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# CULTURE PRACTICE AND DISEASES OF FINNISH FOREST NURSERIES

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## ABSTRACT

In Finnish forest nurseries, 99% of seedlings of Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and European silver birch (*Betula pendula*) are grown in containers in plastic-covered greenhouses. The main diseases of conifer seedlings are Scleroderris canker (*Gremmeniella abietina*), snow blights (*Herpotrichia juniperi* and *Phacidium infestans*) and needle casts (*Lophodermium seditiosum* and *Meria laricis*). Recently, Scleroderris canker has become a problem in Norway spruce, the most common species produced by Finnish nurseries since 2000. Root dieback (uninucleate *Rhizoctonia* sp.) in container-grown spruce and pine was a problem in the 1990s. Today, the disease has become less common in modern nurseries due to improvements in hygiene and cultivation practice. Birch stem lesions (*Phytophthora cactorum*) and birch rust (*Melampsoridium betulinum*) have also been a problem, but are among the diseases successfully controlled with intergrated pest management. Seedlings stored over winter must be routinely sprayed in order to combat grey mould (*Botrytis cinerea*). Fungal pathogens can also infect seedlings undergoing short-day (SD) treatments necessary for summer or autumn plantings and prior to freezing. Nurserymen are encouraged to use cultural and integrated pest management techniques that focus on improved hygiene such as hot water washing of containers, work surfaces and tools, as well as removing plant debris and diseased seedlings and trees around the nursery.

## INTRODUCTION

Fifty percent of the Finnish tree flora is Scots pine (*Pinus sylvestris.*), 30% is Norway spruce (*Picea abies*), and several (mostly *Betula* spp.) broad-leaved species represent the rest (Finnish Statistical Yearbook of forestry 2008). However, in contrast to these proportions, most seedlings delivered from nurseries to reforestation sites in 2007 were of Norway spruce (66%; 168 million), followed by Scots pine (31%), silver birch (*Betula pendula*) (2%), downy birch (*B. pubescens*) (0.02%) and other tree species (0. 98%), the most important of which were Siberian larch (*Larix sibirica*), lodgepole pine (*Pinus contorta*), Carelian curly birch (*B. pendula* var. *carelica* ) and black spruce (*Picea mariana*). Most diseases known to cause problems in forestry species are fungal. In container production, the use of constant-temperature greenhouses, selected seed, pathogen-free growth medium, and carefully controlled irrigation and fertilization results in good seedling growth but may also provide ideal conditions for many biotic or abiotic diseases. Modern nurseries must optimize culture conditions to maximize seedling production while minimizing the risk of a disease outbreak. In addition to culture conditions, abiotic stress caused by environmental conditions, e.g., frost, or injury can also expose rapidly growing seedlings to fungal attack. In this article we give a short introduction on container tree nursery management, major diseases in Finland and collate the results on recent studies on pathogens.

## SEEDLING PROPAGATION AND NURSERIES

99% of seedlings are grown in containers, germinated in greenhouses and later transferred outdoors (Finnish Statistical Yearbook of Forestry 2008). Modern container trays are composed of hard plastic cells with air slits at regular intervals on the sides to stimulate natural air pruning of roots around the periphery of the root plug. Most seedlings are cultured in densities of 400-900 $m^{-2}$ (conifers) or 150-400 $m^{-2}$ (hardwoods), depending on seedling size and age. Container cells are filled with medium-texture, low-humified Sphagnum peat that is often supplemented with dolomite lime and a base fertilizer. Seeds are sown with an automatic seeder and growth medium covered with a thin mulch of vermiculate, sand or sawdust. The pH of the growth medium is 4.5-5.1 (Rikala and Heiskanen 1995). Fertilizers are provided as fertigation according to the electrical conductivity press-water extracts from the growth medium (0.8-1.5 mS $cm^{-1}$) depending on the seedling developmental stage (Juntunen and Rikala 2001) and watered with mobile irrigation booms or fixed overhead sprinklers (Tervo 1999, Poteri 2003), according to container weight (peat moisture between 40-50%; V/V). The first crop of one-year-old Norway spruce seedlings is started in heated greenhouses under photoperiodic lighting in March or April and moved outdoors three months later. The second crop (two-year-old seedlings) is kept inside until the beginning of October and then moved outdoors where they remain for winter and the second growing season. Scots pine seedlings are sown in May and seedlings remain in the greenhouse until July when they are moved to a hardening site. Birch seedlings are cultured similar to the one-year-old Norway spruce crop.

Seedlings to be planted in late summer or autumn are normally short-day (SD) treated to speed the hardening process and improve the extent to which they withstand autumn frosts (Kohmann and Johnsen 2007, Luoranen and others 2007). Seedlings stored in freezer storage or outdoors might also benefit from SD-treatment by extending the storage window and/or avoiding irrigation during frost. The 2-3 week treatment consists of placing the seedlings behind blackout curtain to shorten the photoperiod to 12-14 h from 16-20 h during the growing season. Treatments are conducted from late June to the beginning of August depending on planting time and the photoperiod adjustment takes into account the seedling origin.

Approximately half of the seedlings to be delivered in spring are removed from containers in the autumn and packed in cardboard boxes. Pallets of stacked boxes are often wrapped with a thin plastic sheet to protect seedlings from drying and are stored at -1 to -4 °C for 6-7 months. The other seedlings are left to overwinter outdoors where snow cover may be thin or even absent during some winters in southern Finland. Because snow cover provides seedlings with some protection, some nurseries use snow machines to supplement the snowpack. By storing seedlings in freezers, risks related to outdoor storage are avoided and the nursery and forester enjoy greater flexibility in delivery time in spring.

## DISEASES

### Scleroderris canker

Recently, a new type of disease similar to Scleroderris canker, caused by *Gremmeniella abietina*, was found on nursery grown Norway spruce seedlings in Norway and Finland (Børja and others 2006, Petäistö 2008). Symptoms were similar to those observed on Scots pine; infected needles browned from the base and eventually dropped from the seedling. Necrotic lesions were also present on Norway spruce shoots (Børja and others 2006). In inoculation trials, Norway spruce needles first began browning in the mid section of the shoot, whereas in pine browning began from the top of the shoot (Petäistö 2008). The top needles of Scots pine are typically arranged in an umbrella-like form (Poteri 2008). During their first growing season, Scots pine seedlings are most susceptible to infection when buds are forming (Petäistö 1999). Second-year seedlings, however, have a higher infection risk during the period of active shoot growth (Petäistö and Laine 1999). Similarly, the vulnerable period on spruce begins later in first-year seedlings than in second-year seedlings (Petäistö 2008). During humid conditions, a peak in conidiospore release has been noted in June-July, although conidiospores may be present in the air throughout the summer months (Petäistö and Heinonen 2003).

Winter storage temperatures also influence infection rate in Scots pine seedlings; those overwintering at -7 °C and -3 °C were more diseased than those kept at 0 °C (Petäistö and Laine 1999). Seedlings stored at lower temperatures broke bud later than those kept warmer, suggesting that a physiological factor related to growth initiation may increase vulnerability (Petäistö and Laine 1999).

Infected seedlings usually appear green and healthy immediately after the snow has melted. Development of symptoms depends on weather conditions and may take a number of weeks to manifest. Control of Scleroderris canker requires repeated spray application of propiconazole (250 g/L), a triazole fungicide that has protective, curative and systemic activity. An alternative treatment is to use a mixture of prochloraz (400 g/L) and propiconazole (90 g/L).

### Snow blights

Snow blights of conifers are caused mainly by *Phacidium infestans* and *Herpotrichia juniperi*. The black snow mold (*H. juniperi*) infects Norway spruce and junipers (*Juniperus* spp.), whereas *P. infestans* can infect conifers generally (Björkman 1948, Kujala 1950, Roll-Hansen 1987) and especially *Pinus* in northern parts of Europe and Asia where snow cover is deep and prolonged. Recent studies of Finnish nurseries and inoculation trials suggest that *P. infestans* also infects container seedlings of Norway spruce (Petäistö and Hantula 2009). Needles infected by *P. infestans* become yellow to red-brown following snow melt, whereas *H. juniperi* is characterized by a dark mycelium that covers and binds needles and shoots together.

Snow blights can cause considerable damage on overwintered plants in northern latitudes and at high altitudes in the south where there is sufficient snow cover during winter (Jamalainen 1956a,b, 1961). However, Petäistö and Hantula (2009) suggested that *P. infestans* was not dependent on snow cover and seedlings stored in freezers were also vulnerable to infection. Furthermore, *H. juniperi* infections in Estonia have been recorded up to a height of three meters in Norway spruce in dense forest stands during moist winter conditions where only a few inches of snow covered the ground (Hanso and Tõrva 1975).

Effective control of snow blights in nurseries requires spraying with fungicides such as propiconazole (250 g/L) or a mixture of prochloraz (400 g/L) and propiconazole (90 g/L). Seedlings overwintered outdoors should be sprayed as late as possible in the autumn before the formation of permanent snow cover. As the onset of winter can be unpredictable, treatment may have to be repeated several times.

**Needle casts**

Needle casts caused by *Lophodermium seditiosum* and *Meria laricis* are problematic on nursery seedlings of Scots pine and Siberian larch, respectively. Both diseases are widely distributed throughout Europe and cause discoloration and browning of needles that later fall from the tree. However, seedlings infected with *L. seditiosum* may go undetected as they can appear healthy when planted in the early spring. Typically, infected seedlings do not survive planting stress (Lilja 1986) so there is a need to identify latent infections in material stored below 0 °C prior to planting.

*L. seditiosum* preferentially infects green primary and secondary first-year needles via ascospores (Lazarev 1981, Minter 1981a, b). Infection with *M. laricis* occurs during the early part of the growth period in spring while succulent foliage is present on second year seedlings. Both pathogens overwinter in fallen needles. Since infections occur during wet periods, seedlings can escape infection if dry conditions prevail during spore release. The ascocarps of *L. seditiosum* open during wet periods between June and October (Hanso 1968, Kurkela 1979). In Finland, the only registered chemical for control of needle casts is azoxystrobin (250g/L), a wide spectrum fungicide based on naturally occurring substances found in certain species of wild mushrooms.

**Root dieback**

Typical symptoms for root dieback disease are stunted growth of shoots and roots and the patchy occurrence of diseased plants (Venn and others 1986, Lilja 1994, Børja and others2006, Hietala 1995, 1997). The fungal root flora of seedlings suffering from root dieback includes at a minimum, species of *Pythium* and uninucleate *Rhizoctonia* (Galaaen and Venn 1979, Unestam and others 1989, Lilja and others 1992, Lilja 1994). In inoculation experiments, both uninucleate *Rhizoctonia* sp. and *Pythium* spp. caused damping off-like disease on seedlings younger than 5-6 weeks in which the root system is still only sparsely developed. In older seedlings only *Rhizoctonia* sp. spreads throughout the root system where hyphae can be observed on the surface of lateral root tips and inside cortical cells in the main root (Hietala 1995, 1997).

It has been hypothesized that root dieback is a disease of successive infections. Infection with uninucleate *Rhizoctonia* sp. is often initially detected with wet growth medium, because the infected seedlings cannot fully utilize the irrigation water. Wet conditions promote secondary attack by *Pythium* spp. or other saprophytic species (Unestam and others 1989, Lilja 1994).

Seedlings occasionally suffer root dieback without conspicuous symptoms, especially when infected with uninucleate *Rhizoctonia* sp. but without any secondary infection. Seedlings in this category are shorter than disease-free stock but otherwise appear healthy. Infected seedlings should always be culled since they either suffer increased mortality or reduced growth rates after outplanting (Lilja and Rikala 2000). Today it is possible to detect the disease in planting material using a DNA based test. One benefit of this test is its higher sensitivity compared to traditional isolation (Hantula and others 2002).

Root dieback has become less common in modern nurseries due to improvements in hygiene (Iivonen and others 1996, Kohmann and Børja 2002), cultivation practice and targeted treatments, i.e., immersion in 80 °C water baths for 1 minute kills *Rhizoctonia* sclerotia (Iivonen and others 1996). One of the most important factors in modern cultivation practice is that containers are supported on racks during the growing season, which improves ventilation and drainage and thus prevents waterlogging of roots; a problem known to increase the incidence of root dieback (Venn and others 1986, Unestam and others 1989, Lilja and others 1998).

**Stem lesions and top dying of birch**

In Finland, necrotic stem lesions and top dying have been a severe problem in container-grown silver birch seedlings (Lilja and others 1996, Juntunen 2000). In 1991, *Phytophthora cactorum* was isolated from lesions and inoculations resulted in symptoms identical to those seen on birch seedlings in nurseries (Lilja and others 1996, Hantula and others 1997, 2000). Symptoms caused by *P. cactorum* vary according to seedling development. Following heavy rains in late June, the first lesions often appear and seedlings can suffer top dying. Seedlings infected at an early or succulent stage often die. When the bark is more suberized, lesions are more often born at the base of stems where moisture collects and a wetter microhabitat can persist. Older infected seedlings either die or snap depending on the place of the lesion. Snapped seedlings can develop a new leader or produce a new shoot from the base because the pathogen does not infect roots (Lilja and others 1996, 2007).

Because *P. cactorum* can overwinter in organic material, nursery hygiene such as removing diseased, zoospore-producing seedlings and plant debris has proven effective in the control of stem lesion. It is also important to keep the microclimate within birch seedling stands as dry and well ventilated as possible. *P. cactorum* is capable of infecting seedlings through intact bark, although disease severity was generally higher in seedlings in which inoculations were made on leaf scars (Lilja and others 1996, 2007). Thus, even small wounds can increase the risk of stem lesions. A systemic fungicide fosetyl-aluminium (800g /L) is authorized for the chemical control of this pathogen.

**Birch rust**

Birch rust is caused by *Melampsoridium betulinum* and manifests as yellow urediniospores in late summer on the undersides of leaves of *Betula* spp. Poteri (1992) has suggested that *M. betulinum* has two *formae speciales*. When urediniospores collected from silver birch (*B. pendula*) and downy birch (*B. pubescens*) were used in cross-inoculation trials, downy birch showed partial resistance to silver birch rust in the form of necrotic lesions at infection sites and reduced production of new urediniospores. In contrast, downy birch rust was equally virulent in both birch species and no hypersensitivity reactions were found even though several different clones of silver birch were tested (Poteri 1992, Poteri and Ryynänen 1994). Scanning electron microscopy of appressoria formation, location and penetration of stomata failed to recognize any of these factors as the basis for resistance (Poteri and Ryynänen 1994). Silver birch clones were found to have different resistance to silver birch rust, and clones grown at low nitrogen levels were more resistant than those grown at higher levels (Poteri and Rousi 1996). Intensive culture (high seedling densities and high nitrogen supply) create wetter conditions on leaf surfaces that favor urediniospore germination (Sharp and others 1958).

*M. betulinum* is capable of overwintering in buds or fallen leaves as uredinial mycelium (Liro 1906) or as urediniospores (Dooley 1984). The epidemic phase of *M. betulinium* often starts in late June. It is necessary to control birch rust in nurseries because of growth reduction and high mortality after outplanting (Lilja 1973). Two mixtures are used for rust control: trifloxystrobin (187.5 g/L) and propiconazole (125 g/L), or trifloxystrobin (125 g/L) and propiconazole (125 g/L).

**Grey mold**

Grey mold is caused by *Botrytis cinerea* and often occurs on young seedlings when humidity is high (Sutherland and Davis 1991). Low light intensity coupled with environmental stress (e.g., 30-40 °C or prolonged drought) might also be an important predisposing factor (Zhang and Sutton 1994, Zhang and others 1995). It can also develop after damage by frost, fertilizers or herbicides (Sutherland and Davis 1991) and during seedling storage. While a short-day treatment is necessary for summer and autumn plantings and beneficial prior to freezer storage, reduced photosynthesis, increased respiration and humid conditions within the blackout curtains can weaken seedlings and encourage fungal infections, e.g., *B. cinerea*. Risks associated with high humidity and carbohydrate depletion are also high when seedlings are packed into closed boxes for storing and transportation. Venn (1981) isolated *B. cinerea* from moldy needles of bare-rooted Norway spruce seedlings in cold storage. Infections were common in the lower, shaded branches and were probably initiated in seedling beds (Venn 1979). Petäistö (2006) also found *B. cinerea* to be an important fungal pathogen during freezer storage, where an infection spread readily from diseased seedlings to healthy ones inside cardboard boxes during thawing.

Cultural pest management techniques together with chemical control are needed to avoid losses caused by grey mold. The microclimate within the canopy should be kept as dry and well aerated as possible by regulating the seedling density, irrigation and ventilation of nursery greenhouses (Mittail and others 1987). Irrigation in the morning ensures rapid drying of foliage during the day and it has also been recommended to brush seedling tops with plastic pipe or a wooden dowel after irrigation to dislodge water droplets and encourage drying (James and others 1995). There are situations, however, when fungicide treatment of *B. cinera* is needed, e. g., packing of seedlings into tight boxes and during winter storage (Venn 1979, Petäistö 2006). A number of fungicides are used for the control of grey mold. Today three products having iprodione (750 g/L) or thiophanate-methyl (700 g/L) as their active ingredient and are authorized for use in this respect.

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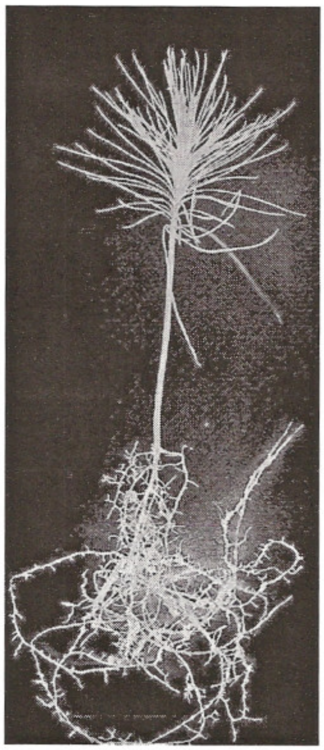
# Proceedings of the 7th Meeting of IUFRO Working Party 7.03.04 Diseases and Insects in Forest Nurseries



2010

# Proceedings of the Seventh Meeting of IUFRO Working Party 7.03.04

## Diseases and Insects in Forest Nurseries

Hilo, Hawai'i USA
July 13 to 17, 2009

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Forestry Service, Southern Region
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