A Brief History of *Bacillus thuringiensis* (Bt)

Michael B. Dimock, Ph.D.
Certis USA, L.L.C.

Few may realize that a key tool in the grower's pest management arsenal had its beginnings in the growth of the Japanese silk industry over a century ago. As the 20th century dawned, Japan was rapidly becoming the world's leading supplier of raw silk, and Japanese sericulturists became more attuned to diseases that affected the health and productivity of their highly valuable silkworms. In 1901, microbiologist Shigetane Ishiwata determined that one particularly troublesome disease, called "sotto" or "sudden collapse" was caused by a rod-shaped, spore-forming bacterium, which he called "sotto bacillus." He suspected that the symptoms were caused by a toxin that might be located either within the spore or in close contact with the spore.

The formal scientific name *Bacillus thuringiensis* (Bt) was first applied in 1915 by German scientist Ernst Berliner, who discovered the same organism infecting flour moth larvae in the province of Thuringia. Berliner was the first to suggest the possibility of controlling insects through deliberate application of Bt. Field tests began in the late 1920's, leading to the introduction of the first commercial Bt product (Sporeine) in France in 1938. The success of insect control with Bt was highly variable because there was little understanding about how Bt killed insects, or the influence of strain selection and growth media on product quality and performance in the field.

During the 1940's and 1950's, American scientist Edward Steinhaus (widely regarded as the father of the modern discipline of insect pathology) conducted basic and applied research that demonstrated the potential of Bt as a microbial insecticide. For the first time, Bt began to attract the serious attention of the modern crop protection industry that had grown from the early discoveries of synthetic chemical insecticides before and during the Second World War. The first large-scale Bt product, Thuricide, was introduced in the USA in 1957 by Sandoz. Around the same time, Canadian scientist Thomas Angus determined that the parasporal crystal was the source of the Bt insecticidal toxin. His research confirmed and explained Ishiwata's observations, made over half a century earlier.

In the 1960's Howard Dulmage of the US Department of Agriculture isolated a more effective strain (named HD-1) that is still the basis for some of today's Bt products. Dulmage and his colleagues led the way in development of rigorous standards for determining potency of Bt products to allow comparison of results between different laboratories, strains, and products.

Until the late 1970's, Bt was only known to be effective against larvae of the insect order Lepidoptera (caterpillars). Then, the Israeli researchers Goldberg and Margalit discovered a new subspecies, Bt *israelensis*, toxic to larvae of certain flies (order Diptera). Products based on Bti have become important tools in the control of mosquitoes and other biting flies that transmit malaria and other life-threatening diseases of human populations around the world. Subsequent discoveries have revealed Bt subspecies and strains toxic to beetles (Coleoptera), ticks, nematodes, and other groups of pests.

The rapid development of recombinant DNA techniques and the advance of molecular biology late 1970's and through the 1980's transformed our knowledge and understanding of the genetics of Bt toxin expression and mode of action. In 1981, molecular biologists Ernest Schnepf and Helen Whiteley became the first to clone a Bt toxin gene, for which they later determined the complete DNA sequence. This allowed the construction in the laboratory of synthetic versions of the gene, opening the door to creating new Bt strains with higher potency, broader spectrum of activity, and higher production efficiency than previously available. It also pointed the way toward insertion of Bt toxin genes into the DNA of plants in order to render them resistant to plant-feeding insects. Although their introduction in the late 1990's generated debate that is vigorous today, widespread adoption of transgenic Bt cotton and corn has been shown to result in significant reductions in overall pesticide usage on these crops in the US. The molecular basis of Bt toxicity, the interaction between the toxin molecule and the cells of the insect midgut, has been studied in great detail using these and other advanced techniques unavailable to earlier researchers.

Some classes of synthetic chemical pesticides have come and gone, largely due to overuse and resistance, safety concerns, or adverse environmental impact. But a full century after it was first discovered, and 75 years after it was first used in the field, Bt still predominates the global biopesticide market, accounting for over 90% of the $160 million in biopesticide sales recorded in 2000. Advances in Bt genetics, strain selection, fermentation media, and formulation over the past 20 years have resulted in more potent, stable Bt spray products with more consistent performance against a broader array of insect pests. Because it has little or no impact on nontarget organisms and offers an alternative mode of action for delaying or managing insecticide resistance in pests, Bt remains a key tool for integrated pest management (IPM).

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