Root Pruning of Bareroot White Spruce Planting Stock Does Not Affect Growth or Survival After Six Years

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Pruning roots of bareroot white spruce planting stock to as short as 10 cm before planting had no effect on survival. Effects of pruning on growth were small in the first year after planting and had diminished 5 and 6 years later. Tree Planters' Notes *43(1):4-6; 1992.*

Many bareroot nurseries endeavor to produce planting stock with compact, readily plantable root systems using nursery bed root-culturing treatments such as undercutting, root wrenching, and lateral root cutting (Daniels and Simpson 1990). Even with root culturing, however, long lateral roots often grow within the drill rows. Seedlings with long roots are more difficult to plant and may be more prone to root deformation.

It is therefore common practice after lifting to prune the roots of bareroot seedlings. Root pruning may remove many root tips, thus reducing root fibrosity; in some cases it can result in reduced root growth potential (Simpson unpublished data). As well, seedling root-to-shoot ratios are decreased by pruning. These factors are usually associated with decreased stock quality and field performance.

This experiment was undertaken to determine if root pruning bareroot white spruce planting stock would affect survival and growth after outplanting.

Methods

In mid-June 1985, two types of white spruce planting stock were taken from cold storage (- *2 °C)* and used in this experiment. Plug-transplant stock had been raised in 1983 as 1 + 0 container-grown stock at Ruff's Greenhouses, Prince George, BC, then stored overwinter (- *2 °C)* and transplanted in the spring of 1984 in the bareroot nursery beds of Industrial Forestry Service Ltd.'s Ness Lake nursery near Prince George, BC. These seedlings were lifted from the nursery bed in October 1984, packaged, and stored. Conventional 2 + 0 bareroot white spruce seedlings were produced at the British Columbia Forest Service Surrey Nursery near Vancouver, BC; they were sown in spring 1983 and lifted to storage in December 1984.

The planting stock, although stored frozen (- 2 °C) for most of the winter, was thawed (to + 2 °C) almost 3 weeks before planting. One day before planting, 625 seedlings of each stock type were divided into 5 groups of 125 seedlings and randomly assigned to one of five treatments. Root pruning to 25, 20, 15, or 10 cm below the root collar was done on bundles of seedlings using a sharp meat cleaver. A control group was left unpruned. Thus, the trees with the least amount of roots left were those in the 10 cm group. This method of pruning is common in bareroot nurseries and although some variation in root length results, root drying, which might occur if roots were individually pruned, is reduced.

The seedlings were outplanted on a vegetation-free site, formerly the Northwood Pulp and Timber Co.'s Willow Canyon bareroot nursery, 20 km east of Prince George. The soil throughout the planting site is a deep sandy loam. Moisture stress during the growing season is uncommon at this site because it receives ample precipitation during the growing season. The June-September average for 1950-1980 was 254 mm (10 inches).

The seedlings were outplanted in a randomized block design with five blocks. Within each block, each treatment was outplanted as a row of 25 seedlings. The spacing between rows was 2 m while spacing between seedlings within rows was 1 m.

Terminal shoot growth of each seedling was measured at the end of the first growing (FY GRO) season, and the total height of each plant was measured after the seedlings had 5 (YR 5 HT) and 6 (YR 6 HT) field growing seasons. Terminal shoot growth in the 6th growing season (YR 6 GRO) was determined by subtracting YR 5 HT from YR 6 HT. As the amount of growth can be affected by the size of the trees, the relative shoot growth (RS GRO) in the 6th year from planting was determined as (1/YR 6 HT) x (YR 6 HT - YR 5 HT) x 100% = RS GRO.

Growth data for each stock type were subjected to a one-way analysis of variance (ANOVA on file with author) and where treatment effects were significant differences between means were tested using Duncan's multiple range test (a = 0.05).

Results

Pruning roots of plug-transplant or conventional 2+0 bareroot white spruce seedlings had no effect on survival 6 years after outplanting (table 1). First growing season shoot growth of both stock types was significantly ($P <_ 0.05$) affected by root pruning such that growth was reduced the most in the most severe treatments (table 1). Although the treatment effects were statistically significant, the greatest treatment differences were in fact rather small (1.4 cm for plug-transplant and 0.6 cm for 2 + 0 bareroot).

Total seedling height after 5 and 6 growing seasons from planting as well as actual and relative (percent) terminal shoot growth in the 6th growing season was slightly but not statistically significantly affected by the most severe root pruning of either stock types.

It is clear, for these field conditions at least, that apart from a slight reduction of first-year shoot extension, pruning of white spruce bareroot planting stock (plug-transplant or traditional 2 + 0) has no effect on growth of seedlings for at least 6 years from planting.

Discussion

Root pruning plug-transplant or 2 + 0 bareroot white spruce planting stock even to what seems an extreme degree (10 cm below the root collar) has a very minor effect on field performance. The small, albeit statistically significant, reduction in first field season shoot growth due to root pruning is unlikely to be of practical significance. It is clear that, at least under the field conditions experienced in this experiment, the pruned root systems of plug-transplant or bareroot white spruce were able to provide sufficient moisture during the early growing seasons so that mortality did not occur and growth was only slightly impaired. In a similar study with Douglas-fir (Hermann and Lavender 1976), root pruning of 2 + 0 and 2 + 1 bareroot stock to as short as 12.5 cm did not affect survival on "favorable sites"; however, on "moderate" and "severe" sites, root pruning the smaller 2 + 0 stock reduced survival. It is unclear what the results of the present experiment might have shown had the outplanting environment been more stressful. Planted spruce seedlings are known to regenerate adventitious roots (Coutts et al. 1990), which might replace lost nursery roots and thus minimize the potentially adverse effects of root pruning. Blake (1983) found that pruning to reduce root area by as much as 75% had no effect on measured root area after 6 weeks of growth. Thus in his experiment, root pruning prior to planting substantially stimulated new growth such that no effects on water relations or drought resistance were evident.

Application

White spruce bareroot (2 + 0 or plug-transplant) planting stock can be root pruned to facilitate easier planting without adversely affecting short-term field performance on moist planting sites. Longer term effects of root pruning on root form and tree stability of white spruce as well as interactions) between root pruning and planting site stresses will require further consideration.

Table 1—*Effects of root pruning on growth and survival of white spruce*

Depth of root pruning (cm)	FY GRO (cm)	YR 6 GRO (cm)	YR 5 HT (cm)	YR 6 HT (cm)	RS GRO (%)	YR 6 Survival (%)
Plug transplant						
Control	6.4 a	10.2	73.6	83.8	14.4	99
25	6.5 a	8.5	74.4	82.9	11.8	98
20	6.1 a	9.5	73.3	82.7	13.3	98
15	5.6 b	9.8	72.5	82.3	13.6	98
10	5.1 c	9.2	69.6	78.8	13.5	96
Bareroot						
Control	3.7 a	10.0	68.4	78.4	14.8	96
25	3.4 ab	8.8	65.5	74.3	13.8	98
20	3.2 b	8.2	66.5	74.8	13.4	93
15	3.2 b	8.4	66.0	74.4	13.6	97
10	3.1 b	8.1	65.3	73.4	13.5	92

Means followed by the same letter(s) are not significantly different ($P \leq 0.05$). FY GRO = first year's growth, YR 6 GRO = terminal shoot growth in year 6, YR 5 HT & YR 6 HT = total height growth after 5 and 6 years, RS GRO = relative shoot growth in year 6.

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Triadimefon on Controls White Pine Blister Rust on Sugar Pine in a Greenhouse Test

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Seven systemic fungicides were applied to sugar pine (Pinus lambertiana Dougl.) seedlings, as foliar sprays, to determine their efficacy against white pine blister rust-the major limiting factor in regenerating sugar pine. Benodanil and triadimefon showed strong protection after the initial inoculation, with triadimefon showing residual protection for up to 6 months. This protection was verified by a followup test. Tree Planters' Notes 43(1):7-10;1992.

Sugar pine *(Pinus lambertiana* Dougl.) is one of the most important and valuable timber species in California. However, it is highly susceptible to white pine blister rust, caused by *Cronartium ribicola* J. C. Fisch. in Rabenh. Since its introduction into the Pacific Northwest in 1910, white pine blister rust has become the major limiting factor in the natural and artificial regeneration of sugar pine. Seedlings and young saplings (figure 1) are most susceptible to lethal infection, especially when environmental conditions favor disease development.

A systemic fungicide effective against *C. ribicola* could be a useful tool in the management of young sugar pine plantations and could possibly be used in combination with cultural methods, such as pruning. The potential for fungicide use has been demonstrated in another host-pathogen system. In the southeastern United States, fusiform rust *(Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. fusi*forme) is* a serious disease in southern pine nurseries (Kelley 1978b, Mexal and Snow 1978). Use of systemic fungicides has been effective in controlling this disease (Kelley 1978a & b, Kelley and Williams 1985, Mexal and Snow 1978, Rowan 1982 & 1984).

This paper reports the results of a greenhouse test of seven fungicides applied as foliar sprays to sugar pine seedlings to determine their efficacy against *C. ribicola.* The test was conducted at the Institute of Forest Genetics, Pacific Southwest Research Station, USDA Forest Service, Placerville, California.

Figure 1—*Sugar pine sapling showing aecial infection and pycnial scarring from white pine blister rust.*

Methods

After 90 days of cold stratification (Schopmeyer 1974), seeds from an open-pollinated sugar pine parent known to be susceptible to white pine blister rust were sown (September 1984) into a peat-vermiculite mix (Redi-Gro Corporation, Sacramento, California) in Leach Super Cells (Ray Leach "ConeTainer" Nursery, Canby, Oregon) in a greenhouse. Seedlings subsequently were transferred to a lath-house to overwinter and, in April 1985, returned to the greenhouse under a 16-hour photoperiod regime to encourage secondary needle production. In July 1985 they were returned to the lath-house for 3 months, whereupon 400 healthy seedlings were

selected and divided into eight groups of 50 for treatment.

Seven fungicides were selected for testing: benodanil (MF-654), diniconazole (Spotless®), myclobutanil (Systhane®), oxycarboxin (Plantvax®), propiconazole (Tilt®), triadimefon (Bayleton®), and triforine (Funginex®). These products were selected for their systemic action and efficacy against rust fungi. Formulations and application rates are listed (table 1). All fungicide applications were made on the same day (October 1985), using a .7-liter (3-pint) hand-held garden sprayer with the nozzle adjusted to deliver a heavy mist; the single application was applied to runoff for each fungicide. Although several techniques have been used to apply fungicides for control of fusiform rust (Kelley 1978a, Kelley and Williams 1985, Rowan 1982 & 1984), a foliar application is the most practical for use against *C. ribicola* in the field (especially on young seedlings) and was our choice for this test. After treatment, seedlings remained in the lath-house, under ambient conditions and overhead irrigation, until inoculation.

The experimental design for the inoculation was a complete block consisting of seven treatments (fungicides) plus an untreated control, with 50 replicates in single tree plots. Seedlings were randomly arranged into 50 replicates of 8 seedlings each (1 seedling from each treatment per replication). Five containment racks were required to hold the seedlings.

Three weeks after treatment, the seedlings were inoculated with *C. ribicola* using procedures already described (Kinloch and Comstock 1980). Briefly, teliabearing European black currant (*Rites nigrum* L.) leaves were suspended over the seedlings in a moist inoculation/incubation chamber for 48 hours. One inoculation was required to expose the five racks of seedlings to *C. ribicola*. Temperature in the chamber ranged from 20 to 25.5 °C (68 to 78 °F) with relative humidity ranging between 98 and 100%. Inoculum density, measured by five glass slide traps, was 98 ± 48 basidiospores/mm^2. The target spore density desired to attain full inoculation, based on prior experience, was 100 spores/ mm^2. Spore traps were located within each rack of seedlings (1 trap per rack, each trap covering an area equivalent to that of 3 seedlings); spore trap locations were randomly assigned. After inoculation, the seedlings were returned to the lath-house for overwintering.

In February 1986 the seedlings were brought back into the greenhouse to expedite development and expression of the disease. In March 1986, seedlings were scored for severity of infection. Seedlings were examined for needle symptoms, yellow or red needle spots (susceptible response), and necrotic needle flecks (resistant response) (Kinloch and Comstock 1980). Absence of needle symptoms was used as an indicator of fungicidal effectiveness. Because seedlings escaping fungal penetration and those lacking symptoms due to fungicidal efficacy are indistinguishable from each other, the control seedlings provided us with an estimate of the proportion of escapes that might have occurred within the treatments.

Results

Of the seven treatment groups, only triadimefon treated and benodanil-treated seedlings did not develop detectable needle symptoms (table 2). The remaining treated seedlings, with the exception of those treated with myclobutonil, expressed needle symptoms comparable to or greater than the control group. Although the myclobutanil treatment had fewer infected seedlings than did the control group, we attributed that result to seedlings escaping fungal penetration, not effectiveness of the fungicide. Regardless, 25 seedlings without symptoms out of 48 (23 infected) was not considered adequate protection in this test. Escapes for the benodanil and

Table 1—*Fungicide formulations and application rates tested*

Active ingredient	Trade name	Rate/gallon
Triadimefon	Bayleton 50W	.08 oz
Propiconazole	Tilt 1.1E	.16 oz*
Benodanil	MF-654 50W	.32 oz
Myclobutanil	Systhane 40W	.12 oz
Oxycarboxin	Plantvax 75W	.24 oz
Triforine	Funginex 18.2E	.16 oz*
Diniconazole	Spotless 12.5W	.08 oz

All fungicides were applied once as a foliar spray.
*In liquid ounces; other measurements in dry weights.

Table 2—*Infected seedlings by treatment group (seedlings were inoculated 3 weeks after fungicide application)*

Treatment	No. of seedlings	No. Infected	% Infected
Control	50	38	76
Triadimefon	50	0	0
Propiconazole	50	48	96
Benodanil	50	0	0
Myclobutanil	48*	23	48
Oxycarboxin	50	34	68
Triforine	50	38	76
Diniconazole	50	39	78

*Two seedlings died before evaluation from causes other than rust.

triadimefon treatments were not determinable because of the efficacy of the fungicides; it is highly unlikely that all 50 seedlings in both of these treatment groups escaped fungal penetration, considering the random placement of seedlings within racks.

Rechallenge. To determine residual potential, we rechallenged the seedlings treated with triadimefon and benodanil. Two seedlings, one from each treatment, died from causes other than rust before the second inoculation.

Seedlings were reinoculated in April 1986, nearly 6 months after the initial challenge, using procedures previously described. Spore trap counts were 189 ± 72 basidiospores/mm^2. All of the control seedlings (12 control seedlings without symptoms from the first inoculation plus 13 residual seedlings from the original sowing) and 88% of the seedlings receiving an initial treatment with benodanil became infected (table 3). The six benodanil-treated seedlings not infected may have been escapes. The one triadimefon-treated seedling that became infected did not express any needle symptoms but did develop stem symptoms in spring 1987 (see below).

One year after the initial application of fungicide, in October 1986, 23 triadimefon-treated seedlings, 6 benodanil-treated seedlings, and 4 controls (residual stock for the original sowing) were inoculated a third time (second rechallenge). Spore trap counts were 272 ± 85 basidiospores per square millimeter. Three triadimefon-treated seedlings died after the second inoculation from causes other than rust; the remaining 23 seedlings were withheld from the third inoculation to serve as checks against latent infection from the second inoculation. Residual activity was greatly reduced compared with the protection observed following the second inoculation at 6 months (table 3). All of the controls and benodanil-treated seedlings developed needle infections, as did most of the triadimefon-treated seedlings (the 5 seedlings not infected may have been escapes). One of the withheld checks developed stem symptoms from the second inoculation, and two died from causes other than rust. The remaining 20 seedlings did not develop any rust symptoms. The results indicate residual activity of triadimefon protects sugar pine seedlings from *C. ribicola* for up to 6 months after treatment.

Verification of test results. To verify our findings, another test was conducted in 1987. Forty-nine triadimefon-treated seedlings were paired with 49 untreated controls; all seedlings were from the same open-pollinated source used in our initial test. Sowing, treatment, and inoculation procedures followed those previously described. The first inoculation was in December 1987 followed by a rechallenge 6 months later in May 1988. Spore trap counts were 202 ± 50 and 279 ± 57 basidiospores/mm^2, respectively. Results of the 1987 test were very similar to those from 1985 (table 4). One change from our original procedure was to withhold 10 seedlings from the second inoculation to be examined for latent symptom development. None of these seedlings developed stem symptoms by the time of their final evaluation, nearly 9 months after inoculation.

Discussion and Conclusion

Important considerations in the selection of any pesticide are timing of application and resulting efficacy. Treatment effectiveness is enhanced by extended residual activity, which minimizes the need for application to coincide with pest exposure.

Triadimefon and benodanil showed promising protection against white pine blister rust, and triadimefon demonstrated apparent residual activity, lasting at least 6 months. Although these results need to be verified under field conditions, our tests indicated a strong potential for protecting young sugar pine

Table 3—*Infected seedlings after second and third challenge of 1985 treatments*

Treatment	No. of seedlings	No. Infected	% Infected
Second challenge			
Control	25	25	100
Benodanil	49*	43	88
Triadimefon	49*	1	2
Third challenge			
Control	4	4	100
Benodanil	6	6	100
Triadimefon	23†	18	78

Second challenge was 6 months after treatment; third challenge was 1 year after treatment.
*One seedling died from causes other than rust before the second inoculation.
†Three seedlings died from causes other than rust before the third inoculation; 23 seedlings were withheld to observe for latent symptom expression resulting from the second inoculation.

Table 4—*Infected seedlings in verification test (1987)*

Treatment	No. of seedlings	No. Infected	% Infected
First challenge			
Control	49	45	92
Triadimefon	49	0	0
Second challenge			
Control	10	9	90
Triadimefon	39	1	3

Initial inoculation was 3 weeks after treatment; second was 6 months after treatment.

stock with a single annual application of triadimefon, if it is strategically timed. Since *C. ribicola* normally infects sugar pine in the fall, a late summer application (end of August or early September), before fall rains and cooler temperatures prevail, should be optimum.

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Priming Black Spruce Seeds Accelerates Container Stocking in Techniculture Single-Seed Sowing System

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Black spruce (Picea mariana (Mill.) B.S. P.) seedling emergence and container stocking in Techniculture containers was accelerated by about 1 week by priming seeds in aerated water for up to 6 days. Priming in polyethylene glycol 8000 was less effective than priming in aerated water, and priming in a salt mixture killed the seeds.
Tree Planters' Notes 43(1):11-13; 1992.

In container nurseries, successful use of automatic single-seed sowing systems depends on technology to automatically deliver one seed per container and to ensure that each seed germinates and grows, thus stocking each container in the tray or rack. Various methods are being developed in attempts to achieve these requirements. For example in Sweden, that country's entire tree seed production is currently sorted to remove dead and unfilled seeds (Andersson 1991). Attempts are also in progress to integrate sorting (Simak 1984) with germination acceleration treatments (Bergsten 1987), which have the potential to achieve a more rapid and uniform crop emergence. Seed priming (soaking in water or osmotic solutions) has the potential to accelerate germination and seedling establishment.

Seed priming is a well-established practice for some horticultural crops, providing faster and more uniform germination (Heydecker and Coolbear 1977, Coolbear *et al*. 1980, Ellis and Butcher 1988). Primed seeds of black spruce *(Picea mariana* (Mill.) B.S.P.) and slash pine (*Pinus elliottii* Engelm.) were also shown to germinate more rapidly, particularly under less favorable environmental conditions such as temperature extremes (Fleming and Lister 1984, Haridi 1985). However, priming tree seed is not a widespread practice in North America. Some benefit is likely to be derived from using primed seeds in a greenhouse situation due to the shortened germination and culture period and the more uniform crop emergence. We tested various priming treatments on a sorted and stratified seedlot of black spruce seed with a high germination rate (98%) that were planted by hand in Techniculture (formerly Castle and Cooke) containers. Here we report on the optimal priming conditions for black spruce seed, an important commercial boreal species.

Materials and Methods

Black spruce seeds that were stratified for 30 days were obtained from the Ontario Ministry of Natural Resources' seed plant at Angus, Ontario. The seeds were sorted according to the method of Skeates (1972)-first they were sieved, then each size class was sorted in a wind tunnel into 60 size/density classes. The 40 classes corresponding to average weights between 0.85 and 1.2 mg were combined. Total germination of this sorted seedlot was 98%. Skeates (1972) has shown that germination can be affected by weight; by not using heavy or light seed, this confounding effect was minimized.

Preliminary trials were done in 1.6-liter narrow beakers covered loosely with a plastic lid through which passed a tube bringing air to the bottom of the beaker through an airstone. Cotton wad-filtered air was supplied by a large air pump so as not to cause excessive foaming. Seeds were primed at room temperature (18 to 22 °C) in 3 different regimes: 400 ml of autoclaved water; polyethylene glycol 8000 (PEG 8000) at concentrations of 10 to 30% (w/w); or a salt mixture of 0.105 M K_3P0 + 0.209 M $KN0_3$, according to the method of Haigh *et al*. (1986). At the end of the priming treatment, the seeds were collected through a strainer, rinsed with deionized water, surface-dried on paper towels, and sown directly. In one set of preliminary experiments, primed seeds were air-dried overnight on several layers of paper towels and then sown on the next morning. Control seeds were not treated in a priming solution before sowing.

To ensure that each of the 400 containers (cavities) in each tray was loaded, seeds were sown manually with a Plexiglas® template that precisely matched the containers (Techniculture, Inc., Salinas, California;

formerly Castle and Cooke). Trays were placed in a misting chamber for 1 week under natural photoperiods at day/night temperatures of 24 to 27 °C/18 to 23 °C. The trays were then removed from the misting chamber and placed in a greenhouse under natural day-length supplemented with sodium lights set at 16-h photoperiod at day/night temperatures of 25 to 30 °C/15 to 18 °C. Seedlings were fertilized once a week (unless otherwise indicated) to field capacity with 20-20-20 Plant products (Brampton) fertilizer, which also contained Mg, S, and micronutrients and watered twice daily with an automatic watering system (Andpro, Waterford, ON).

The final priming protocol was the outcome of several preliminary, similarly designed experiments. Seeds were primed for 6 days in aerated water, washed, surface-dried, and sown. The experiment was repeated three times, with three trays sown per treatment, resulting in 9 replicates (3,600 cavities). The control treatment was unprimed.

Seedlings were counted as "emerged," and thus a container was considered filled, when the seedling had grown up above the edge of the container, about 3 to 4 cm. Albino or ageotropic mutant seedlings (about 1 %) were counted initially but were deleted from total container stocking values as they died off.

Results and Discussion

Preliminary experiments. There appeared to be no benefit to using PEG 8000 at 10, 20, or 30% (w/w) over simple priming with aerated water. PEG 8000 slowed down germination, lengthening needlessly the duration of the priming treatment. Priming in the aerated mixture of salts (0.105 M K_3P04 + 0.209 M $KN0_3$) killed the black spruce seeds after about 2 days' exposure to the salts, which readily penetrated the seeds. Movement of seeds due to aeration appeared to dissolve and extract seed proteins and fats, causing foaming and killing the seeds. Less vigorous aeration led to anaerobiosis and fungal attack of the dying seeds.

Overnight drying of the seeds after priming in water or PEG 8000 set back the germinative metabolism and resulted in decreasing the effectiveness of the priming treatment. Therefore, in the final protocol, seeds were only surface-dried after priming and sown immediately.

Final experiment. In terms of accelerating seedling emergence, priming followed by surface drying and immediate sowing was superior to the control (figures 1 and 2). Under these conditions, all water-primed seeds had germinated prior to placement into the cavities. This resulted in an increased portion (about 1%) of the seedlings growing ageotropically, that is root up, and dying. Seedlings emerged 1 week faster with water-priming than without (controls). It appears that for black spruce, priming in water for 5 to 6 days, that is, bringing the seeds to the point where the radicles were about to emerge, immediately followed by surface-drying and sowing may be best for accel-

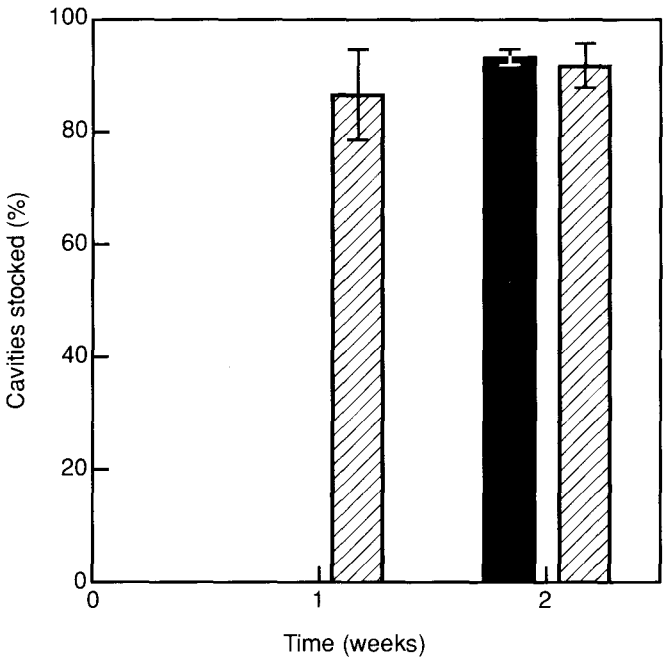

Figure 1—*Percent emergence of black spruce seeds primed for 6 days in aerated water (hatched columns) and untreated controls (solid columns). Standard deviation included in brackets. None of the controls had emerged during the first week.*

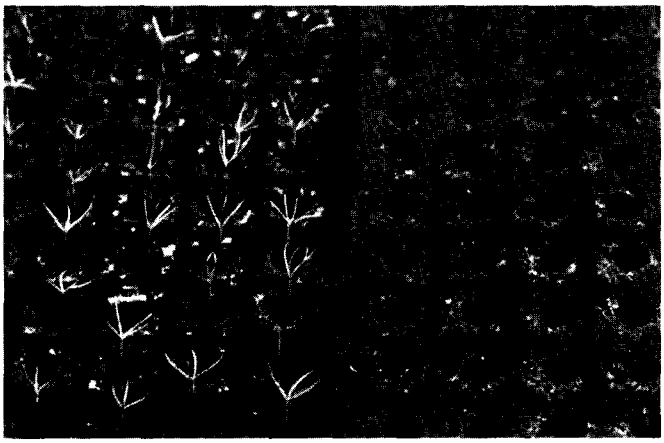

Figure 2—*Difference in emergence at 2 weeks after sowing of primed (***left***) and control (***right***) black spruce seedlings.*

erating seedling emergence and container stocking on a commercial scale.

In summary, priming black spruce seeds in water rather than not priming them or priming them in osmotic solutions appears to have merit for single seed sowing into containers. It may shorten production time by about a week, thus lowering greenhouse heating costs. However, this treatment alone cannot increase absolute container stocking. Further efforts are in progress to integrate the priming treatment with flotation-based removal of nonviable seed (Bergsten 1987). By far the greatest economic gains in terms of single-seed sowing systems will be made by using seeds as close to 100% germination rate and cavity stocking rate as possible (figure 3).

Figure 3—*Nearly perfect cavity-stocking of black spruce using the Techniculture container system.*

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A Pest Survey System for Forest Nurseries

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A recently developed systematic insect and disease survey for forest nurseries involves inspecting seedlings in sample plots for indications of pest problems. Surveys are conducted at strategic intervals, when all parts of sample plants are examined for evidence of pest injury. Tree Planters' Notes 43(1):14-16; 1992

A number of different seedling inventory and inspection systems have been used in forest nurseries (Belcher 1964, Landis and Karrfalt 1983). The North Carolina Division of Forest Resources has historically used a system of life history and inventory plots to monitor seedling quality, as well as growth and inventory in division nurseries operated by the division. The life history plots are supplemented by systematic team inspections designed to pinpoint any seedling problems. Although pest problems are considered during inspections and inventories, they are not the primary focus of the inventory systems. Because of this, a supplemental system was developed to locate and provide early warning of insect and disease problems. The system has been in place since 1985. It supplements the traditional inspections and gives pest control personnel an opportunity to systematically examine seedlings for pest problems at optimum detection times.

Methods

The sampling system that was developed requires three pest inspections per year. The first inspection is conducted just after seed germination, a second in the middle of the growing season, and a third just before lifting. Seedlings carried beyond one growing season in the nursery bed have additional inspections each year, conducted in the early spring, mid-growing season, and early fall.

During the inspections, a systematic sampling scheme is used. Numbers of sampling plots required may be based on seedlot or nursery bed length. If seedlot is used as a basis for the inspection, a minimum of four plots are taken per seedlot. If over 122 m (400 feet) of bed length is planted in a single seedlot, one additional plot is taken for each addition 305 m (1,000 feet) of bed length. When seedlot sampling is impractical, samples are based on bed length, with one sample being taken per 305 m (1,000 feet) of bed length.

A plot is measured using a standard 15-cm (6-inch) wide nursery counting frame (figure 1). All trees in the frame are counted and examined for evidence of insect or disease damage.

The early sample (taken just after germination) requires a simple surface examination. The two subsequent examinations are destructive and involve digging the seedlings so that entire plants may be examined. Leaves or needles, buds, stems, and roots are carefully scrutinized for pest problems and in addition, mycorrhizal occurrence is noted. The Seedling Pest Inspection Form is an example of the form used for data collection. The early sample normally requires 3 to 5 min per plot, and the latter destructive samples require 4 to 10 min per plot. When pest problems are found, they are identified and quantified whenever possible. Most identification, particularly when diseases are involved, requires laboratory analysis. As soon as problems are found, nursery personnel are notified and appropriate action is begun. Integrated pest management strategies are preferred when alternatives are available.

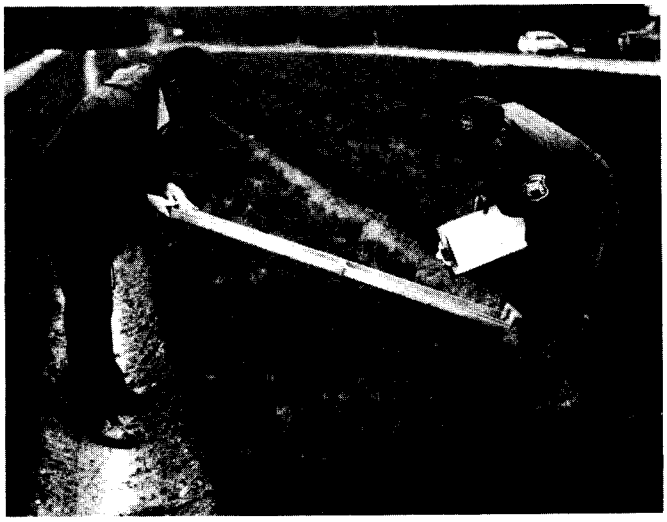

Figure 1—*Using a standard nursery counting frame to survey beds in a North Carolina Division of Forest Resources bareroot nursery.*

Seedling Pest Inspection Form

Nursery _____ Field _____

Species _____ Seed lot _____

1. Newly germinated Date _____

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7
Location							
Total							
Damping off							
Insects							
Disease							

Comments

2. Mid-summer Date _____

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7
Location							
Total							
Needles							
Buds							
Stem							
Roots							
Mycorrhizae							
Other							

Comments

3. Hardened-off Date _____

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7
Location							
Total							
Needles							
Buds							
Stem							
Roots							
Mycorrhizae							
Other							

Comments

Plots checked by _____

Discussion

The pest inspection system is a useful supplement to normal life history plots. It offers an opportunity to systematically examine all parts of seedlings at critical periods in their development. The number of samples is kept at a minimum to reduce the number of se edlings lost through destructive sampling. The survey is designed to be an early warning system and not a statistically sound sampling system. A number of pest problems have been located through the survey. Some of the insects found to date during the inspections include tipmoth, bagworm, cricket, webworm, and pine bark adelgid (aphid). Diseases include damping off, fusiform rust, pitch canker, chlorosis, and chemical damage. So far, overall damage by pests has been low, averaging .5 to 1% of sampled seedlings.

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