lists the most promising uses for *Bt*.

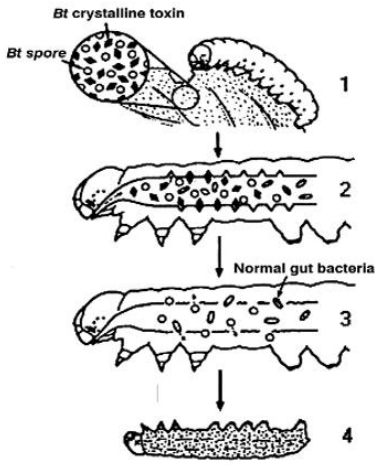
The microbial insecticide *Bt* discussed in this publication is regulated by the United States Environmental Protection Agency (US EPA). Although this publication provides background information on *Bt*, readers should consult product labels for specific application directions. All insecticides should be used only in the manner specified on the product label.

Bacteria

Bacterial pathogens used for insect control are spore forming, rod-shaped bacteria in the genus *Bacillus*. They occur commonly in soils, and most insecticidal strains have been isolated from soil samples. Bacterial insecticides must be eaten to be effective; they are not contact poisons. Insecticidal products comprised of a single *Bacillus* species may be active against an entire order of insects, or they may be effective against only one or a few species. For example, products containing *Bacillus thuringiensis* var. *kurstaki* kill the caterpillar stage of a wide array of butterflies and moths. In contrast, *Bacillus popillae* (milky spore disease) kills Japanese beetle larvae but is not effective against the closely related annual white grubs (masked chafers in the genus *Cyclocephala*) that commonly infest lawns.

The microbial insecticides most widely used in the United States since the 1960s are preparations of the bacterium *Bacillus thuringiensis* (abbreviated as *Bt*). *Bt* products are produced commercially in large industrial fermentation tanks. As the bacteria live and multiply in the right conditions, each cell produces (internally) a spore and a crystalline protein toxin called an endotoxin. Most commercial *Bt* products contain the protein toxin and spores, but some are cultured in a manner that yields only the toxin component.

How *Bt* works. When *a susceptible insect ingests Bt*, the protein toxin is activated by alkaline conditions and enzyme activity in the insect's gut. The toxicity of the activated toxin is dependent on the presence of specific receptor sites on the insect's gut wall. This necessary match between toxin and receptor sites determines the range of insect species killed by each *Bt* subspecies and isolate. If the activated toxin attaches to receptor sites, it paralyzes and destroys the cells of the insect's gut wall, allowing the gut contents to enter the insect's body cavity and bloodstream. Poisoned insects may die quickly from the activity of the toxin or may die within 2 or 3 days from the effects of septicemia (blood poisoning). Although a few days may elapse before the insect dies, it stops feeding (and therefore stops damaging plants) soon after ingesting *Bt*.



Bt does not colonize or cycle (reproduce and persist to infect subsequent generations of the pest) in the environment in the magnitude necessary to provide continuing control of target pests. The bacteria may multiply in the infected host, but bacterial multiplication in the insect does not result in production of abundant spores or crystalline toxins. The usual result is that few or no infective units are released into the environment when a poisoned insect dies. Consequently, *Bt* products are applied much like synthetic insecticides. *Bt* treatments are inactivated fairly rapidly (within one to a few days) in many outdoor situations, and repeated applications may be necessary for some plants and pests.

Symptoms of infection. Caterpillars infected by *Bt* become inactive and stop feeding. The caterpillar becomes flaccid and dies, usually within days. The body contents turn brown to black as they decompose.

***Bt* formulations that kill caterpillars.** The best-known and most widely used *Bt* insecticides are formulated from *Bacillus thuringiensis* var. *kurstaki* isolates that are pathogenic and toxic only to larvae of the butterflies and moths. Many such *Bt* products have been registered with the United States Environmental Protection Agency.

Trade names. The most common trade names for these commercial products include Dipel®, Javelin®, Thuricide®, Worm Attack®, Caterpillar Killer®, Bactospeine®, and SOK-Bt®, but many small companies sell similar products under a variety of trade names. These products are commercially successful and widely available as liquid concentrates, wettable powders, and ready-to-use dusts and granules. They are used to control many common leaf-feeding caterpillars, including caterpillar pests on vegetables (especially the "worms" that attack cabbage, broccoli, cauliflower, and Brussels sprouts), bagworms and tent caterpillars on trees and shrubs, larvae of the gypsy moth and other forest caterpillars, and European corn borer larvae in field corn. Several of these products are used to control Indianmeal moth larvae in stored grain, One product with a very specific target is Certan®, formulated from *Bacillus thuringiensis* var. *aizawai*, and used exclusively for the control of wax moth larvae in honeybee hives.

Specificity. *Bt* products that kill caterpillars are NOT effective against other types of pests; they will not control aphids, beetles, flies, or additional pests other than caterpillars. Even certain caterpillars are not effectively controlled by *Bt*, especially those that live in the soil or bore into plant tissues without consuming a significant amount of the *Bt* applied to plant surfaces. (Again, *Bt* is a stomach poison that must be ingested to be effective.) The corn earworm in corn and the cutworms that clip off field crops or garden plants are examples of caterpillars seldom controlled by *Bt* treatments.

Common caterpillar pests that are controlled effectively with *Bacillus thuringiensis* var. *kurstaki* (*Bt*) include:

- European corn borer in corn
- Indianmeal moth in stored grain
- cabbage looper
- imported cabbageworm
- diamondback moth
- tomato/tobacco hornworm
- tent caterpillars
- cutworms
- io moth
- fall webworm
- mimosa webworm
- bagworms
- spring and fall cankerworm
- orangedog
- redhumped caterpillar
- sod webworms
- loopers
- oleander moth

Common caterpillar pests that are NOT controlled by normal applications of *Bt* include:

- corn earworm (on corn)
- squash vine borer
- cutworms

Using *Bt* insecticides. Insecticides containing *Bt* can be very effective for insect control in a variety of situations. Reviewing a few key facts about these products can help users obtain the best results possible. Each *Bt* insecticide controls only certain types of insects; therefore, it is essential to identify the target pest and to confirm that the *Bt* insecticide controls only certain types of insects; therefore, it is essential to identify the target pest and to confirm that the *Bt* product label states that the insecticide is effective against that pest. Separate stages of insects differ in their susceptibility to *Bt*; isolates that are effective against larval stages of butterflies or moths, will not kill adults. Because susceptible insects must consume *Bt* to be poisoned, treatments must be directed to the plant parts or other material that the target pest will eat. Where this is not possible (for example, where pests bore into plant tissue without feeding much on the surface foliage or fruits), *Bt* is usually not very effective. *Bt* does not kill susceptible insects

immediately. Poisoned insects normally remain on plants for a day or two after treatment, but they do not continue feeding and will die soon.

Where *Bt* is applied to plant surfaces or other sites exposed to sunlight, it is deactivated rapidly by direct ultraviolet radiation. To maximize the effectiveness of *Bt* treatments, sprays should thoroughly cover all plant surfaces, including the undersides of leaves. Treating in the late afternoon or evening can be helpful because the insecticide remains effective on foliage overnight before being inactivated by exposure to intense sunlight the following day. Treating on cloudy (but not rainy) days provides a similar result. Production processes that encapsulate *Bt* spores or toxins in a granular matrix (such as starch) or within killed cells of other bacteria also provide protection from ultraviolet radiation. Registration and sale of products containing encapsulated *Bt* are forthcoming.

Precautions. Users are advised to handle all microbial insecticides cautiously. Bacterial spores, as well as other microbes, become "foreign proteins" if they are inhaled or rubbed into the skin and can cause allergic reactions. The dusts or liquids used to dilute and carry these microorganisms also can act as allergens or irritants. These problems do not prevent the safe use of microbial insecticides, but users should not breathe dusts or mists of microbial insecticides. Users should wear gloves, long sleeves, and long trousers during application and wash thoroughly afterwards. These are commonsense precautions that will help prevent unexpected reactions and minimize any effects from unknown toxicity.

Summary

Microbial insecticides offer effective alternatives for the control of many insect pests. Their greatest strength is their safety, as they are essentially nontoxic and nonpathogenic to animals and humans. Although not every pest problem can be controlled by the use of a microbial insecticide, these products can be used successfully in place of more toxic insecticides to control many lawn and garden pests and several important field crop and forest insects. Because most microbial insecticides are effective against only a narrow range of pests and because these insecticides are vulnerable to rapid inactivation in the environment, users must properly identify target pests and plan the most effective application. But these same qualities mean that microbial insecticides can be used without undue risks of human injury or environmental damage. Consequently, microbial insecticides are likely to become increasingly important tools in insect management.

1. Spray when caterpillars are still small.
2. Completely cover all leaf surfaces. The insects must ingest the bacteria when they are feeding.
3. Spray in the evening or during cloudy (but not rainy) days.
4. There may be a need to reapply if it rains soon after application.
5. Caterpillars will take several days to die, but they will stop feeding soon after infection.
6. *Bt* is not persistent. It may need to be reapplied. Follow label instructions.
7. Mix only enough product needed and use immediately. This is especially important in areas with high pH water (alkaline).
8. Use a spreader-sticker to enhance product coverage on leaves.

Footnote

This publication was revised and modified for homeowner use by Adrian Hunsberger, Urban Horticulture Agent, Miami-Dade County and Entomologist. April 2000

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