

Bt Basics for Vegetable Integrated Pest Management

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What is Bt ?

"Bt", first discovered in Japan in 1901, refers to a spore-forming bacterium, *Bacillus thuringiensis*, which occurs naturally in soils. Some leaf-feeding caterpillars (larvae of butterflies and moths) are killed when they eat very small amounts of leaves or other plant parts that have been coated (sprayed) with Bt.



Healthy cabbage looper.



Both upper and lower cabbage leaf surfaces are sprayed with fine mist of Bt when actively feeding caterpillars are present. Caterpillars feed on Bt-coated leaves.

Thousands of strains of Bt bacteria exist and a few of these have been used to manufacture what have been termed microbial or biological insecticides. Most of these commercial products contain crystal-shaped proteins and living spores (Figure 1) from Bt bacteria. There are many commercial brands of Bt; two Bt subspecies are commonly used against caterpillars which feed on cabbage and other vegetable crops.

How does Bt work ?

It is very important to understand that Bt does not work like most conventional insecticides. While very effective against certain insect pests, Bt has no contact or "knock-down" effect, i.e., pests are not killed instantly after spraying.

Insects must eat a minute amount of Bt-coated plant material to

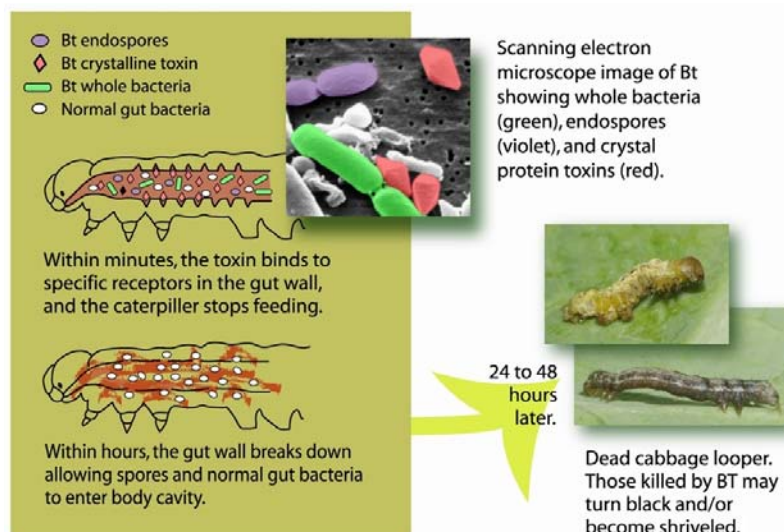


Figure 1. How Bt works.

be killed. When enough Bt is consumed, toxins in the crystal proteins paralyze the caterpillar's mouth and gut (Figure 1). Pests begin to move slowly and *stop feeding within minutes to an hour* after consuming a sufficient dose. The toxins break down the insects' gut wall within hours, allowing Bt spores and the insects' normal gut contents to invade the body cavity. This causes death by starvation, septicemia (blood poisoning), and/or osmotic shock within 24-48 hours. Some larvae killed by Bt may become discolored or turn black; dead larvae often become shriveled (Figures 2-3) and fall from the plant where they are not easily observed by farmers or IPM scouts.



Figure 2. Larvae killed by Bt may become discolored or turn black (larva on right).



Figure 3. Dead larvae often become shriveled

Why should vegetable growers use Bt ?

Bt has many advantages. It is non-toxic to humans, fish, and animals and leaves no toxic residue on fruits and vegetables. Most Bt products are exempt from pesticide tolerance limits and have no preharvest interval (waiting period).

The toxins found in Bt are biodegradable and do not persist in the environment. Bt is also very specific in that it kills only certain types of insects. Unlike many conventional insecticides, most strains of Bt are non-toxic or only mildly toxic to beneficial insects.

Natural enemies (predators and parasitoids) of insect pests are protected and help control these pests. Several species of parasitic wasps (especially *Diadegma* spp.) contribute significantly to the natural control of diamondback moth (DBM); DBM control becomes much more difficult when these parasitoids are eliminated by harsh insecticides.



Figure 4. *Diadromus collaris*, a pupal parasitoid of diamondback moth.

When used as part of an integrated pest management program, Bt also protects natural enemies that can enhance natural control of important pests *in addition to* the target pest(s). When Bt was used to control armyworms on tomatoes, for example, *Liriomyza* leafminers then became much less of a problem. In this case, Bt allowed natural enemies of leafminers to survive and help control the pest, reducing the need for other insecticide applications.



Figure 5. Vespine wasp (predator) carrying imported cabbage worm.

Can Bt be used for certified organic vegetable production?

In most cases, yes. Many formulations of Bt are made using natural processes and have been approved by “Organic Thailand” for certified organic production in Thailand (<http://organicthailand.net>). Also the IFOAM accredited “Organic Agriculture certification Thailand” (ACT) approves the use of Bt in organic farming (<http://www.actorganic-cert.or.th/>).

Bt products that are genetically modified are not approved in organic agriculture. Check your certifying agency for a list of approved brand names.



Figure 6. Organic product logos used in Thailand

What vegetable crop pests are controlled by Bt?

Two subspecies of Bt (*Bt kurstaki* and *Bt aizawai*) are commonly used against cabbage and other vegetable pests (Figures 7-12 and Table 3). These control only larvae of butterflies and moths but not beetle larvae or other insects.

Other Bt products have been developed for use against unrelated pests. *Bt tenebrionis* (Novodor®), for example, can be used to control larval stages of some types of beetles. Other forms of Bt are used to control mosquito larvae, fungus gnats (in greenhouses), etc.

Many commercial formulations of *Bt kurstaki* and *Bt aizawai* are available for use on vegetable crops; the only reliable way of identifying the most effective Bt product for the target pest(s) is through local field trials. General differences between *Bt kurstaki* and *Bt aizawai* products are discussed on the following page:



Figure 7. Diamondback moth



Figure 8. Cabbage looper



Figure 9. Imported cabbageworm



Figure 10. Tomato fruitworm



Figure 11. Cluster caterpillars (*Spodoptera litura*)



Figure 12. Egg mass and group of 1st instar larvae of cluster caterpillar.

Bt *kurstaki*: controls diamondback moth (*Plutella xylostella*), cabbage looper (*Trichoplusia* sp.), imported cabbageworm (*Pieris* sp.), and tomato fruitworm (*Heliothis/Helicoverpa* sp.). Keep in mind that there are differences among commercial strains of Bt *kurstaki*. Some—but not all—*kurstaki* products are effective against small larvae of cluster caterpillar (*Spodoptera litura*).

Bt *aizawai*: controls diamondback moth, cabbage looper, imported cabbageworm, and tomato fruitworm. In general, Bt *aizawai* products are more effective against small larvae of cluster caterpillar (*Spodoptera litura*) than Bt *kurstaki* products. Bt *aizawai* may still be effective in areas where diamondback moth has developed resistance to Bt *kurstaki*.

What is the difference between these two types of Bt?

The two types of Bt are sold under various trade names (Table 3). The two subspecies contain different toxic crystal proteins (delta-endotoxins or “Cry” toxins) (see Table 1 and Figure 1). These toxins differ in their effectiveness against different pests. In addition, crystal proteins from both Bt *kurstaki* and Bt *aizawai* have been combined in some newer products to increase their effectiveness. Table 1 lists the different crystal toxins found in two common Bt *kurstaki* and Bt *aizawai* products:



Figure 13. Two types of Bt commonly found in Thailand: trade names Florbac (Bt *aizawai*) and Bactospeine (Bt *kurstaki*).

Table 1. Crystal protein toxins (Cry) found in two common forms of Bt used for cabbage and other vegetable pests

Crystal toxins	Bt <i>kurstaki</i>	Bt <i>aizawai</i>
Cry 1Aa	+	+
Cry 1Ab	+	+
Cry 1Ac	+	--
Cry 2A	+	--
Cry 1C	--	+
Cry 1D	--	+

Note:

Different commercial Bt products may contain differing proportions of these toxins; blue “+” signs indicate the most common differences. The gene for Cry2B protein is also present in both subspecies but is usually not expressed.

Have pests developed resistance to Bt?

Yes. Although it was very slow in coming, resistance to Bt *kurstaki* has been documented for diamondback moth in Thailand, Malaysia, the Philippines, China, Taiwan, Honduras, Costa Rica, Guatemala, New York, Florida and Hawaii. Insects become resistant when:

1. only one Bt subspecies is applied frequently as the only insecticide to control a pest,
2. when the pest has a short life cycle with many generations (like diamondback moth) over a long growing season (or where crops

3. are grown continuously as in Thailand and in other tropical climates), and when the treated pest population is isolated from populations of the same pest from non-treated areas. Some cabbage production areas in Thailand are relatively isolated with climates that permit 20 or more generations of DBM to develop each year.

How can resistance to Bt be prevented or delayed?

“Resistance management” is especially a concern when Bt is used for diamondback moth control. Perhaps the best way to avoid resistance is to avoid continuous Bt applications and to use the product only when necessary. This requires frequent observations or scouting in the field and the use of treatment thresholds whenever possible. Early detection of infestations is especially important when Bt is used as the primary pest control tool.



Figure 14. Looking for insect pests and natural enemies

Simple, presence/absence scouting methods and percentage-based thresholds have been used effectively in cabbage and other crucifer crop IPM programs. An example for cabbage is shown in Table 2.

Table 2. An example of treatment thresholds for diamondback moth and other caterpillar pests in fresh market cabbage (from Foster and Flood, 1995).

<u>Growth stage</u>	<u>Threshold (% plants infested)*</u>
After transplanting, before cupping	≥ 30%
Cupping to early heading	≥ 20%
Early heading to mature head	≥ 10%

* Percentage of plants that have one or more larvae of diamondback moth, cabbage looper, or imported cabbageworm; treat when the percentage of plants infested reaches or exceeds this number.



Figure 15. Early “cupping” stage of cabbage growth

One of the most important principles of resistance management is to avoid continuous, repetitive use of the same insecticide (or different insecticides but with the same mode of action).

Organic growers can alternate Bt with neem-derived azadirachtin or products like the OMRI-approved version of spinosad.

For conventional vegetable growers, Bt can be rotated with many other classes of insecticides although some of the benefits of Bt (conservation of natural enemies) could be lost. Newer, “reduced risk” insecticides should be used whenever possible. Pyrethroid insecticides should be avoided.



Figure 16. Bt and neem products can be alternated to reduce diamondback moth’s development of resistance to Bt.

It may also be beneficial to rotate between Bt *kurstaki* and Bt *aizawai*. These two subspecies share some crystalline toxins but differ in others (Cry1C, Cry1D, see Table 1). These different toxins can have different modes of action. For organic growers in the U.S., it has become standard practice to use 2-3 Bt *kurstaki* product applications alternating with one Bt *aizawai* product application. Table 3 lists most of the Bt products on the market in Thailand in 2005.

Table 3. Bt products available in Thailand (*kurstaki* and *aizawai* forms)

Bt <i>kurstaki</i> Products	Potency (IU/mg*)	Bt <i>aizawai</i> Products	Potency (IU/mg*)
Bactospeine HP**	32000	Florbac FC	8500
Biobit 32B (FC)	8499	Florbac HP (WP)	24000
Biobit WP	16000	Florbac WDG	?
Bact 2 side S (FC)	8000	Turex 50 WP	25000
Delphin (= Javelin***) WG	53000	Quark FC	3000
Delphin ES	17600	Agree WG	25000
Dipel 2X (WP)	32000	Cheetahbac FC	8500
Dipel ES	17600	XenTari DF (= Centari)	35000
Dipel DF	32000	Extra SC	8500
Thuricide HP (WP)	16000		
Quistocin	55000		
CoStar OF	?		

* IU/mg = International Units per milligram; because of different testing methods used by different manufacturers, *it is often not possible to directly compare IU/mg contents among different Bt products*. Use the product's label recommendations to determine field application rates.

** HP = high potency, DF = Dry flowable, FC = water-based flowable concentrate, ES = oil-based emulsifiable suspension, WP = wettable powder, WDG or WG = water dispersible granules, SC = oil-based formulation, OF = oil flowable (oil-based).

*** These products may not be locally available.

What does “potency” mean?

Manufacturers often provide potency data for their products; these data are usually reported in terms of International Units per milligram (IU/mg) or billions of International Units per kilogram (BIU/kg). This is often a source of confusion for trainers, advisors and growers. Potency is a measure of the number of effective killing units of the product (crystal proteins, spores, etc.) in bioassays against cabbage loopers compared to the killing power of a Bt reference strain which is assigned an arbitrary potency value. This generally means that the higher the potency number, the more concentrated the product.



Figure 17. Label close-up (with potency circled in red).

Unfortunately there are no international standards for potency testing and manufacturers often report potency against different species of test insects for different products. Some products, for example, may be more effective against diamondback moth than cabbage looper, so potency is reported in terms of diamondback moth units. It is therefore not possible to make direct comparisons of potency among products tested against different test insects. Potency reported for XenTari®, for example, is “35,000 Diamondback Moth Units per mg of product” while Dipel ES® contains “17,600 Cabbage Looper Units per mg of product”.

Potency should not be used to adjust field application rates of the product. Different products may have very different percentages of active ingredient by weight (see product label). Only the manufacturer’s label recommendations should be used to determine field application rates.

Which product should I recommend to farmers?

Local experience and field trials with various brand names and formulations will help you select the best Bt product for the intended pest(s). In some countries, for example, diamondback moth is more resistant to Bt *kurstaki* than to Bt *aizawai*. Also choose a formulation which is easy to use and which disperses well in water. Bt products are made through a fermentation process and water-based liquid formulations will only last one season. Dry and oil-based formulations have a shelf life of at least two years. For water-based formulations, it is important to obtain fresh stock each year from reputable agricultural supply dealers.

WARNING!

Some Bt products formulated in Thailand may contain other active ingredients (in addition to Bt) that are not approved for organic production and that are *not listed on the product label*. These illegal formulations can be dangerous for applicators and are toxic to beneficial insects. The best protection is to buy well-known products from reputable dealers and ask questions about the product you are buying.

Can Bt be mixed with other insecticides/pesticides?

Should Bt be mixed with other pesticides?

Bt products can be mixed with other insecticides and other pesticides; however, the possible negative impacts on natural insect predators and parasitoids should be considered. Many broad-spectrum conventional insecticides kill natural enemies together with pests. By mixing these products with Bt, one of Bt’s most important benefits—the conservation of natural enemies—may be lost. Any tank mix solutions used should remain close to pH 7 (between 6 and 8). Chemical pesticides that are alkaline should not be mixed with any Bt product; some Bt products should not be mixed with any of the common chlorothalonil-based vegetable fungicides (Chlorothalonil, Daconil®, etc.).

Are there times when the Bt application rate should be increased?

Increased rates of Bt may be required when the crop foliage increases and/or when high caterpillar populations or older caterpillars are present. If possible, Bt applications should be timed with egg laying (20% hatch) of the target pest. If that is not possible, Bt must be used *when insect larvae are small* and before economic thresholds are reached. Obviously this requires regular field scouting. Knowing the population dynamics of the target pest is essential to any IPM program and is especially important for good control with Bt. When obvious insect damage is visible, it may be a bit late for effective control with Bt at the lowest rates. In the absence of scouting or if overlapping generations or mixed insect pest species are present, regular calendar-timed applications may be the only effective control strategy.



Figure 18. Spray when larvae are small (cabbage looper)

Photo credits:

Scanning electron micrograph of Bt in Figure 1 by Dr. Brent Selinger, Dept. of Biological Sciences, University of Lethbridge, Alberta (used with permission).

Figure 13. courtesy of Alton N. Sparks, Jr., The University of Georgia (www.ipmimages.org)

All other photographs by the author.

What are some general guidelines for using Bt?

Size of larvae: Bt products are most effective against *small larvae* (1st and 2nd instar); large larvae, especially *Spodoptera* spp., are difficult to control with Bt.

Effects of sunlight: Direct sunlight will inactivate Bt products as well as some other insecticides. It is highly recommended to do a thorough application by spraying Bt above and on both sides of the crop foliage. It is very important to use a spray volume which will cover both sides of leaves and to make sure that the spray penetrates dense foliage. Bt that is shaded from direct sunlight by foliage will last longer. If practical, afternoon applications will enhance Bt longevity.

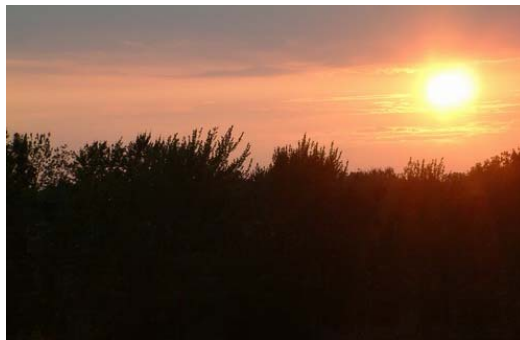


Figure 19. Avoid strong sunlight. Spray Bt in late afternoon.

Use of sticker: Since Bt products are not completely soluble, the use of a sticker or “spreader-sticker” is recommended on hard-to-wet crops such as cabbage. If heavy rainfall occurs within 24 – 48 hours after application, it is recommended to re-apply Bt.



Figure 20. Mix Bt with a spreader/sticker

Irrigation method: Sprinkler irrigation or hand watering can wash off Bt. Drip or furrow irrigation will enhance pest control with Bt by reducing washing off of the product.



Figure 21. Using drip irrigation instead of sprinkler or hand watering will help Bt products last longer and be more effective.

Shelf life: Dry and oil-based Bt products have a longer shelf life than water-based liquids. Water-based “FC” formulations will not last as long as most other formulations at high temperatures and *should be used for one growing season only*. Dry products may still be effective for 3-4 years when kept at or below 25-30°C. All Bt products should be kept as cool and dry as possible in storage.

Other: Continuous agitation of the mixture in the sprayer tank or recirculation is highly recommended.

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