



Bt-Based Biopesticides in Crop Production

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In today's modern farming, there have been significant advancements in the production of crops. Synthetic pesticides have brought about issues including resistance, contamination of foods and soils, contamination of water sources and even affecting helpful insects. The above issues have driven scientists and farmers to seek out a method that would not only be effective but also environmentally friendly. *Bacillus thuringiensis* is a highly effective microbial pesticide that is widely used to fight insect pests. It has a protein that kills the pests when consumed. These proteins are commonly referred to as Cry proteins. Bt biopesticides have been utilized in the strategy of integrated pest management due to its specificity, degradability and good compatibility with other non-chemical methods. The use of Bt biopesticides is done in crops like cotton, maize, vegetables, pulses and fruits in order to control insect pests. However, the efficiency of the biopesticides can be hindered by exposure to sunlight, rainfall, climate, proper timing and resistance of the insect pests. Innovations in the production, strain selection, protection, and precise application of these products are making them more efficient. Use of biopesticides formed using Bt along with monitoring systems for crops that adopt effective cultural practices and possess natural enemies would promote sustainability and eco-friendliness in crop production.

Keywords: *Bacillus thuringiensis*, Bt, biopesticides, sustainable agriculture, biological control agents, integrated pest management, insect pests.

Introduction

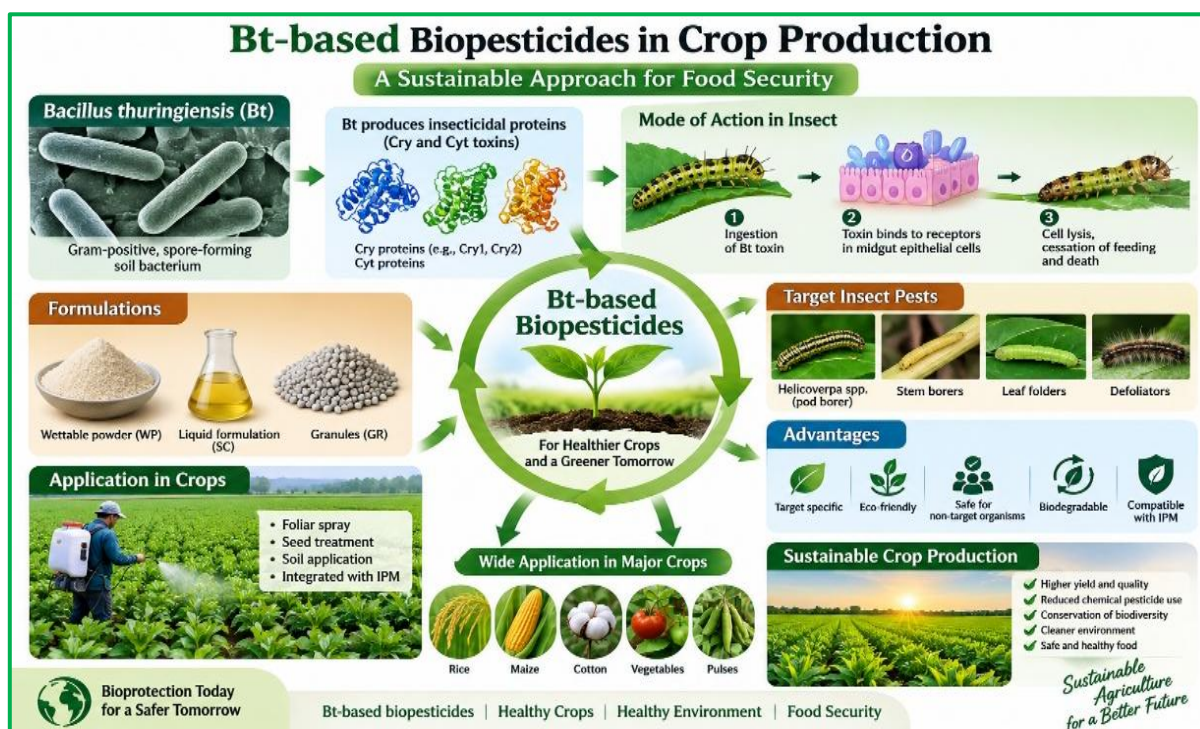
Insect pests are just some of the problems facing agriculture globally. The reliance by farmers for a long time on the use of insecticides to combat these pests is due to their effectiveness and fast action. Misuse and overuse of these chemicals can cause pest resistance, infestation, killing of beneficial insects, and pollution of the agricultural environment. All these have led to the need for sustainable pest control methods. IPM provides a way to reduce dependence on chemical pesticides. It combines cultural, physical and sometimes chemical approaches based on ecological and economic needs. In this model, microbial biopesticides have become especially interesting. Some of the commonly utilized microbes include *Bacillus thuringiensis*. This microbe makes toxins that are directed against insect larvae. As stated by the United States Environmental Protection Agency, the toxins made by different strains of Bt are specifically against certain insect species.

Biopesticides

- ❖ “*Bacillus Thuringiensis* is a gram-positive bacteria that can make spores. It can be found in the soil and elsewhere.” The insecticidal activity of *Bacillus Thuringiensis* results from the production of certain proteins in the process of sporulation. These are Cry proteins but other toxins were also been discovered.
- ❖ If the larvae of a vulnerable insect eat the plants containing Bt proteins, the proteins attach to the receptors in the insect’s gut. As a result, feeding stops and leads to death. The process is time-consuming and rather accurate.
- ❖ The specificity of Bt is one of its features. Different strains produce proteins that target different groups of insects. Many commercial Bt products work well against caterpillars, particularly those in the order Lepidoptera.

Role of Bt in crop production

- ❖ Sustainable agriculture is concerned with maintaining the productivity of crops without causing any harm to the soil, water, biological diversity, and human well-being. The use of Bt-based biopesticides has a part to play in this respect.
- ❖ One major benefit of Bt is that it acts on certain pests. Unlike broad-spectrum insecticides that affect species indiscriminately, properly selected Bt products can fit into pest management plans with few side effects on non-target organisms.
- ❖ Using Bt can also help with managing pesticide residues. With proper use of Bt along with IPM techniques, fewer insecticide sprays will become necessary. This helps achieve farming practices that require minimum use of chemicals but maintain maximum production capacity.



Application in crops

- ❖ Bt-based biopesticides can be useful in controlling many different insect pests.
- ❖ In cotton Bt products help manage pests such as bollworms. Cotton is also an example of Bt technology used in genetically modified form.
- ❖ In crops, Bt formulations can be employed to fight off pests such as diamondback moth and leaf-eating caterpillars. Their selective action makes them ideal for use in vegetable growing due to concerns about residues.
- ❖ In pulse crops like chickpea, *Helicoverpa armigera* is a pest. Research on local Bt strains has shown promise in reducing damage to pods. Such adapted microbes may play a growing role in creating effective and sustainable biopesticide solutions.

Integration with pest management

- ❖ Bt should not be seen as a solution for every pest problem. Its real strength lies in working alongside Integrated Pest Management practices.
- ❖ A sustainable pest management strategy will involve crop monitoring and application of Bt only when the presence of young, susceptible larvae is identified along with other cultural practices such as crop rotation, field sanitation and proper fertilization, which help in reducing pest pressure.
- ❖ Bt may also help in managing the pest. Predators and parasites are very important in agriculture. Since Bt usually acts upon particular insects, it will be more compatible with natural enemy-based strategy than broad-spectrum insecticides.
- ❖ Some of the other IPM strategies include planting of resistant varieties, use of pheromone traps, mechanical control and selective pesticide application.

Advantages of Bt-based biopesticides

- ❖ Bt-based biopesticides offer benefits in crop production.
- ❖ Target specificity: Different Bt strains and proteins can attack pests, reducing harm to non-target creatures.
- ❖ Compatibility: Bt gives a natural option that helps reduce reliance on synthetic insecticides.
- ❖ Compatibility with IPM: Bt fits well with cultural, biological and mechanical control methods.
- ❖ Biodegradability: Bt-based materials break down over time. How they last depends on weather and how they are made.
- ❖ Reduced chemical dependency: Using Bt wisely can cut the number of insecticide sprays needed in certain farming systems.
- ❖ Resistance-management potential: Using Bt in a planned IPM system helps diversify control strategies and slows down resistance development.

Limitations and challenges

- ❖ External conditions such as UV rays can damage proteins found on plants. Rain can cause Bt to be washed off before having any effects.
- ❖ Application timing matters a lot. Bt works best when young feeding larvae are around. So growers must monitor crops. Apply treatments at the right time.
- ❖ Resistance development is another concern. When pests are exposed repeatedly to the Bt toxin, resistant individuals may survive and multiply. Managing resistance requires rotation or combination of different modes of action along with following recommended guidelines.
- ❖ Formulation quality, storage conditions, shelf life and product consistency also influence effectiveness. That's why ongoing research into formulations and delivery systems remains important.

Future Prospects

- ❖ The fate of Bt biopesticides depends on advances in biotechnology and formulations. New Bt strains, insecticidal proteins, and more efficient formulations are being discovered and developed by scientists.
- ❖ Bt biopesticide stability can be enhanced using encapsulation techniques and applying UV-resistant coatings. Selecting Bt strains that are native to an area can increase efficacy against local pests. Precision agriculture can aid in optimal application through hotspot detection and targeted spraying.
- ❖ Future research should focus on making formulations cheaper and more efficient, extending shelf life, understanding how resistance develops, checking compatibility with enemies and combining Bt with other sustainable technologies.

- ❖ Bt-based biopesticides are a tool for sustainable crop production. Their biological origin, target specificity and ability to fit into Integrated Pest Management make them excellent alternatives or supplements to traditional insecticides.
- ❖ The best strategy is to combine Bt with crop monitoring, economic thresholds, resistant crop varieties, cultural practices, conservation of enemies and other compatible pest-control methods. Continued research into strains, better formulations, resistance management and precision application will help strengthen Bt's place in environmentally responsible farming. So, using Bt-based biopesticides wisely can help build a productive, resilient and sustainable agricultural system.