FOUR ENGINE AIRCRAFT EXPERIENCE IN THE APPLICATION OF BACILLUS THURINGIENSIS AGAINST THE SPRUCE BUDWORM IN QUEBEC

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Introduction

I want, during this presentation, to give you a spray program coordinator point of view on Bt and try to explain why things are always different in Quebec. Not alays better but always different, even in the application of *Bacillus thuringiensis* where 4 engine aircrafts were used to control the spruce budworm, *Choristoneura funiferana* (Clem.), infestation.

First, a background of the situation is required: background of the Quebec forest and background of our perception of Bt. In order to progress in our approach to use Bt, some KEY FACTORS and GOALS have been established. This brought us into two major periods in the use of Bt: the 1971-1980 period where we learned to live with Bt and its constraints, and the 1981-1983 period where some of the constraints have been solved to a certain degree. Finally, the 1984 project is discussed.

Background

To fully understand the approach, it is important to know that 95% of the Quebec forests are crown lands which are leased to forest industries for wood supply. In order to keep the industrial activity going, one of the tasks of the Quebec Department of Energy and Resources is to organize protection programs against any forest enemies. In the perspective of spruce budworm infestation which attacked softwood species, the major component of the Quebec forest economy, this meant protecting a very large area during a short period of time, the period of the year where the insect was active (6 weeks), in parts of the province where roads and airstrips were scarce. This situation led us to organize spraying programs on large blocks of continuous forests on crown lands, while other approaches like salvation cutting were organized on more accessible but patchy private woodlots. In this strategy, the use of large aircrafts with large capacity payloads was the only alternative available to achieve adequate protection.

The major species attacked by the budworm in Quebec is balsam fir. White spruce and, to a minor degree, red and black spruces are also attacked but being not an important part of the softwood volume, they are not considered in our approach with respect to timing, efficacy and damage.

Programs were initially conducted in western Quebec where the infestation was first reported but by the mid seventies, as the infestation moved from west to east and covered the whole province, the treatments were concentrated in eastern Quebec, where the most important softwood forests were located.

The fact that Bt is a living organism had a major influence on our techniques used to evaluate spray deposit and on mixing procedures. Petri dishes with gelose were used on the ground to evaluate deposit in term of colonies/cm^2, without any reference to size of droplets because the addition of dye (needed for drop sizing) could affect the viability of the spores. Likewise, the addition of water for final formulation was done just prior to application, to avoid activation of the spores.

Key Factors and Goals

In order to evaluate progress achieved thru years with Bt, the treatments had first to be characterized, then some KEY FACTORS were chosen to evaluate efficacy, GOALS were set up as bench marks for what we considered adequate results.

The important points chosen for the characterization of treatments were:

- areas treated (hectares)
- type of *Bacillus thuringiensis* (oil and water basis)
- concentration of the initial formulation (BIU/litre)
- volume used (litre/ha
- dosage (BIU/ha)
- final formulation (%)
- type of aircraft used (altitude (meter)
  (speed (Km/s)
  (capacity (litre)
  (swath (meter)
  (pressure (litre/s)
- navigation system
- spraying system
- weather condition
- timing (Insect and shoot development)

The KEY FACTORS that were examined to evaluate the efficacy of the treatment were:

- Pre spray population (larvae/45cm branch)
- Residual population (pupae/45cm branch)
- Larval mortality (at peak pupae)
- Previous damage (years of severe defoliation)
- Annual defoliation
- Deposit (number of colonies/cm^2)
- Synchronization of insect and shoot development.

GOALS

The treatments were conducted to reduce stress on the trees and to keep the forest alive. Experience with chemical insecticides told us that, as long as the annual defoliation was kept below the 50% threshold, a treatment could be considered as adequate and successful.

THE 1971-1980 PERIOD: Learning to live with Bt and its constraints

When the spruce budworm infestation was first reported in Quebec during the late sixties, *Bacillus thuringiensis* (Bt) was the only biological alternative to chemical insecticides. Under the technical advice of the Laurentian Forest Research Center, the Quebec Department of Energy and Resources initiated in 1971 some experimental work with Bt.

On a trial and error basis, it soon appeared that the application of Bt was more sensitive than the application of chemical insecticides. Detailed treatments conducted from 1971 to 1980 have been described in detail in an earlier presentation (Dorais and al. 1980) and the major conclusions that could be drawn from that period were that:

- good results with Bt have always been associated with good deposit. A spray deposit of 20 colonies per cm^2 collected on petri dishes was the rule of thumb to consider a treatment to be effective;

- spray volume required to achieve such a deposit varied from 4.68 (for single engine) to 7.0 l/ha (for four engine aircraft). Under those circumstances, a dosage of 20 BIU/ha could adequately control population levels up to 25 larvae/45cm branch;

- timing also appeared to be very critical. As a stomach insecticide, Bt has to contaminate the annual foliage and has to be ingested in order to kill the larvae. No treatment could be done prior to bud flare and, on a block basis, a treatment conducted within 10 days after the bud flare could be considered as adequate. On a spray program basis, like in eastern Quebec, 20 days was the usual maximum period available per year to apply Bt for proper timing;

- products manufactured became more concentrated thru time (16 to 32 BIU/USG) to suit forestry needs: these more concentrated formulations increased the plane efficiency per year and the area treated could then be increased (Table 1;

- since spores are activated after 12 hours in water, the final formulation was prepared only when the block was ready and when we were absolutely sure that the product could be applied. 30 minutes of mixing time was then required prior to application. This procedure limited the use of Bt to one load per spray period;

- oil base formulations diluted in water required a higher volume to be sprayed than water base formulations, because the amount of water needed in the final formulation had to be at least equal to the amount of oil to avoid inverted emulsion;

- planes used thru the years were: Stearman, TBM Avenger, CL-215, Constellation L-749, DC-6B, and DC-4G. The larger planes came into use to improve spray load capacity.

The 3 major constraints that limited our confidence in Bt at the end of this period were:

- the poor efficacy against high populations (population > 25 larvae per 45cm branch)

- the poor plane productivity (efficiency) per year

- and the cost of the treatment; still 3 times more expensive than a double application of chemical insecticides

Resulting Spray Policy

Even as all efforts were oriented to increase the area treated annually, results obtained were highly variable and the use of Bt was limited to highly sensitive areas where chemical insecticide could not be applied.

Based on experience the norms followed to achieve good results with Bt were:

- population level > larvae/45cm branch tip
- dosage 20 BIU/ha
- volume 4,68 l/ha for single engine aircraft
  7,0 l/ha for four engine aircraft
- deposit 20 colonies/cm^2
- timing 0 to 10 days after bud flare
- cost of treatment (1981): $9.48 for chemical treatment and $31.43 for biological treatment.

Based on the payload of a DC-4G (20 000 lbs) at the rate of 7 l/ha, one plane could normally treat (over a 20 day period) 24 000 hectares per year compared to 125 000 hectares (x2) with chemical insecticide.

The 1981-1983 Period: Solving The Bt Constraints

During the period of 1981 to 1983 some new highly concentrated formulations have been developed and tested in the field. It was expected that the droplets produced, being more concentrated, could kill the insect faster than the former diluted formulations and could therefore reduce the damage caused. At the same time, a smaller amount of material being applied per hectare would increase the annual plane productivity.

Tests were conducted with one of these concentrated formulations (FUTURA 51 BIU/USg). Applied in a volume of 2.5 l/ha, this concentrated formulation for 2 years in a row gave very good larval mortality plus an overall striking degree of foliage protection, even against population levels as high as 35 larvae per 45cm branch tip. These observations changed completely the picture of our aerial spraying programs with Bt. The major changes were:

- limitations for the concentrated Bt, regarding population levels, seemed to be identical to chemical insecticide; concentrated Bt in fact performed as well as chemical insecticides against population levels as high as 35 larvae/45cm branch tip;

- dosage of 20 BIU/ha provided adequate results in tests conducted in Quebec with FUTURA while in other provinces or states a dosage of 30 BIU/ha seemed to give more consistent results; 20 BIU/ha was considered then as a marginal dosage that could be successful if other factors like timing, deposit, etc. were favorable. Volumes lower than 2.37 l/ha never gave adequate deposit with 4 engine aircraft, so dosage was chosen in order to respect the 2.37 l/ha volume limit;

- deposit of 10 to 15 colonies per cm^2 could be considered adequate; since droplets were more concentrated, a fewer number was required for good results, compared to diluted material. Meanwhile, in order to improve spray technology, an experiment was carried out to correlate deposit with foliage protection (without success!). This raised questions about the colonies per cm^2 in petri dishes as a valuable technique, and left the question about ideal size and concentration of droplets that <u>should</u> be generated (the smaller size droplets collected on foliage contained a lethal dosage) unresolved.

- oil-base concentrated formulations when applied undiluted (neat) have an advantage over water-base formulations, with respect to payload. Oil being lighter than water, a higher volume could be carried by the plane per load compared to water-base formulation. On the other hand, plugging problems have been encountered with oil-base material when water, created from condensation in the tank, produced an inverted emulsion with oil (Table 2);

- because concentrated formulations were applied undiluted, mixing procedures were simplified. The product was stable by itself and required only agitation to make an homogeneous suspension prior the application. Without elaborate mixing procedures just prior to application, two loads per spray period could be planned, weather permitting, the same as for chemical insecticide applications.

The 3 major constraints that were discussed from the previous period were reduced to a certain degree with the new concentrated formulation. That is:

- improved efficacy against high larval populations

- an increase in plane efficacy each year (by 2 to 3 times)

- the cost of treatment was still 2 times more expensive than the cost of a double application of chemical insecticide, but the cost of the B.t. product has been decreasing for 2 years in a row, as a result of larger scale economics based on more confidence in the reliability of B.t.

Planned 1984 Spraying Program

After 13 years of research and development to utilize Bt on large scale budworm spraying programs, the Quebec Department of Energy and Resources decided that the major improvements achieved in the three past years warranted giving Bt an honest try; thus, 300 000 of the 800 000 ha contemplated for 1984 will be treated with Bt (200 000 ha with undiluted material and 100 000 with diluted material).

The criteria now recognized to achieve good results with Bt are:

- population level: < 35 larvae/45 cm branch tip
- deposit: 10 to 15 colonies/cm^2
- volume: 2.37 l/ha (undiluted) to 4.68 l/ha (diluted)
- dosage: 20 to 30 BIU/ha
- timing: 0 to 10 days after bud flare
- cost (1983): $10.99 for chemical treatment $26.86 for biological treatment

So, in 1984, based on the payload of a DC-4G (20 000 lbs) at the rate of 2.5 l/ha, one plane could treat over a 20-day period a total of 65 000 to 83 000 hectares, compared to 125 000 hectares using chemical insecticides (Table 2).

Planned 1984 Experimental Program

In order to keep improving Bt control for spruce budworm, our research priorities for 1984 have been established as:

- to develop a reliable spray deposit technique which can be correlated with foliage protection;

- to investigate the ideal droplet size and concentration (i.e. the smallest droplet which contains a lethal dose);

- to test in the field some formulations of Bacillus thuringiensis Kurstaki (isolate HD-1) concentrated at 64 BIU/USg and a new isolate (NRD-12), potentially more toxic for the budworm than the former HD-1.

Conclusions

Technological development of new formulations which increased efficacy of Bt and plane efficiency, the growing pressure of the larval population that survives in the forest to cause increasing tree mortality, and the collective history created about chemicals by uniformed people, are the factors which have contributed to greater use of Bt. B.t. still remains the only operational biological alternative to chemicals for spruce budworm control.

The growing use of Bt generated an important diversified expertise. Research programs, like CANUSA, have helped by a joint effort to sort out the good and bad experiences, but the important thing is that a climate of confidence has been created towards B.t. by users and producers. With all this interest generated, major improvements are still to come in the near future: increased toxicity and effectiveness at a lower cost.

References

Dorais, L.; Pelletier, M.; Smirnoff, W. Aerial spraying applications of *Bacillus thuringiensis* Berliner conducted on Quebec forests (CANADA) from 1971 to 1979 against the spruce budworm, *Choristoneura fumiferana* (LEPIDOPTERA TORTRICIDAE) VIth International Agricultural Aviation Congress held in Turin, Italy, September 1980.

Table 1.--Comparison of aerial applications of Bacillus thuringiensis cconducted in Quebec from from 1972 to 1980

Year	Area treated (ha)	Concentration (BIU/USg)	Volume (/ha)	Aircraft used
1971	80	16B	18,72	Stearman
1972	4000	16B	18,72	TBM Avanger
1973	120	26B	4,6	CL 215
				TBM Avanger
1974	3250	26B	4,6	DC 6B
				CL 215
1975	91000	16-26-36	2,3 - 4,6	DC 6B
1976	120	32B	4,7	S-55T Helicopter
1977	NONE	---	---	---
1978	13300	32B	9,36	DC 6B
			4,68	Ag Cat B
1979	17030	32B	4,68 - 7,0	L-749
1980	22180	32B	7,0	L-749

Table 2.--Alternative treatments of Bacillus thuringiensis for 1984

Product	Concentration (BIU/USg)	Dosage (BIU/ha)	Volume (ℓ/ha)	Plane productivity (ha/year)
Thuricide 32LV and Novabac-3	32B	20	2.37 (neat)	70 040
		20	4.68 (diluted)	42 740
		30	3.55 (neat)	46 760
		30	7.01 (diluted)	28 580
Dipel 88	32B	20	2.37 (neat)	83 540
		20	5.85 (diluted)	32 000
		30	3.55 (neat)	55 780
		30	8.84 (diluted)	22 500
Futura TM	51B	20	2.5 (diluted)	65 600
		30	3.75 (diluted)	43 740
Thuricide 48LV	48B	20	1.58 (neat)	105 060
		30	2.37 (neat)	70 040
Dipel 132	48B	20	1.58 (neat)	125 320
		30	2.37 (neat)	83 540