# Integrated Pest Management In Canadian Forest Nurseries-Current Perspectives and Future Opportunities[1]

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**Abstract** - Concepts and practices of integrated pest management (IPM) from the applied perspective of the forest seedling grower in Canada are discussed. An overview of IPM in forest seedling production is provided; current status of IPM practices in Canada are outlined; and a continuing education opportunity for nursery professionals is introduced. Concepts, techniques and principles for planning, implementing and evaluating IPM programs are examined within the broader scope of Integrated Resource Management (IRM).

Integrated Pest Management (IPM) has been defined as: "...an approach to pest control that utilizes regular monitoring to determine if and when treatments are needed and employs physical, mechanical, cultural, biological and educational tactics to keep pest numbers low enough to prevent intolerable damage or annoyance. Least-toxic chemical controls are used as a last resort." (Oklowski et al.1991).

## REFORESTATION STOCK PRODUCTION

Nearly one million hectares of forest were harvested in Canada in 1990 (Anon. 1992a). During the period 1975-85 the area harvested increased from 680 to 900 thousand hectares, an increase of 32%. The percent of harvested area replanted increased from 19% in 1975 to 29% in 1985 (Kuhnke 1989). Despite these efforts, most provinces have a regeneration gap between the area harvested and the area regenerated either naturally or artificially.

Approximately 140 nurseries produce forest seedling planting stock in Canada. Container seedlings represent approximately 70% of total production, the remainder are bareroot seedlings (Canadian Forest Nursery Weed Management Association, unpubl. data). The proportion of seedlings produced in containers has increased dramatically from the approximately 17% of total production in 1975 (Kuhnke 1989).

Response to this increasing demand for planting stock is an increase in both absolute production and in production efficiency. To date, substantial increases in production efficiency are realized through refinement in cultural practices and reduction in losses, especially from pests. Economics of scale have increased efforts in this regard because of a diminishing cost per seeding to minimize pest losses. These forces influenced the relatively recent development of integrated pest management programs in seedling production throughout Canada and are responsible for regional differences in program development and practices. Accordingly, regions supporting the greatest demand for seedling production are often those with the most refined integrated pest management programs.

## INTEGRATED INSECT AND DISEASE MANAGEMENT

Concepts and practices of integrated pest management in forest seedling production have been discussed and reviewed elsewhere (Daar et al. 1992; Hamm et al. 1990; James et al. 1992; Krelle et al. 1992; Linderman and Hoefnagels 1992; Olkowski et al. 1991; Stein and Trummer 1992; Sutherland 1991; Sutherland et al. 1990).

Seedling stock production, from the perspective of functional ecosystem diversity, is highly prone to insect and disease outbreaks (Schmidt 1978). In an applied sense, this means pest damage can occur quickly over a large area. This damage can occur randomly throughout the crop, and if temporally segregated, be undetected and untreated until late in the rotation. If the damage is aggregated, both temporally and spatially, then therapy is

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often applied with the concern towards continuing potential damage. Both of these responses are biased towards perception. Considerations of real and potential pest impact are based on a growers experience and judgement. The same situation is often true for pest preventative measures. The expressed level of concern is often based on perceived pest impact.

The increasing complexity in practicing integrated pest management, along with the increasing scope of liabilities associated with these actions, requires an even greater precision in management decisions. Accordingly, decision support is identified as a high priority in recent national strategic directions (Anon. 1992b). Thompson et al. (1992) have designed a prototype of an expert system for diagnosis of forest seedling nursery insect, disease and abiotic problems. The cornerstone of decision support from an integrated nursery pest management perspective is information on the impacts of specific pests and management alternatives. Impact information includes prediction to evaluate possible outcomes. Conceptually, this is simple; what level of damage is related to what level of pest, at what time, under what conditions. The same conditional parameters also apply to questions regarding environmental impact and public safety (Scholtes 1991; Dumroese et al. 1991; Landis et al. 1991; O'Hara 1991). The most sophisticated or effective nursery pest management practice is limited by constraints in this information. These are the exact questions, however, a nursery manager or grower must consider during the planning process and when a problem becomes evident. The high research priority assigned to these questions is further indicative of both the need and lack of information specifically as it pertains to nursery pest management.

The next order of nursery pest management decision support is integrating all the mentioned information, if it existed, for all potential pests and management practices. This task is incumbent and performed by the seedling grower since the responsibility for nursery stock production is usually theirs. From this discussion, the question of what is the procedure for formulating integrated pest management decisions with the lack of information is obvious. The answer is also obvious, those who are responsible to make decisions do so through experience and supposition.

## An Ontario IPM example: Treating the symptoms, not the disease

Damping-off is considered a collection of diseases of similar symptomatology causing seedling losses during germination and early emergence. Many different species of fungi can be the causal agents, either independently or in combination. Disease losses are related to environmental conditions which retard germination and prolong early emergence. Traditional disease management included the coating or 'pelletizing' of powder formulations of fungicides, usually Captan or Thiram, to the seed coat prior to sowing. This practice was routinely followed because it was considered effective and did not harm the seed. The loss of these fungicides to the seedling grower, either through changes in use registration or regional restrictions, incited growers to rely more on the traditional practice of

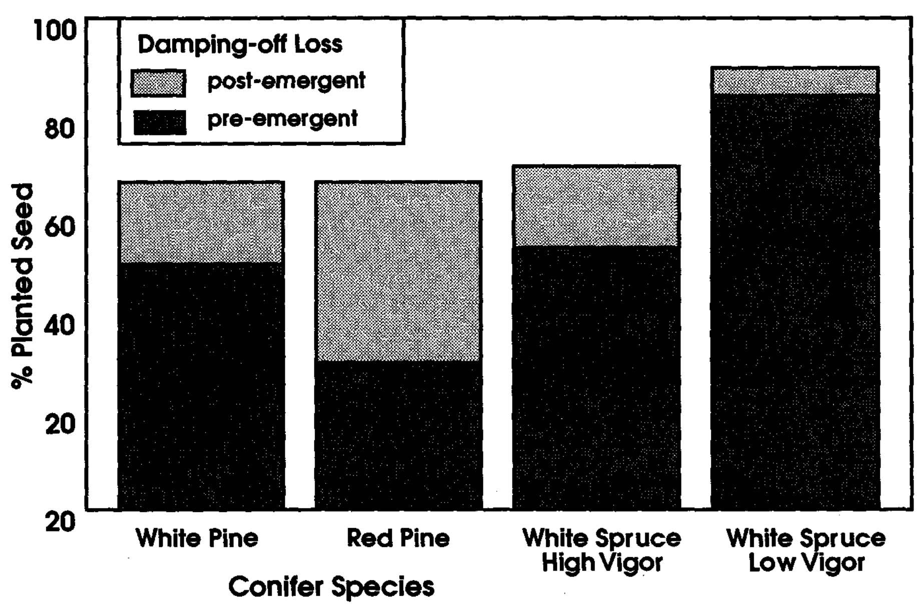


Figure 1 – Damping-off losses, Kemptville, Ontario, 1990

fungicide drenching of seed beds which is still in practice today.

In Ontario, many growers expressed concern regarding the lack of 'control' of damping-off losses, especially after drenching once mortality was observed. A request was made to search for 'newer' effective fungicides. Many assumptions of past management practices for damping-off needed to be reevaluated to effectively manage damping-off losses. Intensive monitoring of seed bed emergence and early growth demonstrated preemergence losses can account for over 80% (Fig. 1). Post-emergence damping-off was substantially less and appeared unrelated to pre-emergence losses. Traditional practices were mostly concerned with post-emergence losses. Pre-emergence losses were accounted for by high seeding density to ensure minimum numbers of seedlings. During growing seasons when damping-off losses were minimal seedling density was very high causing another order of disease problems from competition stress later in the life of the crop.

Information on the effectiveness of chemical control, nature of losses, and influence of the environment on disease biology provided for effective decisions in damping-off management. The basis for these strategies is, in a sense, biological control. Fungicides are no longer recommended, even if their use is registered, for social, environmental and biological reasons. Management efforts for damping-off are through promoting and maintaining seed quality as it pertains to germination vigour and contamination. It is recognized that damping-off losses are a direct function of the length of time that it takes for a seedling to become lignified. The quicker the germination and growth, the less likelihood of losses from damping-off. Disease management efforts involving methods of seed extraction, storage, handling, stratification, and precision sowing are successful in reducing losses from damping-off, and minimizing stress-related pests of older crops, and provide consistent crop production while virtually eliminating the use of traditional fungicide practices.

This example demonstrates the inter-relatedness of disease (and/or insect) problems and how a successful approach was achieved through applying the principles of IPM. Identification of the 'actual' problem regarding pest impacts was the first step in the decision process followed by 'treating' the disease through application of existing knowledge. This' win-win' example is very simple where the consequence of action is rarely with negative consequence or compromise. Root diseases in stock production, in contrast, often involve very complex interactions. Nevertheless, the same principles apply and information is critical to decisions in pest management.

## INTEGRATED WEED MANAGEMENT IWM

Traditionally, IPM has dealt with insects and diseases. As the literature on these topics is voluminous, and as IWM is a relatively new concept in the field of IPM, this section will deal with specific tactics and strategies of IWM.

Swanton and Weise (1991) defined integrated weed management (IWM) as the application of numerous alternative weed control measures, which include cultural, genetic, mechanical, biological and chemical means of weed control. An individual control measure will not provide acceptable levels of weed control, but if the various components of an IWM are implemented in a systematic manner, significant advances in weed control technology can be achieved.

Development of an IWM strategy starts with an examination of the crop cultural system. Nursery culture of bareroot seedlings begins with sowing in either late fall or spring into field beds. Seedlings will grow in the beds, with or without transplanting, for a total of one to four years, depending on species and location. The low end of this range would be for fast-growing hardwoods in warm parts of Canada; the high end of the range would be for conifers in more northerly nurseries. An alternative scheme is to start the seedlings as plugs in a greenhouse, and then transfer them to nursery beds to reach target size for outplanting. The cultural systems that have developed in particular areas have generally proven to be the length of time required to grow a tree with acceptable size (as measured by height and root collar diameter) and thus able to cope with competition after outplanting. Grower preference and nursery history also influence the type of stock grown in particular nurseries.

## Tillage system

Swanton and Weise (1991) give a strategy for the type and relative order of studies needed in the development of an IWM program. The place to begin to improve weed control in a crop is by re-examining tillage practices. The trend in agricultural production to reduced tillage systems cannot be applied to bareroot nursery culture. This perennial system is already no-till for all but one year of a crop growing cycle when a destructive tillage is unavoidable at the time of lifting.

## Critical period of weed interference

The second part of the Swanton and Weise (1991) plan is the study of critical period of weed interference. This was defined by Weaver and Tan (1983) as the specific minimum period of time during which the crop must be free of weeds in order to prevent yield loss (growth reduction). Its two components are the length of time weeds can remain in a crop before growth reduction begins, and the length of time that weed emergence must be prevented so that subsequent weed growth does not reduce crop yield (Weaver and Tan 1983). These components are experimentally determined by measuring crop yield loss as a function of successive times of weed removal or weed emergence, respectively (Weaver et al. 1992).

The traditional way to analyze critical period information has been to compare crop yields achieved after various periods of weed infestation or weed control through use of a multiple comparison procedure such as Duncan's New Multiple Range (DNMR) test or Student-Newman-Keuls (SNK), though such procedures were not suitable for structured data such as these (Warren 1986; Cousens 1988). Cousens (1988) recommended the use of regressions to describe the data.

Several mechanisms have been proposed for the basis of competition, as explanation for results observed in critical period studies. For example, interference with photosynthetic photon flux density (PPFD) interception has been implicated as the basis of weed competition. Weaver and Tan (1983) found that weed interference was primarily due to shading as opposed to water stress in transplanted tomatoes. Hall et al. (1992) found that increasing periods of weed interference achieved this effect by reducing the area of individual corn leaves, and by hastening the senescence of older leaves.

In forest nurseries, critical period information is useful because it tells us when to allocate limited budgets for costly inputs such as handweeding in order to maximize benefit. It is an important first step in developing an integrated weed management strategy.

## Alternative methods of weed control

The third part in the development of an IWM strategy as outlined by Swanton and Weise (1991) is the examination of alternative methods of weed control, including such things as cover crops, cultivation and biological control. All three have limited applicability to the nursery system. Juzwik and Testa (1991) found that the use of cover crops of alfalfa (Medicago sativa L. cv. Vernal) or Sudan grass (Sorghum bicolor (L.) Moench, cv. Green Leaf) led to increases in the levels of Cylindrocladium sp. in the soil. Cylindrocladium sp. is a damaging and persistent pathogen of spruce seedlings. The use of cover crops such as Sudan grass, oats (Avena sativa L.) beans (Phaseolus vulgaris L.) or peas (Pisum sativum L.) increased the population densities of Fusarium spp. and Pythium spp. when compared to bare fallow controls in a conifer nursery (Hansen et al. 1990). Both Fusarium and Pythium have been implicated as pathogens of conifer seedlings. Other cover crop species have had a neutral (spring wheat, Triticum aestivum L. cv. Glen Lea) or deleterious (flax, Linum usitatissimum L.) effect on Cylindrocladium populations (Juzwik and Testa 1991). Clearly the considerable danger of a wrong choice and the inconsistent weed control benefits (Moore 1992) associated with cover crops limit their usefulness in a forest nursery IWM strategy. Despite these problems, the use of companion crops has the potential to reduce the use of shades to provide protection from excessive sun and wind.

In the nursery system, a companion crop of spring wheat should be neutral to pathogens, and provided it is not allowed to grow too tall, should not interfere with PPFD interception any more than wooden shades. Root development of a spring wheat companion crop would be drastically reduced as a result of applications of chlorthal-dimethyl or napropamide. As nutrients are applied to the nursery crop at luxury levels, and water is applied through irrigation as required, a spring wheat companion crop should not compete with nursery stock. A spring wheat companion crop would result in substantial cost savings if the use of shades could be reduced.

Interrow and bed cultivation is already being practised in many Canadian nurseries, although there may be some room for improvements of equipment, timing and techniques. Problems of tight row spacing in the beds, shallow rooted crop plants, and the potential for interference with preemergence herbicides limit the usefulness of this technique to some extent.

Likewise, classical biological control is of very limited value because in the nursery system many weed species are present and interfering with nursery production. Inundative biological control (bioherbicides) may be useful but given the regulatory environment, these fall under the same restrictions as herbicides, and more data are required for registration of these products.

### Enhancement of crop competitiveness

Swanton and Weise (1991) suggest cultivar competitiveness, planting pattern and nutrient placement as methods to enhance crop competitiveness.

There are two factors limiting our ability to improve cultivar competitiveness:

1 In forestry in Canada, selection in most nursery crops is not being practised except to collect seed from sources that have consistently produced good seed in the past. This is changing as seed orchards come into production, but because of the long life cycle of forest trees, we will always lag behind agriculture in our ability to improve crop competitiveness through selection.

2 Unlike agricultural crops, the attributes that improve nursery competitiveness may not be the same attributes that are desirable in forest trees.

The goal of improving cultivar competitiveness is worthwhile, but a very long-term goal.

Improving planting pattern has already paid benefits in the nursery system. Precision vacuum seeders were first introduced to the nurseries over five years ago, and are now used for most crop seeding. These have improved crop competitiveness by increasing the uniformity of the stand, thereby reducing intraspecific competition and increasing the growth rate.

In theory, nutrient placement should offer benefits by making nutrients more available to the crop and less to the weeds. In reality, nutrients are applied to the seedlings at luxury levels to bring seedlings to target shipping size within a reasonable period of time. There may be benefits in the use of a nitrification inhibitor to keep applied nitrogen in the ammonium form, available to the gymnosperms, but not to weedy angiosperms. This would be an interesting study, that could potentially lead to better fertility management in the nurseries.

## MODELLING OF CROP-WEED INTERFACE

Using approaches such as the critical period of weed removal, and models of growth under competition or free of competition, we can understand the dynamic interaction between weeds and the nursery crop.

### Crop rotation and seed bank dynamics

Bazzaz (1979) defined succession as a process of continuous colonization of, and extinction on a site by species populations. Arable land is a special successional case, being characterized by regular, recurrent and often highly predictable disturbance (Bunting 1960). Froud-Williams (1988) stated that the composition and density of weed floras are, in general, a reflection of the crop production and agronomic practices employed. In agriculture, including nursery culture, weed populations can respond to changes in cultivation (Froud-Wiliams et al. 1983; Chancellor 1985), fertilization (Pysek and Leps 1991) or herbicide regime (Roberts and Neilson 1981; Mahn and Helmecke 1979). Understanding how nursery cultural practices influence weed communities will help us plan IWM strategies that do not create problems, such as when overuse of a preferred herbicide leads to problems with escapes of weeds that are tolerant of that herbicide. An example is triazine-resistant weed biotypes, a result of overuse of triazine herbicides such as prometryne and simazine.

## Current practices

Weed control in container production is achieved through use of weed free growing media, and sanitary measures such as controlling the weeds in the floors of greenhouses and cold frames, and in holding areas. In enclosed structures, filtering the air during times of much airborne seed reduces weed establishment. Handweeding is the major means of controlling weed escapes, with limited use of postemergence herbicides such as glyphosate. Preemergence herbicides such as napropamide are also used in some situations to prevent weed establishment in containers.

Weed control in bareroot production may begin after crop sowing but before seedling emergence with an application of a nonselective posternergence herbicide such as glyphosate to kill emerged weeds. This stale seedbed method is gaining acceptance because nurserymen have very few options for postemergence weed control in the established crop.

DCPA is applied at the time of sowing in conifers at some nurseries, because other registered herbicides are not tolerated then. Following the movement of the apical meristem away from the cotyledonary whorl (usually six to ten weeks after sowing), napropamide is well tolerated and can be applied. Simazine, napropamide or mixtures of these herbicides are used for seedbeds older than one year or for transplants. A registration for oxyfluorfen is being sought because the preemergence herbicides thus mentioned have serious gaps in weed control, and a problem with triazine resistance has been found at some nurseries. Directed applications of glyphosate are used in the growing crop, and handweeding and mechanical cultivation are also used. Applications of 2,4-D are tolerated by dormant conifers and are used for end of season control of broadleaf weeds. Fluazifop is registered for grass control and can be used at any time during the season. Conifers are generally shipped as 2-0 or 3-0 seedbed stock, or as 1-2, 2-1, or 2-2 transplants. There is a trend towards growing more transplants from greenhouse stock, with a G-1 or G-2 the final bareroot product.

Napropamide is usually applied before crop emergence in hardwoods and reapplied in the first season of growth. Simazine or napropamide or mixtures of the two are used on older hardwoods. Glyphosate is sometimes used prior to budburst in spring for early season weed control. Fluazifop, mechanical and handweeding are used in hardwoods as in conifers above. Hardwoods in Canada are generally shipped as 2-0 stock, except hybrid poplar and walnut, both of which are shipped as 1-0.

## CONTINUING EDUCATION

Research is only useful if it is accompanied by is a continuing education program to ensure adoption of new strategies and tactics by nursery growers. Precision in judgment by experienced nursery professionals can be enhanced by a strong continuing education program in IPM. The Department of Natural Resources through the Forest Pest Management Institute has addressed the issue of expert training in the IPM by spearheading the Advanced Forest Pest Management Training Program (AFPM), a series of courses in Forest Pest Management. The AFPM, through advanced courses directed towards experienced motivated individuals, provides detailed expert level training in forest pest management that is not within the scope of other continuing education opportunities for resource management professionals.

### Integrated Pest Management For Forest Nurseries Course

North America is endowed with a wealth of technical expertise in the field of integrated pest management for forest nurseries. Practical strategies and tactics are available for managing insects, diseases and competing vegetation in an integrated fashion, however often this knowledge is not effectively relayed to the operational nursery people. If nursery managers are to realize the goal of integrated pest management, it is essential that opportunities be created to allow these individuals to acquire expert training that presents multi-disciplinary information in a collated and practical manner.

The Integrated Pest Management Course For Forest Nurseries examines IPM for forest tree nurseries within the context of the following nursery goals:

1 produce high quality seedlings

2. produce needed seedling quantity
3. protect human health
4. protect environment
5. cost efficiency

In this course, pest refers to insects as well as diseases and competing vegetation. Control for some of the more common problems caused by abiotic (such as winter desiccation and heat damage) or cultural (such as fertilizer damage) factors are also discussed.

The course is presented in a ten day block. Education strategies such as lectures, group discussions, group projects, case studies, computer modeling sessions, field demonstrations and field trips are integrated in order to provide for different learning styles. New ideas and approaches are developed from featured evening speakers addressing forest pest management from a variety of perspectives.

The course is divided into main subject areas or modules. The modules are developed as intensive learning packages that bring together the best available technical information on the subject. A typical module features a teaching team of 3 to 6 instructors over a 1 to 3 day time period. The teaching teams ensure that their topics are not only well presented, but learned in an effective manner. Participants frequently add to the depth of the learning experience by bringing their expertise forward in discussion and lecture periods.

Each module is linked to the others so that lessons are integrated in an applied manner. By the end of the course, participants view pest populations, treatment options, prevention options, social and environmental concerns, and other factors, as a dynamic array of considerations that need to be incorporated into a successful integrated pest management strategy.

Participants are evaluated by completing a course practicum. A nursery compartment or greenhouse is assigned to small groups who are charged with developing pest management strategies and prescriptions that are rationalized in terms of cost-effectiveness, environmental consequences and social acceptability. This exercise is completed over the two week period of the course, and the result of each group's work is presented to a discriminating audience of instructors, other course participants and interested members of the public. Written records of these group practicums are expected to be of sufficient quality to eventually become published as case studies in Forest Pest Management Program Planning Guides, targeted at the hands on users in the forest pest management industry.

This course is targeted towards practicing nursery professionals. The basic requirement is extensive experience in forest tree nursery management.

A proposed course outline follows.

### *Module 1 - Introduction*

This module provides participants with a "short course" on IPM in forest nurseries. IPM is defined. The unique elements of the forest nursery environment such as proximity to agriculture and residential areas and IPM in enclosed spaces are outlined. A basic background in pesticides including minimum requirements for certification, human health concerns and occupational safety is provided. Entry points for pests on the nursery such as greenhouses, bare root fields, outside compounds, and cold storage facilities are identified. The relationship between nursery cultural treatments and pest incidence is introduced.

### *Module 2 - Common Insect Pests*

Common insect pests in the greenhouses, outdoor compounds, and bare root fields are discussed. Topics include detection, identification, life cycles, population inventories, monitoring systems and damage thresholds. Cultural, biological, and chemical control options are identified and discussed.

### *Module 3 - Nematodes and Common Disease Problems*

Nematodes and common diseases in the greenhouses, outdoor compounds, bare root fields, and cold storage facilities are discussed. Topics include detection, identification, life cycles, alternate hosts, monitoring systems, and damage thresholds. Cultural and chemical control options are identified and discussed.

### *Module 4 - Vegetation Management*

Common vegetation management problems in the greenhouses, outdoor compounds, and bare root fields are discussed. Topics include entry points for competing vegetation into the greenhouses, outdoor compounds, and bare root fields, and tolerance thresholds. Cultural, manual and chemical control options are identified and discussed.

### *Module 5 - Rodents, Birds and Small and Large Mammals*

Damage from rodents, small and large mammals, and birds are identified and described. Topics include identification of damage and how to make sure that damage is not caused by diseases or insects, tolerance thresholds and safety concerns. Options for control such as cultural and chemical control, deterrents and baits are identified and discussed.

### *Module 6 - Abiotic and Cultural Factors*

Common problems in the nursery that are often confused with insect or disease symptoms are described. Topics include winter desiccation, heat damage, frost and fertilizer damage.

### *Module 7 - Response of Pests to Nursery Cultural Treatments*

This module explores the relationship between nursery cultural treatments and pest incidence. Often cultural treatments to enhance growth, hardening off etc. are responsible for increasing pest problems in the nursery. Topics include fertilization, transplanting, root culturing, dormancy induction treatments, and cold storage.

### *Module 8 - Economics*

This module explores economic inventory and cost/benefit models in relation to IPM in forest nurseries. Topics include assessment of the economic value of the goods and services supplied by the forest tree nursery, and assessment of the costs and benefits of various control options.

### *Module 9 - Management Strategies for Making Appropriate Decisions*

This module will integrate the previous 7 modules in terms of decision making strategies. How a manager decides if a pest needs to be controlled, when to take action and what methods to use are discussed. The four features of effective pest management (clear goals, a planned decision-making process, realistic damage thresholds, and a choice of responses) are examined. Decision support and expert systems are introduced as tools for decision making strategies. Topics include developing an IPM plan for each pest, monitoring and analyzing pest situations, analyzing available control options to determine their impact on control options for other pests, evaluating treatment effectiveness and getting along with the neighbours and communications.

### *Practicum*

The information presented in each of the modules will be integrated by completing the course practicum where participants will be given a greenhouse, nursery compartment, or outdoor compound to apply the information presented in the course. By the end of the course, participants will have fully evaluated the options for managing forest pests on that site.

For additional information on AFPM and suggestions for the Integrated Pest Management for Forest Nurseries Course, feel free to contact Eileen Harvey at the Forest Pest Management Institute (705-949-9461). This course is very much in the development stage and any input will be gratefully accepted.

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