DISEASES AND INSECTS AND THEIR MANAGEMENT

IN CONTAINER NURSERIES

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Abstract.--This paper reviews the major non-pathological and pathological diseases (gray mold, storage mold, *Sirococcus* blight) and insects in container nurseries, especially in British Columbia, and relates their incidence, damage and management to hosts, production and cultural practices. Emphasis is on preventive control via manipulation of cultural practices rather than on eradication of established pests by means of pesticides.

Résumé.--Cette communication passe en revue les principales affections pathologiques ou non pathologiques (moisissure grise, moisissure des plants en stockage, brûlure des pousses) et les principaux insectes relevés dans les pépinières de plants en mottes emballées, particulièrement en Colombie-Britannique. Elle établit le rapport entre l'incidence de ces agents, leur dégâts, leur répression et le rendement de leurs hôtes et les techniques culturales y applicables. L'accent est mis sur la lutte préventive par la modification des techniques culturales plutôt que sur l'élimination des colonies de ravageurs au moyen d'insecticides.

INTRODUCTION

Because of the comparatively long history of producing container-grown seedlings in British Columbia (B.C.), the important, and potentially important, diseases and insect pests have been identified and management practices have been developed (Sutherland and Van Eerden 1980). Management practices have been modified and improved as more becomes known about the pests, their hosts and the container-nursery environment. To date, most of the pests recorded locally on container seedlings had previously been reported from bare-root nurseries. However, their relative incidence has differed in that shoot diseases are much more important in container than in bare-root nurseries, where soil-borne root diseases and damping-off predominate. The lesson here is that changes in seedling growing practices may simply alter the relative importance of certain pests rather than eliminate them. Moreover, as container nursery practices change, so will the kinds and importance of pests and pest management strategies.

In B.C. nurseries, the policy is one of pest prevention rather than eradication of established problems. A vital component of this approach is the pest diagnosis and control recommendation service that the Canadian Forestry Service provides for the B.C. Ministry of Forests (BCMF) and forest industry nurseries throughout the province. This service has been provided since the inception of container nursery production; hence, records for several years are available on pest incidence, damage, identity and the relative success of various control practices. These data serve as the basis for this paper, which has the dual purpose of describing disease and insect problems, and their management, in B.C. container nurseries and of relating the incidence of these pests to certain cultural practices and production changes. This approach will benefit managers of existing container facilities and help

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others to anticipate potential pests in recently established or planned nurseries.

SEEDLING PRODUCTION AND PRACTICES

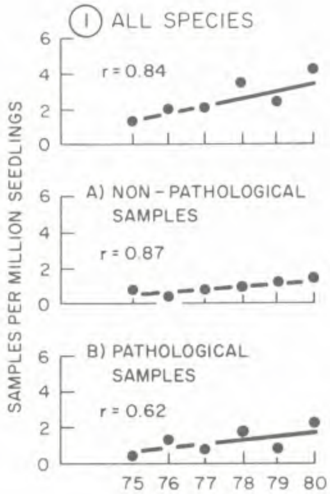
Following research and development of the container concept in the 1960s, BCMF began producing container stock on an operational basis early in the 1970s (Bamford 1974). Production has been limited almost exclusively to conifers and, until 1980, almost all stock was grown by BCMF. From an initial production in 1970 of approximately 750,000 seedlings, consisting of about equal amounts of the coastal form (Hosie 1979) of Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) and western hemlock *(Tsuga heterophylla* [Raf.] Sarg.), production has increased steadily to 37.5 million seedlings in 1980. Production then was made up of about 35% Interior spruce, i.e., white spruce *(Picea glauca* [Moench] Voss) or Engelmann spruce *(Picea engelmannii* Parry) or their hybrids, 23% lodgepole pine *(Pinus contorta* Dougl.), 21% western hemlock, 5.3% coastal Douglas-fir, 3.5% western red cedar *(Thuja plicata* Donn), 3.1% Interior Douglas-fir, 3% Sitka spruce *(Picea sitchensis* [Bong.] Carr.), 1.6% each of mountain hemlock *(Tsuga mertensiana* [Bong.] Carr.) and western larch *(Larix occidentalis* Nutt.), 1% total for Ponderosa pine *(Pinus ponderosa* Laws.) and yellow cypress *(Chamaecyparis nootkatensis* [D. Don] Spach) and 1.4% total for the firs *Abies amabilis* (Dougl.) Forbes, *A. grandis* (Dougl.) Lindl., *A. lasiocarpa* (Hook.) Nutt. and *A. procera* Rehd. Although seedling species are designated according to provenance (Dobbs et al. 1976), it is not uncommon for Interior tree species, especially spruces and Douglas-fir, to be grown in coastal nurseries, but the reverse is seldom practised. Experience suggests that nursery location and pest presence, rather than tree provenance, dictate disease and insect incidence. Smyth (1980) gives the localities, production capacities, tree species grown and other characteristics of B.C. container nurseries and Sjoberg and Matthews (1977) have updated the types of growing facilities and cultural practices employed.

TYPES OF PESTS

Because few pests have been recorded in British Columbia on seedlings of species other than Douglas-fir, lodgepole pine, spruces (aLl species) and western hemlock, and because records are most complete for the 1975-1980 period, the remainder of this paper deals only with seedlings of the abovementioned species over those six years. Figure 1 shows that total pest (non-pathological [abiotic, physiological or noninfectious] plus pathological [biotic or infectious] diseases plus insects) samples per million seedlings produced increased at a constant rate between 1975 and 1980. The trend was similar for non-pathological and pathological samples (Fig. 1A and 1B); numbers of insect samples received over the six years were too few and too inconsistent for any trend to be detected. When the total numbers of pest samples over the 1975-1980 period were partitioned according to seedling species (Fig. 2-5), the data showed that numbers of samples increased sharply for Douglas-fir but less so for lodgepole pine and spruces, and remained fairly constant for western hemlock. The increases for Douglas-fir and lodgepole pine were attributable to increases in non-pathological and pathological disease samples (Fig. 2A and 2B, 3A and 3B), while the increasing numbers of spruce samples were only for pathological diseases (Fig. 4A and 4B), particularly *Sirococcus* blight *(Sirococcus strobilinus* Preuss). Like the overall trend for western hemlock (Fig. 5), neither non-pathological nor pathological samples increased (Fig. 5A and 5B) between 1975 and 1980.

Figure 6 summarizes the numbers and nature of pest samples for the four major kinds of seedlings grown from 1975 to 1980. On a per capita basis, non-pathological and pathological samples were most numerous for Douglas-fir and about equal on lodgepole pine and western hemlock, while pathological problems were most prevalent on spruces. Fertilizer burn of shoots (usually attributable to nitrogen) is the most frequent non-pathological problem on all seedling species, but it seldom causes much direct damage; probably its greatest significance is in predisposing seedlings to gray mold *(Botrytis cinerea* [Fries] Persoon). Fertilizer burn usually results from failure to wash off fertilizers which are applied through overhead irrigation systems or as granular top dressings. Sometimes excessive amounts of fertilizers are applied accidentally and they cause root or shoot killing, or both.

To date, only fungi have been implicated in pathogen-caused diseases of container seedlings. Shoot diseases and, in particular, gray mold and *Sirococcus* blight , are by far the most significant. Gray mold affects all seedlings in the nursery and during storage (designated storage mold), while spruces, lodgepole pine and, infrequently, western hemlock, but never Douglas-fir, are affected by *Sirococcus* (Fig. 6). The most common insects encountered include root/vine weevils, cutworms and shoot- or root-feeding aphids (Sutherland and Van Eerden 1980).



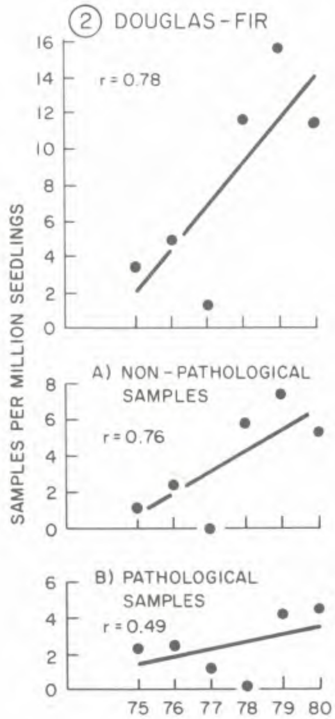
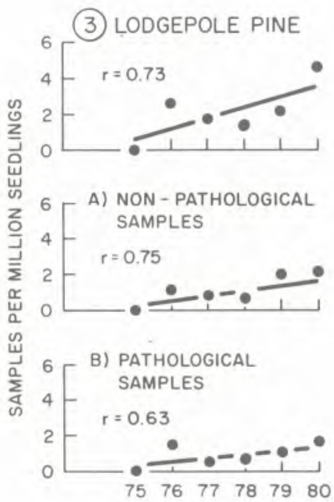
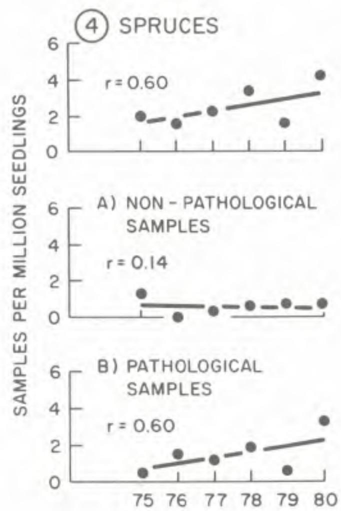
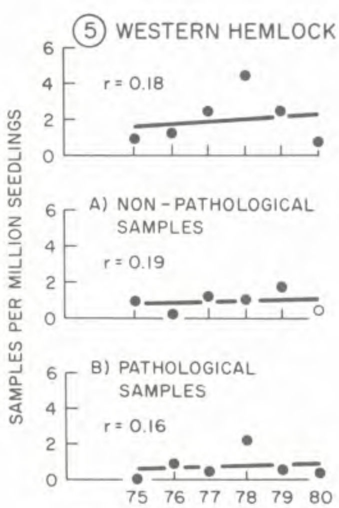


Figure 1. Total, and non-pathological (1A) and pathological (1B) disease samples received (1975-1980) per million seedlings of the four major species (Douglas-fir, lodgepole pine, spruces and western hemlock) produced in B.C. container nurseries; insect samples were insignificant and are not included.

Figures 2-5. Total, and non-pathological (sections A) and pathological (sections B) samples received (1975-1980) per million seedlings of Douglas-fir (Fig. 2), lodgepole pine (Fig. 3), spruces (Fig. 4) and western hemlock (Fig. 5) produced in B.C. container nurseries; insect samples were insignificant and are not included.







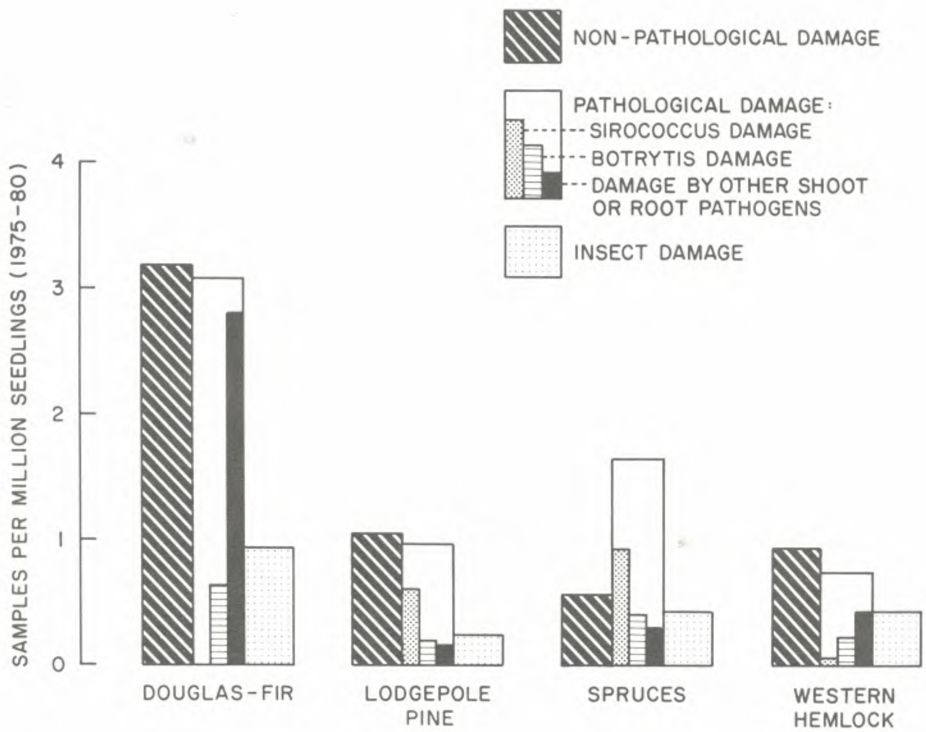


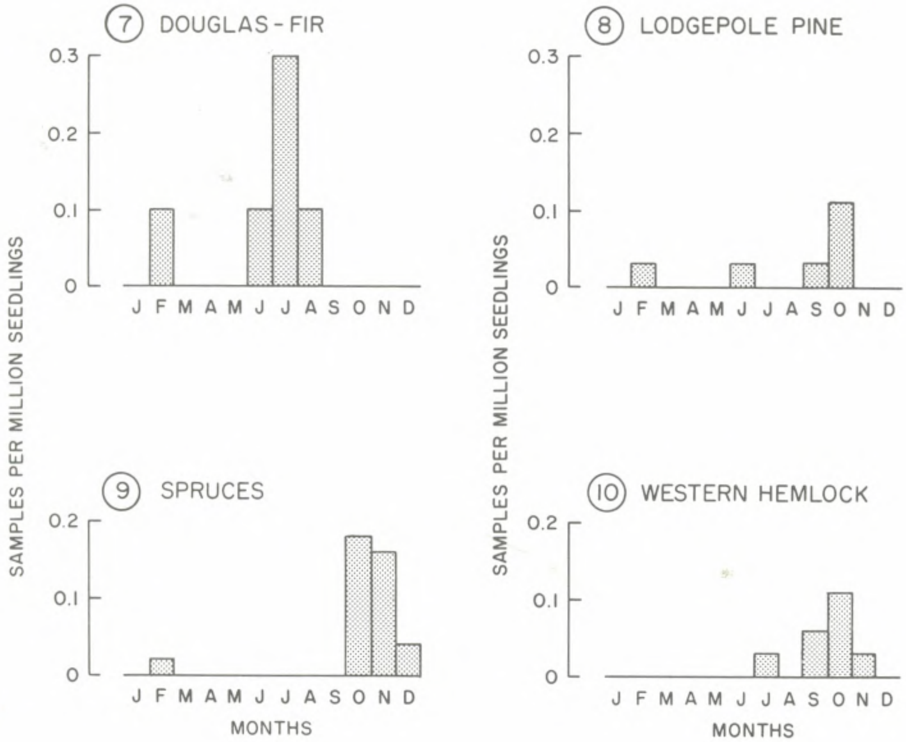
Figure 6. Summary of non-pathological and pathological diseases and insect samples received (1975-1980) per million Douglas-fir, lodgepole pine, spruces and western hemlock seedlings produced; pathological diseases are denoted as gray mold, *Sirococcus* blight and other shoot diseases; other insignificant diseases are not shown.

Gray Mold and Storage Mold

On container-grown seedlings, both diseases are caused by the fungus *Botrytis cinerea.* Gray mold affects seedlings during nursery growth, while storage mold damages them in storage. Frequently, storage mold is a further development of incipient gray mold carried over from the nursery. Damage from both diseases is apparently confined to seedling shoots.

Gray mold: the pathogen and disease

The ubiquitous fungus *B. cinerea* normally lives on dead organic matter, but it can, under certain circumstances, attack living plants. This is how it operates in container nurseries, where it first becomes established on dead (e.g., fertilizer burned) or senescent needles and then spreads to living tissues. Following infection, the pathogen may remain latent until conditions favor disease development. Damage usually occurs from mid- to late summer onward after the seedling canopy has closed. This, plus the weather, provides a combination of conditions favoring the problem: i.e., poor air circulation and high humidity, cooler temperatures, shading and dying of lower needles. In B.C., Douglas-fir and western hemlock are more likely to be affected by gray mold (i.e., *B. cinerea)* infection during the April through August growing season than are lodgepole pine and spruces (Fig. 7-10). Initial symptoms include a watery molding and killing of lower or fertilizer-burned needles which spreads upward, killing needles and woody portions of the shoot. Grayish brown webs of the pathogen's vegetative growth and spores are often present on affected seedlings. Initially, the disease occurs on individual seedlings and spreads to form patches of diseased seedlings, which often coalesce. Spread occurs via vegetative growth of the pathogen or by the massive numbers of air-borne spores. Although the complete life cycle of the pathogen, particularly its method of overwintering, is not known for container nurseries, the pathogen is probably reintroduced annually as air-borne spores from outside the container nursery. Most seedling species are susceptible to gray mold, but the disease seems to be less damaging to species such as pines, whose upright growth habit probably



Figures 7-10. Samples per million seedlings produced of *Botrytis* affected Douglas-fir (Fig. 7), lodgepole pine (Fig. 8), spruces (Fig. 9) and western hemlock (Fig. 10) received (1975-1980) per month.

creates a less favorable microclimate for the pathogen.

Gray mold: management

Because there are no practical methods for excluding spores of the pathogen from container nurseries, management recommendations are based, where practical, on making the nursery environment less favorable for gray mold and applying fungicides to prevent, rather than eradicate, the disease. Cultural practices that should be employed from late summer onward include increasing spacing between containers, improving air circulation and decreasing irrigation--all of which help to reduce •relative humidity--and perhaps increasing temperatures in cool greenhouses. Fertilizer-burned or frost-damaged stock should be monitored closely for gray mold development. Sanitation procedures include removal and destruction of plant debris and diseased plants upon which the fungus sporulates. One or more applications of a protective or systemic fungicide prior to canopy closing should be useful. Another option is the application of alternate sprays of protective and systemic fungicides or of one or two sprays of a systemic fungicide prior to or during the high danger period. Continuous use of a single fungicide, particularly certain systemics, is not recommended, since tolerant strains of *B. cinerea* may develop (Cooley 1981, Hopkins 1980). Even when two or more materials are used in rotation, checks should be made to determine if *B. cinerea* tolerance has developed. Often the quantity of fungicide(s) used can be minimized by applying the materials only to those areas in which disease is evident. Fungicides alone will never give satisfactory control unless used in conjunction with cultural controls (Cooley 1981). Reduction in fungicide use can often be achieved by ensuring that application equipment is as efficient as possible. Obtaining good control of gray mold by combined cultural practices and minimal fungicide use is becoming increasingly necessary, since outplanting crews may be reluctant to handle fungicide-treated seedlings.

Storage mold: the pathogen and disease

Experience in B.C. shows that *B. cinerea* is the sole fungus responsible for molding of stored container stock (Hopkins 1980). Storage mold (September through February) of Douglas-fir and western hemlock, but not spruces and lodgepole pine, seems to be preceded by detectable gray mold in the nursery (Fig. 7-10). Perhaps storage mold of seedlings of the latter two species is simply not a carry-over problem from the nursery, or perhaps *B. cinerea* from the nursery remains latent and undetectable until the stock is stored. Storage mold of Douglas-fir and western hemlock in particular (Fig. 7 and 10) is simply a further development of an already existing, but often undetected, gray mold problem. Seedlings damaged by fertilizer burn, frost or other physiological disorders which create food bases for the pathogen, are especially prone to storage mold. As expected, storage mold symptoms and hosts affected are much the same as for gray mold in the nursery, but seedlings of species that can be stored frozen usually suffer less than seedlings of species such as western hemlock that do not withstand subfreezing storage temperatures.

Storage mold: management

Preventing gray mold outbreaks and incipient disease in the nursery, which will be carried over to storage, is the best approach to reducing storage mold losses. The following procedures are also recommended: store stock, particularly fertilizer-burned or frost-damaged seedlings, for the shortest period possible; avoid storing wet stock; store stock at as low a temperature as it will withstand, even -1 or -2 C if possible; inspect stock frequently; try to outplant stock with incipient mold and ensure that stock is "hardened off" before storing. Also, one or more applications of systemic fungicide late in the growing season may be worthwhile.

Sirococcus Blight

The pathogen and disease

The fungus *Sirococcus strobilinus* causes a shoot blight of conifers in nurseries and juvenile stands throughout the North Temperate Zone of North America and Europe. Incidence of *Sirococcus* blight on *Picea* spp. in B.C. increased steadily (Fig. 11) between 1975 and 1980, paralleling the increased spruce production. Recent studies (Sutherland *et* al. 1980) showed that the fungus can be seed-borne on interior and Sitka spruce container seedlings in B.C. Quite likely it is seed-borne elsewhere, since it has been recorded on cones in the Prairie Provinces and New Brunswick. Besides spruces, other hosts such as lodgepole and Ponderosa pines and, rarely, western hemlock may be affected, but evidence indicates that the pathogen is not seed-borne on them.

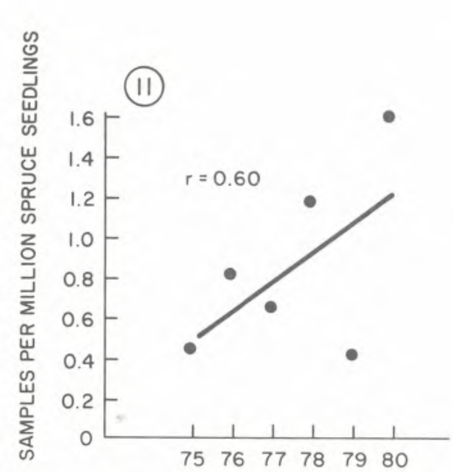
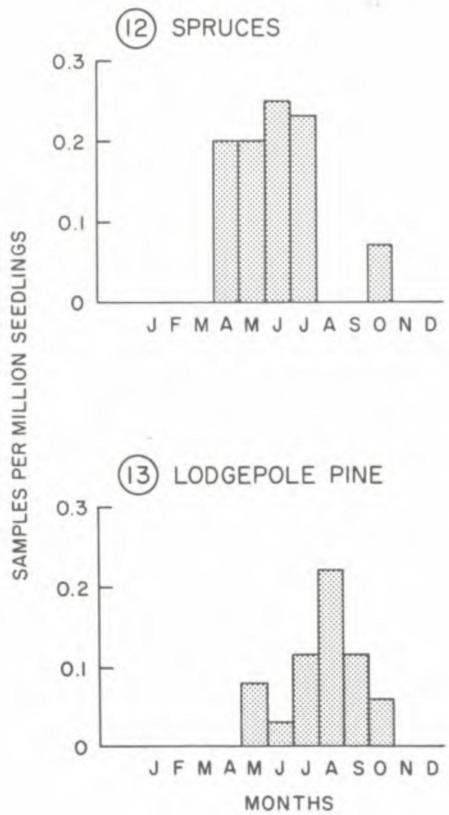


Figure 11. Samples, per million seedlings produced, of spruces affected by *Sirococcus* blight.

Inoculation of seedlings of these species occurs via water or rain-splashed spores originating from seed-borne diseased spruces or diseased trees adjacent to the nursery. Regardless of the primary source of the pathogen, spores for subsequent spread originate from diseased nursery seedlings of any species. On container-grown spruce, symptoms usually appear first on randomly distributed germinants between the period before seedcoat shed through to secondary needle appearance and leader development (Fig. 12). On species such as lodgepole pine (Fig. 13), where the inoculum is apparently not seed-borne, damage tends to appear after secondary needles have developed. When seed-borne, the disease is distinctly noticeable on specific spruce seedlots. Characteristically, the disease kills needles from the base upward and moves up the epicotyl. Small, irregularly shaped, light tan to dark spore-producing bodies (pycnidia) form on killed tissues. Diseased needles are light to reddish brown, desiccated rather than decayed, and killed seedlings remain upright.

Management

At present, most seeds are collected from wild trees; hence, there are no practical methods for reducing or preventing infection of seeds, i.e., seed-borne inoculum, but the incidence of *Sirococcus* blight should diminish as disease-free seeds produced in seed orchards come on stream. Meanwhile, nursery managers should be alerted before sowing seedlots with blight histories so that remedial practices, such as roguing diseased seedlings and applying protective fungicides,



Figures 12 and 13. Monthly incidences (samples received) of *Sirococcus* blight from 1975-1980 on spruces (Fig. 12) and lodgepole pine seedlings (Fig. 13).

can be taken at first appearance of the disease. Confining infested seedlots to a specific nursery area may help prevent disease spread, and removal of diseased trees or application of fungicides to diseased trees adjacent to the nursery would be beneficial. Other recommendations include, where practical, reducing relative humidity, increasing the temperature in cool greenhouses, and supplying supplemental light during periods of excessive cloudiness.

Insects

Kinds and damage

There are many incidental insects such as defoliators that are wind-blown or otherwise invade container nurseries from nearby forests or agricultural areas. Frequently neither the container nursery environment nor the food sources are suitable for the invaders and minimal seedling damage results. Occasionally, container seedlings are damaged by insects that are host specific on forest trees or on young plants, or both. Examples (Sutherland and Van Eerden 1980) include cutworms, spider mites, numerous aphids and root and vine weevils. Since most container nurseries produce only one crop per year, these pests must re-invade the nursery annually. Some insects thrive in container nurseries, where conditions such as high temperatures (autumn through spring) may shorten generation time, decrease overwintering mortality or allow overwintering of life stages advantageous to population increases during the growing season. In B.C., root and vine weevil larvae are among the most prevalent, destructive and difficult to control. They consume seedling roots and can migrate through styroblocks to reach seedlings in adjacent cavities. These pests also have been reported from container nurseries in Ontario and New Brunswick.

Insect problems that have been experienced across Canada are outlined briefly on the next page. To date, no insect damage has been noted on stored container stock.

Management

The rapid and often erratic population buildup of many insects in container nurseries hinders implementation of preventive measures. However, devices such as pheromones, light traps and sticky traps for detecting adults of certain pest insects are becoming commonplace. Ordinarily, it is easier to detect and control adults (which often do little damage) than larvae, particularly larvae that inhabit or hide in the container growing medium. Control of these larvae, especially with insecticide drenches, is further complicated by the short efficacy period and poor ability of most insecticides to penetrate the container growing medium. Standard insecticide sprays or sometimes insecticidal soaps are routinely employed against foliage insects such as aphids. Insect-proofing and pre-sowing fumigation and sanitation of greenhouses and other growing areas should be standard practices. Cull piles and the like that harbor insects should be eliminated. Insecticidal baits are often effective against container nursery insects; their application can be restricted to specific areas where damage occurs or to refuges around the nursery.

Insect	Type of damage	Hosts
Various defoliators	Consume foliage	Numerous
Aphids	Cause chlorosis and unthriftiness	Numerous, often host specific
Cutworms	Clip off and consume very young seedlings	Many
Root/vine weevils	Consume roots	Numerous

DISCUSSION

Experience in B.C. shows that the total number of pest samples (non-pathological and pathological disease plus insects) of container-grown Douglas-fir, lodgepole pine, spruces and western hemlock received by the Canadian Forestry Service increased steadily between 1975 and 1980 (Fig. 1). We strongly suspect that the corresponding increases in seedling production alone were only marginally responsible for the larger numbers of pest samples. Undoubtedly other more important factors were: (i) increased staff awareness of pests resulting from training sessions emphasizing pest identification and abatement, especially preventive practices and control at incipient stages, and (ii) increased production of certain seedling species such as spruces that are more affected by host-specific pests. The best support for these hypotheses is that while pest reports increased per million seedlings produced from 1975 to 1980, no major disease or insect losses were recorded. Incidence of non-pathological diseases (section A of Fig. 2-5 and Fig. 6) such as fertilizer burn should decrease as nursery staff gain more experience with the nutrient requirements and toxicity tolerances of specific seedling species. The use of medium-incorporated, encapsulated fertilizers may also help to reduce the incidence of foliage damage.

Ideal conditions such as crowding, high humidity and shading of lower needles certainly account for the high incidence of shoot diseases, particularly gray mold, in container nurseries. This disease is the greatest threat in B.C. and the major problem in the Maritimes (R.D. Hallett, personal communication) and United States container nurseries (Tinus and McDonald 1979). It seems to be of less concern in Alberta and Ontario, perhaps because seedlings there are outplanted before reaching the canopy-closing stage. If the need arose for larger seedlings or for storing stock, or both, gray mold and storage mold could become more troublesome in these localities.

ACKNOWLEDGMENT

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LITERATURE CITED

Bamford, A.H.
1974. Development of the British Columbia container program. p. 53-60 *in* R.W. Tinus, W.I. Stein, and W.E. Balmer, Ed. Proceedings of the North American Containerized Forest Tree Seedling Symposium. Great Plains Agric. Counc. Publ. No. 68.

Cooley, S.J.
1981. Fungicide tolerance of *Botrytis cinerea* from conifer seedlings. USDA For. Serv., For. Pest Manage., Reg. 6, Portland, Oreg., 13 p.

Dobbs, R.D., Edwards, D.G.W., Konishi, J. and Wallinger, D.
1976. Guideline to collecting cones of B.C. conifers. B.C. Min. For./Can. For. Serv., Victoria, B.C. Jt. Rep. No. 3. 98 p.

Hopkins, J.C.
1980. Storage moulding. (Abstr.) Proc. West. For. Conf., Victoria, B.C.

Hosie, R.C.
1979. Native trees of Canada. Dep. Environ., Can. For. Serv., Ottawa, Ont. 380 p.

Sjoberg, N.E. and Matthews, R.G.
1977. Small containers used in forestry may provide breakthrough for ornamental industry. Am. Nurseryman 145(11):12-13; 55-59.

Smyth, J.H.
1980. A directory of forest tree nurseries in Canada. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Report 0-X-305. 51 p. + Appendix.

Sutherland, J.R., Lock, W. and Farris, S.H.
1980. *Sirococcus* blight: a seed-borne disease of container-grown spruce seedlings in coastal British Columbia forest nurseries. Can. J. Bot. 59:559-562.

Sutherland, J.R. and Van Eerden, E.
1980. Diseases and insect pests in British Columbia forest nurseries. B.C. Min. For./Can. For. Serv., Victoria, B.C. Jt. Rep. No. 12. 55 p.

Tinus, R.W. and McDonald, S.E.
1979. How to grow tree seedlings in containers in greenhouses. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. Gen. Tech. Rep. RM-60. 256 p.