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Canadian Forest Service – Great Lakes Forestry Centre

The history of *Bacillus thuringiensis* research at the Great Lakes Forestry Centre

INTRODUCTION

Bacillus thuringiensis, commonly referred to as Bt, is a biopesticide that was developed from a naturally occurring bacterium found in soil. It is currently the most successful commercial product for use against forest pests, and is used widely in aerial forest protection programs in Canada and throughout the world. Much of the research and development of Bt for use against forest defoliators was carried out in Canadian Forest Service laboratories, which in Sault Ste. Marie were the precursors of the current Great Lakes Forestry Centre (GLFC).

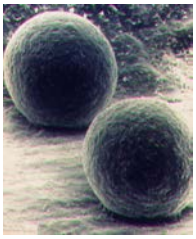
Insects cause significant losses to the forest-based economy. In 2010 for example, 12.7 million hectares (ha) of Canadian forests were moderately to severely defoliated or killed by beetles. Population levels of many insects, such as the spruce budworm, are cyclic in nature. While losses from the spruce budworm have not been substantial in recent years, surveys indicate that a new cycle may be starting, especially in some regions of Quebec (in 2010, 1.5 million ha were defoliated across Canada, up from 1 million ha in the previous two years). As a comparison, during the last spruce budworm outbreak, defoliation was high - almost 52 million ha were defoliated in 1975 and 20 million ha in 1985. Natural Resources Canada, Canadian Forest Service, as part of its commitment to the National Forest Pest Strategy, conducts research and develops tools for effective pest management. Bt, originally developed for control of spruce budworm, is currently the most effective tool for control of this pest.

GREAT LAKES FORESTRY CENTRE (GLFC) ROLE

Early work

A forest insect laboratory was established in Sault Ste. Marie in 1944-45 to conduct surveys and entomological research, largely in response to a serious spruce budworm outbreak that was affecting much of the spruce–fir forests of eastern Canada at the time. The chief of Forest Insect Investigations, biologist J.J. deGryse, had the idea to establish a research institute with the goal of studying possible biological control methods, as an alternative to the chemical agents being used then. Research on biological control agents such as bacteria, viruses and fungi was started at the Laboratory of Insect Pathology, which opened in Sault Ste. Marie in 1950.

During the first 15 years of research at the laboratory, a lot of pioneering work was conducted on understanding the fundamentals of infection and mode of action of Bt. Scientists determined that the toxicity of Bt lay in protein crystals that are produced when the bacteria form spores. When a susceptible insect ingests these crystals, its gut cells are affected, which causes the insect to stop eating and die within a few days. This research led to the first experimental aerial applications of Bt, which were conducted in 1960 against spruce budworm in New Brunswick and against black headed budworm in B.C. These first trials were not highly successful, but progress was made a few years later with the discovery that the *kurstaki* variety of Bt was more toxic to Lepidoptera (butterflies and moths) and it was subsequently adopted for commercial production by the mid 1960s.



Bt droplets

Improvements in formulations and spray technology

Over the next two decades, many refinements were made with regard to formulation of the product and application methods, in collaboration with other agencies and industries in Canada and the United States. A standard way of expressing potency was adopted. Early formulations were standardized on the basis of spore counts, which did not relate directly to insecticidal activity. The new standard became the number of International Units per unit volume or weight, which is still used today.

During the 1970s, many field trials were conducted to improve the effectiveness of Bt, largely for control of spruce budworm. It was felt that variable results could be attributed to inconsistent spray deposition, so efforts were directed towards improving application and spray technology. Various aircraft and delivery systems were tested and improvements were made, but costs were still significantly higher than chemical insecticides. Improvements in cost effectiveness were achieved in the late 1970s when commercial formulations became more concentrated.

Forest killed by spruce budworm

Potency of the formulations was increased from 4.2 Billion International Units per litre (BIU/L) in early products to 8.4 BIU/L. These more concentrated products reduced shipping costs, permitted application of lower volumes and improved spray plane productivity. Bt was used operationally on about 100,000 ha in 1979 and 1980. Some obstacles to its wide acceptance still remained, due to inconsistency in efficacy. This inconsistency was attributed to the use of marginal doses and the difficulty in obtaining adequate spray

coverage. More consistent results were achieved with 30 BIU/L, which led to the registration of even higher potency products. From 1985, Bt was applied at 20 or 30 BIU/ha in 1.6 or 2.4L. Subsequently, increased use led to a substantial decrease in the price of Bt, from about $7/ha to about $3/ha.

Spray technology that allowed for small droplets also led to improved success. Good control of the pest depends on the number of droplets an insect ingests and how much Bt is in each droplet, so formulations must yield droplets of a certain size and toxicity. Early systems delivered spray droplets in the 100-300 micron size range, whereas optimal droplet size was found to be 15-55 microns. It was determined that small droplets are best applied with rotary atomizers, which are capable of generating a high proportion of droplets in the appropriate size range, with flow rates below 2L/min.

Jack pine budworm infestation: Bt-treated and untreated areas

Since 1985, Bt has been used on nearly 8 million ha of insect-infested forests. In addition to controlling spruce budworm, Bt has been used successfully against other defoliating insects, including western and black headed budworm, gypsy moth, eastern hemlock looper, forest and eastern tent caterpillar, and white marked tussock moth.

Recent work

Once Bt became an operational product under full commercial development, the focus of the research shifted to fine-tuning its effectiveness.

Continued research on the mode of action of Bt at the organism and population levels has contributed to the development of a detailed spruce budworm-Bt efficacy model. Operational improvements during the next spruce budworm outbreak are expected to result from the use of this model and from implementation of a host of other tools that were developed during the last spruce budworm outbreak. These include the BioSim phenology model to better time protection spraying; the Spruce Budworm Protection Planning System to prioritize stands for treatment based on projected timber supply impacts; and the Accuair Aerial Management System for real-time optimization of spray application by increasing droplet deposition and reducing off-target drift.

The ongoing discovery of new Bt toxin genes and rapid accumulation of information on their insecticidal activities prompted the construction of a database on Bt toxin specificity. This is a useful tool for fellow scientists, researchers, industry and regulatory agencies from around the world involved in Bt research to share information and allows for their combined results to be accessible in a searchable format.

CONCLUSION

The development of Bt into a commercial pest control product is indeed a success story and NRCan, CFS researchers played a critical role its development. It is still a valuable tool in integrated pest management programs in Canadian forestry for control of defoliating insects such as spruce budworm and gypsy moth. Its success in forestry and its outstanding environmental safety have led to worldwide commercial interest in its use in agriculture and other markets.

COLLABORATORS

Atlantic Forestry Centre

Laurentian Forestry Centre

Provincial forest protection agencies

USDA Forest Service

Valent BioScience (formerly Abbott Laboratories)

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