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A Management System to Control Douglas-fir Tussock Moth, *Orgyia pseudotsugata*, using OpNPV

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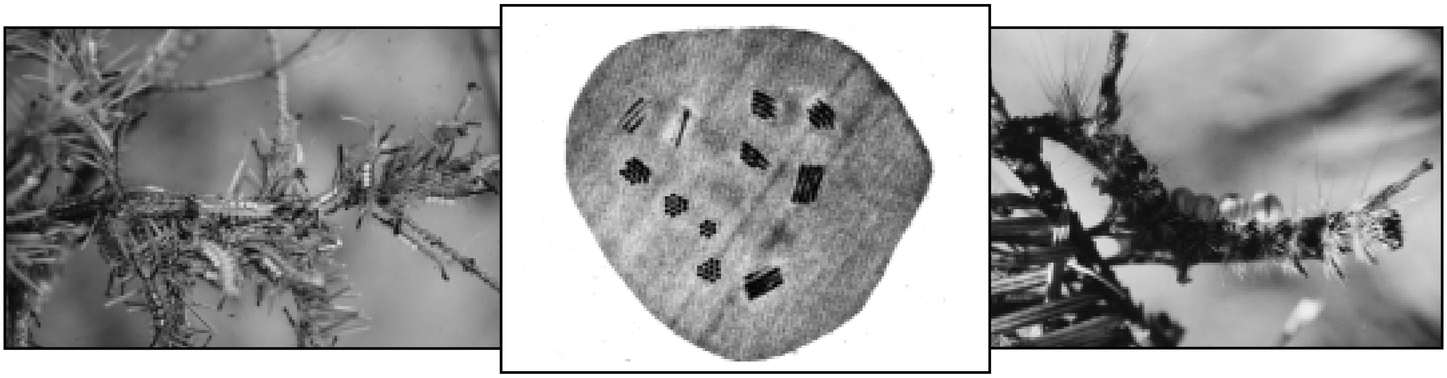

Host-specific baculovirus (OpNPV) can successfully control Douglas-fir tussock moth outbreaks: tussock moth larvae (left); OpNPV virus (centre); infected larva (right)

Strategic Importance

The Douglas-fir tussock moth, *Orgyia pseudotsugata*, is a native defoliator which reaches outbreak proportions in western North America every 7 to 11 years. It is a voracious feeder on interior Douglas-fir, *Pseudotsuga menziesii*, and is capable of defoliating large forested areas, causing top-kill and tree mortality during outbreaks. This reduces forest growth, may affect allowable cuts, and disrupts management plans. An attack may also have significant impacts on private property aesthetics, public health (Tussockosis - an irritation of the skin) and reduced real estate values in urban and rural areas.

The collapse of an outbreak can be hastened by seeding a naturally occurring nuclear polyhedrosis virus (OpNPV) at the beginning phase of an outbreak. A management system using OpNPV to control the Douglas-fir tussock moth has significantly reduced tree mortality and defoliation. The development of such a management system required long-term commitment and collaboration of several researchers and organizations. The Douglas-fir Tussock Moth Management System was a cooperative project developed over a 15-year period, and it has been successfully implemented in British Columbia.

Douglas-fir tussock moth outbreak characteristics

In British Columbia, the stands most susceptible to Douglas-fir tussock moth are located in the driest part of the Douglas-fir's range where it mixes with ponderosa pine, *Pinus ponderosa*. Grand fir, *Abies grandis*, white fir, *A. concolor* and to a lesser degree, subalpine fir, *Abies lasiocarpa*, may also be attacked in some of the western United States. All age classes and sizes of the host trees may be attacked - the most severely attacked trees generally die. Large, but less severely defoliated trees are weakened by these attacks and may be subsequently attacked and killed by the Douglas-fir beetle, *Dendroctonus pseudotsugae*.

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Outbreaks are quite local and intense. Population increases are usually first noticed on open-grown trees in and near settlements. Defoliation occurs in distinct patches in the first year, spreading and coalescing in later years of the outbreak. Dispersal of the tussock moth is limited because the female moths are flightless. The young larvae hang from silken threads and are blown to surrounding trees and adjacent stands. This probably accounts for the patchy pattern of defoliation associated with this insect during the start of epidemic phases.

Viral insecticides: OpNPV

OpNPV is an environmentally friendly means of controlling the Douglas-fir tussock moth. OpNPV's infections have the following characteristics.

- They are highly species-specific, infecting only the host-target insect or very closely related species of the same genus.
- The virus must be ingested by the host insect (The inclusion body protein dissolves in the alkaline gut juices thereby releasing the viral particles. Following the death of the larva, the cuticle ruptures and the polyhedral inclusion bodies, PIBs, are released.)
- Infections are highly effective in causing larval mortality, particularly when population densities are high.
- The infection is a cause of epizootics.
- The infection is relatively slow acting (depending upon temperature, it may take 6 to 8 weeks to kill the larvae).
- The virus is retained in the soil or bark crevices and can serve as an inoculum for future infections.

Single and multicapsid strains of the virus have been isolated from the Douglas-fir tussock moth. The multicapsid virus has been registered in the United States under the name TM BioControl-1®. The same virus, produced in the whitemarked tussock moth, *Orgyia leucostigma*, has been registered in Canada under the name Virtuss®. Both have been registered as biocontrol agents in Canada.

Unlike *Bacillus thuringiensis* subsp. *kurstaki* (Btk), which infects a range of Lepidoptera, OpNPV infections are restricted to the tussock moth. Chemical insecticides, such as Acephate, DDT, or Dimilin, are no longer available for forestry pest control in Canada.

OpNPV infections occur in the natural cycles of the tussock moth and will cause outbreaks to collapse. OpNPV epizootics occur naturally as tussock moth populations near their peak (Figure 1). However, by the time this happens, the tussock moth has usually caused extensive tree damage. Therefore, to prevent or at least minimize damage, forest managers apply the laboratory-produced virus to threatened stands in the early phase of the outbreak.

The Control System

A management system based on biological control (Figure 2) combines a method of detection, an understanding of the biological cycles, and application of the biological control agent at the appropriate point in the population cycle. Studies have shown that introducing OpNPV at the beginning of the outbreak will effectively reduce defoliation and tree mortality. The greatest tree mortality results from severe defoliation in the first years of an outbreak.

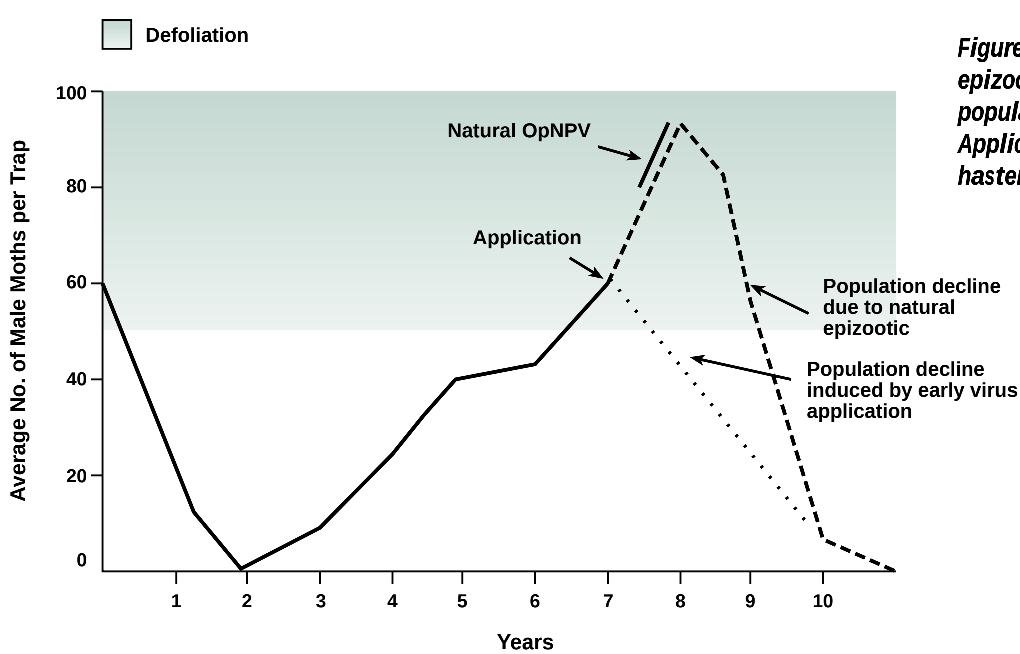

Figure 1. Natural OpNPV epizootics occur as the moth populations near their peak. Application of OpNPV can hasten epizootics.

Overlay maps of previous outbreaks

Set pheromone-baited traps

Identify male moth populations over the years (advance warning)

Fall or winter egg-mass survey to monitor tussock moth population (precise sampling)

Identify insect density at centre of developing infestation

Application of OpNPV Baculovirus

Follow up with defoliation surveys

Figure 2. Steps in a management system for OpNPV control of Douglas-fir tussock moth.

Consequently, identification of tussock moth population trends and a reliable monitoring system are required for effective control. The first step is to identify highly susceptible stands from previous outbreaks by forest type and biogeoclimatic zone.

Monitoring

Pheromone-baited traps are set out in highly susceptible stands to monitor the male moth density annually over successive years. If the number of male moths captured increases and exceeds 25 males per trap for three consecutive years, an outbreak can be expected to occur within the next 1-2 years. There is, however, only a poor correlation between numbers of moths caught and egg-mass density or defoliation estimates in the following generation.

Critical trends indicated by pheromone-baited traps must be verified by more precise egg-mass surveys. Egg-mass surveys are done in the fall or winter. An average density of over 1.7 egg-masses per tree (based on counts from the three lower crown branches per tree) indicates that severe defoliation can be expected in the following year. The egg-mass surveys also indicate the insect density at the centre of the developing infestation and can be used to predict potential damage. This approach should only be used in undefoliated or lightly defoliated stands at the incipient stage of an impending outbreak.

Application of OpNPV

A successful viral infection of Douglas-fir tussock moth larvae can be initiated both by aerial and ground treatments. Studies have shown that applications can be effective at high, medium and low Douglas-fir tussock moth populations. The registered dosage is 2.5×10^{11} polyhedral inclusion bodies (PIB) per ha on first and second instar larvae applied in either emulusifiable oil-based or water-based spray. This dosage will reduce larval populations by up to 95%.

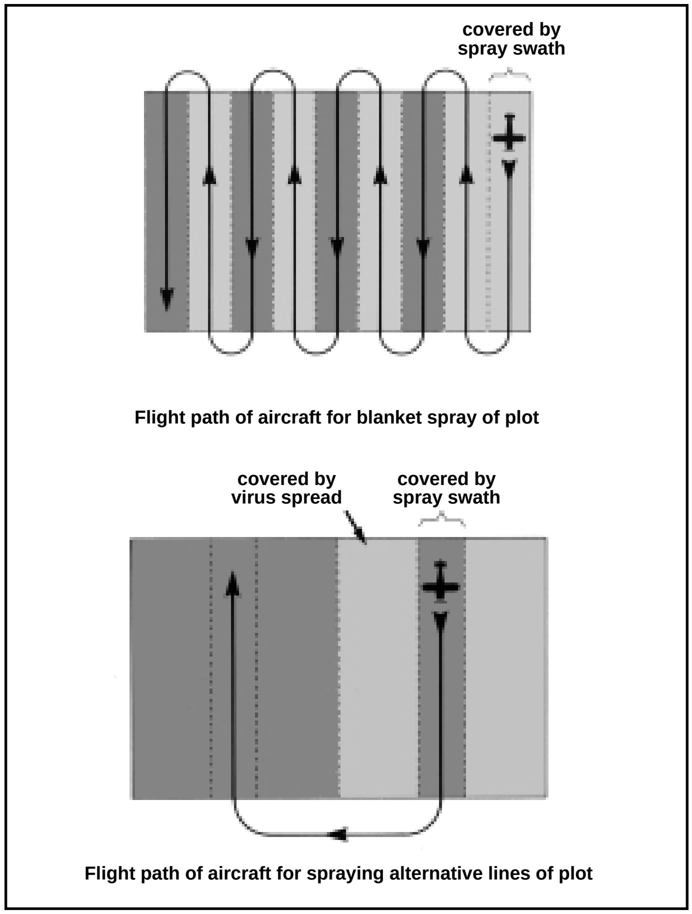

Figure 3. Recommended flight lines for an OpNPV treatment.

Normally, aerial application is applied in adjacent swaths (flight lines) that are about 30 to 35 m wide for a blanket coverage. Studies in the early 1980s showed that OpNPV infection of the Douglas-fir tussock moth larvae spreads up to 100 m beyond the initial treatment area. Because of this infection spread, population control may also be successful by placing the flight line at 50 to 100 m apart to seed the virus into insect populations (Figure 3) and allow other processes to move the OpNPV into the area between the flight lines. OpNPV transmission is greater under the flight lines within the treated areas and will be higher in areas with relatively high larval densities. The application of widely spaced swaths could reduce the costs of operational spray programs by some two-thirds while achieving the same impact (a significant cost of a spray program is the production and culture of the virus, a very labour-intensive process). A portion of a tussock moth outbreak was controlled in 1992 using this widely spaced swath application over a 150-ha area. However, the widely spaced swath application has only been used once and the reliability of this approach needs to be confirmed.

Because OpNPV is slow acting, defoliation can be expected to continue during the year of application, especially if the weather is cool and the epizootic develops slowly. Some growth loss can also be expected, but treated stands will not sustain heavy tree mortality or excessive growth reduction. Consequently, OpNPV should be applied before the Douglas-fir tussock moth reaches high population levels. To achieve this, population detection and monitoring using the management system outlined above is recommended.

Secondary infections

Early application of OpNPV on first and second instar larvae creates the conditions for a secondary Baculovirus infection. Larvae initially infected with the virus die and liberate polyhedra (virus particles) thereby increasing the amount of inoculum available on the foliage. The surviving larvae feed on needles "contaminated" with this inoculum, creating a secondary wave of virus infection. An additional benefit of OpNPV application is increased pupal mortality among the surviving population.

The development of the viral disease is dependent upon a number of factors:

Larval Density
- The rate of spread is influenced by insect density.
- Virus transmission is higher in plots with higher larval densities.

Temperature
- Development of OpNPV infection is temperature dependent.

Secondary Infections
- Baculovirus infection can spread beyond the initial application area.

Limitations of the system

While OpNPV has proven to be successful and has been produced through the trademarks Virtuss® and TM-BioControl-1®, its production is limited. Consequently, monitoring the infrequent tussock moth outbreaks is very important. Lead time is required to test the efficacy of existing OpNPV reserves and activate the necessary partnerships between industry and governments that are required to combat outbreaks.

Additional Reading

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