

Approach and Rationale to Developing an IPM Program: Examples of Insect Management in British Columbia Reforestation Nurseries

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INTRODUCTION

Insects, weeds, and diseases are a significant part of the production process that nursery growers must consider in order to effectively grow the desired conifer seedling. For the pests and seedlings, the underlying theme is survival, which encompasses 3 major components: stimulus, recognition, and response (Shigo 1991). Thus, the continuation of any system depends on its ability to recognize a stimulus that, in the case of the seedling, threatens or, in the case of the insect, enhances its survival. Once recognized, there must be the ability to respond rapidly and effectively. The speed and effectiveness of the response depends greatly on the availability of energy. In the seedling, reserve energy is used to mount a quick and effective block to any agent that threatens its existence. For the insect or disease, how fast the stimulus is recognized and the degree to which a response is developed are key elements to its survival. Every system has strong and weak periods; therefore, any pest management plan must target the most vulnerable phenological stage of the seedling or pest. Reforestation nurseries represent a unique challenge to the pest managers, as they are subject to pest problems originating from agriculture and forest pest complexes. In addition, conifer seedlings destined for reforestation sites are grown to strict specifications, therefore significantly reducing the nursery's level of tolerance to pest damage. Nursery managers are eager to reduce pesticide use to satisfy concerns expressed by nursery workers, tree planters, and regulatory agencies. The following is a summary of insect pest management strategies currently under development and implementation in British Columbia (BC) nurseries.

The majority of insect pests in conifer nurseries feed on the needles and shoots of seedlings. Many insects that are general feeders will readily attack young seedlings before their stems become woody and their needles become resinous. These insects are the most easily detected because pest presence or damage can be seen on inspection. (Shrimpton 1990; Sutherland and others 1989).

CUTWORMS

Cutworms, larvae of moths in the family Noctuidae, are chronic pests in conifer seedling nurseries. To date, 25 different species have been identified on BC nurseries. Though most are not true cutworms (family Noctuidae) they are, for all practical purpose, grouped under the term "cutworm." There are probably populations at all nurseries in every growing season, but the severity of the infestation varies greatly. All conifer species can be attacked, and the degree of damage is generally confined to young, succulent 1+0 seedlings. A single larva can destroy many seedlings in one evening, and only a few cutworms can destroy thousands of seedlings in a couple of weeks. Cutworms feed on foliage and often cut through the stems leaving a short stump.

Pheromones are available for several species, but their use is jeopardized by the fact that nursery stock can be attacked by many different species, and cutworm populations can vary greatly from year to year. Due to the difficulty in predicting the occurrence of cutworms, controls must be applied after the cutworms or their damage have already been found. Traditional control methods have emphasised chemical sprays with permethrin or the biological control agent *Bacillus thuringiensis* (Bt). Unfortunately, Bt is limited in that it is strictly a gut poison. To be effective, the insect must consume enough treated plant material to stop feeding and eventually die of starvation. To counter this limitation, nurseries have implemented intensive scouting programs during the most susceptible period of their crop culture to quickly identify the first signs of cutworm damage. If found, nursery personnel are encouraged to hand remove and destroy small infestations of caterpillars. Otherwise, these areas are spot sprayed and monitored for damage.

In an effort to reduce the impact of these larvae, nursery managers employ a number of other strategies. Various weeds attract moths to ovipose, thus allowing larval populations to buildup in weedy areas in the nursery. These larvae then migrate to feed on the seedling crop. Weed management practices in and around the nursery site are a significant deterrent to pest establishment. However, once cutworms are present, killing the weeds may drive the larvae from the preferred weeds to the seedlings. At the beginning of the growing season, when the sides and roofs of greenhouses are in place, fitting screens over the intake vents and keeping the doors closed help to physically exclude these insect pests. Some nurseries have effectively reduced populations of adult moths in greenhouses by using light traps.

APHIDS

Aphids are important pests in reforestation nurseries because of their feeding damage and the potential for transporting them to the field. Three species are of particular interest to BC nursery managers. They are the giant conifer aphid (*Cinara* sp.), the Cooley spruce gall aphid (*Adelges cooleyi*) and the green spruce aphid (*Elatobium abietinum*). The giant conifer aphid can be found on all species of conifers grown in reforestation nurseries and can cause stunting and chlorosis.

The Cooley spruce gall aphid is a woolly aphid found alternating between spruce and Douglas-fir. It is easily detected because of its white woolly covering, but this also makes them harder to control. The green spruce aphid is primarily of concern on Sitka spruce seedlings. Like most aphids, these species have high reproductive rates, so populations can get out of control very quickly. Aphid infestations are often detected by the presence of wasps or ants, both of which will feed on the honeydew as well as redistribute aphids throughout the nursery crop. Because aphids can increase so rapidly under favorable conditions, chemical control may be necessary to protect plants. In the past, small infestations have been successfully treated with insecticidal soap while large infestations have been treated with diazinon. For the Cooley spruce gall aphid on Douglas-fir seedlings, nurseries are encouraged to remove mature spruce trees in and around the nursery site that serve as an alternate host for the gall forming stage.

A conifer root aphid, *Pachypappa tremulae*, has infested seedling stock at several nurseries in BC. To date, most infestations have occurred on container spruce but related root aphid species also infest pine, larch, and Douglas-fir. These aphids are often discovered during the lift by their secretions of white waxy filaments, and they are often mistaken for ectomycorrhizae. Infestations are usually on the surface of the plug between the roots and the container wall, closer to the top of the plug than the bottom. The other stage in the life cycle is found on the leaves of trembling aspen (*Populus tremuloides*), where the aphids form structures known as leaf nests. Most nurseries that have sustained infestations of this aphid have not reported any damage. Outplanting studies have shown that they have no measurable effect on seedling performance, and as such no control strategies are recommended.

Two aphid predators, the convergent lady beetle or ladybugs (*Hippodamia convergens*) and the aphid midge (*Aphidoletes aphidimyza*) have been tested with promising success against the foliar aphids. Ladybugs are one of the best known of all insect natural predators. Both the larval and adult ladybugs feed voraciously on a variety of aphid species. In fact, a single ladybug larva can consume 50 to 60 aphids per day. Ladybugs can provide long-term, adequate aphid control in a release area only if they reproduce. Test releases have found them to be successful in reducing aphid populations, particularly *Cinara* sp., but only when the aphid populations were considered high. A common problem is that adult female beetles cannot produce eggs until they have fed on prey, and they will only lay eggs where prey is sufficient to support the resulting larvae. Otherwise, they will disperse in search of more abundant prey. Strategies that have been developed to reduce the chances of dispersal are to make releases at dusk (ladybugs do not fly at night), immersing the adults in a sugar solution to reduce their flying abilities, and watering the release area to increase moisture levels. Also, distributing the total release of the adult ladybugs over a few days or weeks helps to increase the chances the adults will find favourable conditions to feed and lay eggs.

The female aphid midge is a gnat-like fly that searches for aphid colonies to deposit her eggs. The eggs hatch out as tiny orange maggots that can feed on 3 to 50 aphids per day. The larvae are known to attack at least 60 different species of aphids, and the adults are such efficient searchers that they can locate 1 aphid-infested plant among many aphid-free plants. Environmental conditions are important to the efficacy of the larvae. The adults prefer shady, humid conditions, and pupal stage survival requires moist soil or organic matter. The larvae stop development under short day length and overwinter as cocoons in the soil. This diapause can be

prevented by the use of low-intensity supplemental lighting. Trial releases of the adult midges against the Cooley spruce gall aphid and the giant conifer aphid have shown them to establish in conifer crops and to reduce aphid populations. More effort is needed to develop an effective aphid monitoring program to facilitate the release of *A. aphidimyza* and *H. convergens*.

LYGUS BUG

In North America, the *Lygus* bug (Heteroptera:Miridae) has been recognized as a severe pest of alfalfa, cotton, and garden vegetables. In the last 15 years, *Lygus* spp. have caused considerable damage to conifer crops in reforestation nurseries in North America and Europe. In BC, they feed on a variety of 1+0 container conifer species, but pines appear to be the most susceptible to damage (Sutherland and others 1989). *Lygus* bug damage has been found at almost every nursery in the province, although it is not always significant. Deformation of terminal shoots, loss of terminal leaders, flagging of the needles, and stem lesions are among the most common symptoms of *Lygus* feeding on seedlings. In general, damage is highest within the first few weeks after germination and declines sharply thereafter. Nurseries in BC use a preventive spray program of 2 to 4 applications of cypermethrin each growing season to prevent *Lygus* bug damage. Although the program appears to be effective, there are concerns over the development of resistance with repetitive applications of 1 insecticide.

To better define our integrated pest management (IPM) objectives, *Lygus* spp. surveys and trap screening studies were initiated to develop a better monitoring strategy to assist in the timing of the cypermethrin applications. Results of our 1997 survey of 5 coast and interior reforestation nurseries positively identified 5 *Lygus* species on lodgepole pine or western redcedar seedlings: *L. shulli*, *L. hesperus*, *L. elisus*, *L. lineolaris*, and *L. robustus*. The composition of *Lygus* species varied with each location. Results from the trap color, size, and location trials suggested that *L. shulli*, *L. hesperus* and *L. elisus* were stimulated to land on traps reflecting yellow and blue wavelengths (540-560 nm and 480-490 nm). These 3 *Lygus* species could, therefore, be monitored effectively with the use of yellow or blue sticky traps. Three sizes of plastic traps were used (small, 12.7 by 19.1 cm; medium, 17.8 by 19.1 cm; large, 19.1 by 30.5 cm) and positioned at 2 heights (5 cm and 30 cm) above the seedling canopy. In general, small traps caught more *Lygus* per trap and per cm² than the medium or large traps. More *Lygus* per trap and per cm² were caught on traps positioned 5 cm above the canopy than 30 cm. The differences in *Lygus* catches between trap sizes and heights were, however, not statistically significant, suggesting that any of these trap sizes or heights could be used for monitoring *Lygus* bugs in commercial nurseries.

Nurseries are now incorporating this preliminary monitoring plan to better time their insecticide applications. Some are also monitoring the surrounding vegetation in an attempt to predict the arrival of *Lygus* bugs within the crop. If chosen, fringe monitoring should start when mean daily temperatures stay above 5 °C and continue until the flight peak of the first generation. More work needs to be done to better refine the monitoring program to link with seedling phenology and degree-day models.

ROOT WEEVILS

Several species of adult weevils have been confirmed or are suspected of girdling container stock, especially in greenhouses. Both the adults and larvae of root weevils can seriously damage seedlings, especially in coastal nurseries. The 2 most common species encountered in reforestation nurseries are the black vine weevil, *Otiorrhynchus sulcatus*, and the strawberry root weevil, *O. ovatus*. The adult weevils usually affect young 1+0 seedlings by girdling the stem in a 1-cm wide band, usually on the fleshy part of the hypocotyl. Seedlings at the edges of the greenhouses and ones on the outsides of the styroblocks are attacked most frequently. Usually only 1 seedling is girdled at a time. Adult root weevils are elusive, feeding at night and hiding during the day. As a result, populations usually go undetected until damage occurs. The larvae are of greater concern because 1 larva can consume almost all the roots of a seedling and may girdle the stem just below the groundline. Larvae are extremely difficult to control with pesticides and because of this weevil control is aimed at killing the adults. Monitoring programs such as weevil boards, bait stations, pitfall traps, indicator plants, and sticky traps have all been tried without success. Cumulative degree-day (CDD) models have proved to be better at predicting the presence of adults. Based on the CDD models, permethrin applications are carefully timed to reduce girdling and to control the bulk of the adult population after emergence but before egg laying commences.

Entomopathogenic nematodes have shown promise in controlling weevil infestation. Numerous studies have shown them to be very effective against weevil larvae, especially in greenhouse container environments. They can be applied through conventional spray equipment with little or no modifications. To ensure greater efficacy, certain environmental and cultural conditions must be maintained in the seedling cavities. The nematodes must be applied to warm (above 10 °C), moist soils, and they must not be exposed to ultraviolet light. Due to the low cavity volumes in our container system, irrigation or fertilizer events must be minimized to maximize the nematode retention time in the seedling plugs. To date, test trials have shown them to be most effective against the later instars of the root weevils. In contrast, they are ineffective against the pupae or adults. In all, this has allowed nursery managers to target 2 root weevil life stages, thus enhancing their management strategy.

FUNGUS GNATS

Larvae of fungus gnats, most commonly *Bradysia* spp., can be a problem in container nurseries where populations buildup rapidly under favorable conditions. Larvae infest containers with no apparent host preference, and they tend to feed on the upper roots. In heavier infestations, the larvae will strip the main roots and sometimes girdle entire stems. Adult fungus gnats are small (2.5 mm) dark colored, mosquito-like flies that are distinguished from shore flies by clear wings, long legs, and long, segmented antenna. Fungus gnats can complete their life cycles in about 3 weeks, so populations buildup quickly under favorable conditions. Though the adults themselves do not feed, they pose a threat of transmitting soil-borne and foliar pathogens, and, in high numbers, are a nuisance to nursery workers. The best form of control is sanitation. The flies are attracted to areas of moss and algae on the styroblock containers to lay their eggs. Good drainage, removing all puddles of water from the greenhouse floors, also helps. After the stock has been lifted the styroblocks should be washed and the greenhouses cleaned out and sanitized. Good cultural practices that produce vigorous healthy stock and proper irrigation to avoid overwatering will make the seedlings less attractive.

There are 2 biological control agents that are currently used for fungus gnat control. They are a soil-inhabiting mite, *Hypoaspis miles*, and entomopathogenic nematodes. The mite is a generalist predator that reproduces rapidly and moves well across soil, feeding on young stages of fungus gnats. This predator is well adapted to greenhouse environments and is most effective when used before fungus gnats become established or when the populations are low. Entomopathogenic nematodes are an alternative biological control strategy if fungus gnat populations are high. These beneficial nematodes, *Steinerinema* sp. and *Heterorhabditis* sp., do not attack the plants but actively seek out insect hosts. The juvenile nematodes, called infectives, enter the insect body and release bacteria that kill the host within 24 to 48 hours. After the nematodes have completed 1 or more generations, a new set of infectives emerges and begin the search for another insect host. The nematodes are effective at reducing high fungus gnat populations and can be used before the introduction of *H. miles*. The key to introducing these biological control agents for fungus gnat control is an effective monitoring program. Adult populations can be monitored using yellow sticky traps. Therefore, if fungus gnat adults are determined to be increasing, the modification of environmental conditions and supplemental applications of nematodes are effective in keeping fungus gnat populations in check.

As with all new initiatives in pest management, and in particular with biological control agents, care must be taken to understand all aspects of the control strategy to optimize its usefulness. The following should be integral components of any IPM program: (1) review traditional pesticide-use pattern, (2) choose an IPM strategy appropriate to the pest, (3) time the application of control strategies to coincide with the susceptible life stage of the target insect pest, (4) use appropriate rates, (5) monitor the efficacy of the strategy, and (6) experiment with monitoring methods to develop a knowledge base for your nursery site.

Pest management in conifer seedling nurseries is a relatively new field. As nurseries are becoming established in new areas and stock types change new insects are becoming pests. As pests are discovered they are identified, their biology investigated, and management programs are developed using all available tools. Control methods are demphasising the use of pesticides while monitoring techniques and cultural and physical controls are being enhanced.

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