# Conditioning Three Boreal Conifers by Root Pruning and Wrenching

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*The effects of root pruning and wrenching on the morphological quality and outplanting performance of white spruce* (Picea glauca *(Moench) Voss) and black spruce* (P. mariana *(Mill.) B.S. P.) and jack pine* (Pines banksiana *Lamb.) seedlings. Root pruning and wrenching successfully modified the morphology of all three species in the nursery by decreasing height and increasing root system size, but did not improve survival or growth after outplanting.* Tree Planters' Notes 40(2):33-39; 1989.

Root pruning and wrenching treatments have resulted in improved seedling morphology and increased survival after outplanting for Monterey pine (*Pines radiata* D. Don.) in New Zealand (6, 18), loblolly pine (*Pines taeda* L.) in the southern United States (19), and Douglas-fir (*Pseudotsuga menzieseii* (Mirb.) Franco) in the Pacific Northwest (22). Root pruning and wrenching modified the morphological quality of red pine (*Pines resinosa* Ait.) in southern Ontario (1-4) and white spruce (*Picea glauca* (Moench) Voss) in northern Ontario (12), but increases in survival and growth after outplanting were only obtained with red pine.

The benefits of root pruning and wrenching in the nursery have been cited as increased root fibrosity, improved shoot-root balance, increased root growth potential, and early cessation of top growth (17, 23). Some nurseries in the Pacific Northwest use root wrenching to prevent late flushing of pines (9). Root pruned and wrenched seedlings may also show better survival through storage, withstand longer periods of root exposure, show increased drought tolerance and have improved growth after outplanting (23).

Problems with the survival and growth of bareroot nursery stock after overwinter storage and outplanting in Ontario resulted in research on root pruning and wrenching white spruce, black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) during the final year on the nursery. A previous study with white spruce (12) indicated that root pruning and wrenching could be used to modify the morphology of white spruce transplants in the nursery but the treatments did not improve survival or growth in the first year after outplanting. The lack of increase in survival or growth after outplanting was attributed to the warm, moist growing season, which resulted in every high survival for all plantations in that year. No trials of root pruning and wrenching black spruce are reported in the literature.

The major problem in producing 2+0 jack pine bareroot stock in northern Ontario is its excessive height growth during the second year on the nursery. This results in tall, unbalanced seedlings. In northern Ontario, jack pine was root pruned early in the spring of the 2+0 year (5). The treatment had no effect on top-root ratio, nor did it increase survival or growth the first season after outplanting. Similar treatments applied to jack pine in the southern United States showed similar results (13). Reports of root pruning combined with wrenching of jack pine are lacking from the literature.

Potassium is thought to increase the cold hardiness of plants, but the literature on this is inconclusive. Some studies have shown increased cold tolerance at high levels of potassium and others no effect. Potassium deficiency has been shown to increase the susceptibility of seedlings to frost damage (15). Increased cold hardiness is important for nursery stock exposed to variable temperatures in the fall and spring. Potassium is also important in regulating plant water status (11) and may help avoid winter dessication.

The objectives of the study were as follows:

1. To assess the effects of root pruning and wrenching treatments on the morphological and physiological quality of white and black spruce transplants and jack pine seedlings during the final year on the nursery.
2. To assess the effects of potassium fertilizer on bud development and on morphological and physiological quality of white and black spruce transplants and jack pine seedlings during the final year on the nursery.
3. To assess the effects of the root pruning and wrenching and potassium fertilizer treatments on the performance of white and black spruce transplants and jack pine seedlings after outplanting.

**Methods**

**Root conditioning and potassium fertilizer trials.** A split-plot design consisting of three root conditioning treatments and two potassium treatments was set up in four blocks in each of a compartment of rising 2+2 white spruce, a compartment of rising 1½ + 1½ black spruce and a compartment of rising 2+0 jack pine at the Thunder Bay Forest Nursery in May 1985. The three root conditioning treatments were

1. Control, no root pruning, or wrenching applied.
2. Early season root pruning followed by wrenching at 21-day intervals.
3. Early season root pruning followed by wrenching periodically to coincide with peak root growth.

Treatment 2 was wrenched four times after pruning whereas treatment 3 was wrenched twice. An additional treatment, consisting of root pruning after shoot elongation (July) followed by wrenching at 21-day intervals, was applied to the black spruce stock because of its small size at 1½ + ½ stage. This treatment was wrenched three times after pruning.

The two potassium fertilizer treatments were

1. Control, 0.0 kg/ha supplemental elemental potassium applied.
2. 75 kg/ha of supplemental elemental potassium applied as potassium sulphate at five times throughout the summer.

Altogether 375 kg/ha (840 ppm) supplemental elemental potassium were applied.

The root pruning was carried out at a depth of 7.5 to 10 cm, using a single, sharp, horizontal blade mounted on a double-acting hydraulic system beneath a tractor. The root wrenching treatments were carried out at a depth of 12 to 15 cm, using a single, blunt blade angled at 35 degrees on the same hydraulic system.

Height growth and root collar diameter were measured on a permanent sample of 25 seedlings per variate at 21-day intervals throughout the growing season. These same seedlings were fall lifted and assessed for standard morphological characteristics (7).

The data were checked for normality using Rankit plots and homogeneity using Bartlett's F-test. Analysis of variance and Tukey's honestly significant difference were used to determine the significance of difference between individual treatments (21).

A sample of black and white spruce stock was fall lifted and overwinter frozen stored at -2 °C in polylined waxed kraft boxes.

**Outplanting trials.** The outplanting site was located near Great Lakes Forest Products Camp 45, 115 km north of Thunder Bay, ON. The site, which originally supported an aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.), balsam fir (*Abies balsamaea* (L.) Michx.),

white spruce (*Picea glauca* (Moench) Voss) mix, had been cutover in 1983, then was site-prepared in the fall of 1984 with Young's teeth (20) spaced at approximately 2 m. The site was a loamy sand on a northeast-facing slope with relatively heavy slash and little advance growth. The competition consisted mainly of raspberry *(Rubus ideaus* L.), alder (*Alnus rugosa* (Du Roi) Spreng.), hazel (*Corylus cornuta* Marsh.),and aspen. The stock was lifted early in the spring and placed in cold storage (+ 2 °C) with the overwinter frozen stored stock. Each species was planted in separate trials at 2- by 2-m spacing with four blocks in each trial in May of 1986. A total of 48 plots with 25 transplants in each were established for white and black spruce and 24 plots of 25 seedlings each were established for jack pine. The stock was monitored for survival, height growth, and root collar diameter in the fall of 1986 and 1987.

The field data were analyzed as described above for the nursery trials.

## Results

**Root conditioning and potassium fertilizer trials.** *White Spruce.* The height, root collar diameter, and bud diameter of the white spruce transplants were reduced by root pruning and wrenching (table 1). Initial and final measurements of height and root collar diameter refer to measurements made before outplanting and at the end of the season.

**Table 1**—*Morphological characteristics of root pruned and wrenched white spruce transplants*

| Conditioning treatment | Height (cm) | | RCD (mm) | | RAI | TDW | RDW | | BD |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Initial | Final | ($cm^2$) | (g) | (g) | T/R | (mm) |
| 1. Control | 12.5 | 23.3 a | 3.2 | 6.4 a | 86 | 7.3 a | 2.9 | 2.7 a | 4.0 a |
| 2. 21 day | 11.4 | 18.3 b | 3.1 | 5.5 b | 96 | 5.3 b | 2.6 | 2.2 b | 3.5 b |
| 3. Periodic | 11.6 | 19.5 b | 3.1 | 5.7 b | 78 | 5.8 b | 2.5 | 2.5 ab | 3.6 b |

Values in columns followed by different letters are significantly different at the 95% level of confidence. RCD = root collar diameter, RAI = root area index, TDW = top dry weight, T/R = top–root ratio, BD = bud diameter; initial refers to measurements before treatment, final to measurements at the end of the season.

No significant difference in mean root dry weight or root area index was apparent between the three root conditioning treatments, but top dry weight was reduced by root conditioning (table 1). Root pruning and wrenching treatments had more effect on the shoots than on the roots of the stock. Top dry weight was reduced by 25%, whereas root dry weight was only reduced by 12% which was not significant. The mean top-root ratio (T/R ratio) of treatment 2 was significantly smaller than that of treatment 1.

All stock was above the minimum desirable standard for shippable 2 + 2 white spruce stock (height, 15 cm; root collar diameter, 3.0 mm; and root area index, 36 $cm^2$) for Ontario's north central region (14). Only treatment 1 stock reached the objective mean height of 21 cm, even thought root collar diameter and root area index were above the objectives of 3.9 mm and 65 $cm^2$ respectively.

Supplemental potassium fertilizer had no significant effect on the morphological quality of the white spruce transplants.

*Black spruce*. Because of the small size of the 1½+ ½ stock, the early season root pruning treatment removed only one to three new root tips per transplant. This treatment was more of a shallow wrenching than a pruning treatment because of the poorly developed root systems of the recently transplanted 1½+ ½ stock.

The height, root collar diameter, and bud diameter of the black spruce transplants were reduced significantly by root pruning and wrenching (table 2). The largest reduction was effected with treatment 2, which was pruned in May and wrenched most frequently. The root pruning and wrenching treatments had no significant effect on the mean root volume or root area index of -the stock (table 2). Top and root dry

**Table 2**—*Morphological characteristics of root pruned and wrenched black spruce transplants*

| Root conditioning treatment | Height (cm) | | | RCD (mm) | | RAI ($cm^2$) | RTVOL | BD (mm) |
|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Growth | Initial | Final | | | |
| 1. Control | 8.7 | 23.7 a | 15.7 a | 2.1 | 5.2 a | 73 | 7.5 | 2.8 a |
| 2. Early–21 day | 8.7 | 17.8 c | 11.4 b | 2.1 | 4.2 c | 75 | 6.6 | 2.2 c |
| 3. Periodic | 8.7 | 19.3 bc | 11.5 b | 1.9 | 4.4 bc | 63 | 5.5 | 2.5 b |
| 4. Late–21 day | 8.9 | 20.6 b | 12.4 b | 2.0 | 4.8 ab | 79 | 7.2 | 2.5 b |

Values in the same column followed by different letters are significantly different at the 95% level of confidence. RCD = root collar diameter, RAI = root area index, RTVOL = mean root volume, BD = bud diameter.

weight measurements were not made for the black spruce stock so top-root ratio could not be evaluated.

All stock was above the minimum desirable standard for shippable 1½+1½ black spruce stock (height, 15 cm; root collar diameter, 2.6 mm; and root area index, 31 $cm^2$) for Ontario's north central region (14). Not even treatment 1 stock reached the objective mean height of 29 cm, even though mean root collar diameter and root area index were above the objectives of 4.0 mm and 60 $cm^2$, respectively.

Supplementary potassium fertilizer significantly decreased the root area index (24%) and root volume (17%) of treatment 2 stock.

*Jack pine.* The height, bud diameter, root collar diameter, top dry weight, and top-root ratio of the jack pine seedlings were significantly reduced by root pruning and wrenching (table 3).

Root dry weight of treatment 2 stock was increased by root pruning and wrenching (table 3). The root area index of treatment 2 stock was also increased but the differences were not significant (table 3).

All stock was above the minimum desirable standards for shippable 2+0 jack pine stock (height, 13 cm; root collar diameter, 2.6 mm; root area index, 20 $cm^2$) in Ontario's north central region (14). Only treatment 1 stock reached the objective mean height of 18 cm, even though mean root collar diameter and root area index were above the objectives of 3.4 mm and 30 $cm^2$ respectively.

Supplementary potassium fertilizer had no effect on the morphological quality of jack pine seedlings.

**Outplanting performance.** *White Spruce*. Survival was high in both years with no significant differences occurring between the root conditioning treatments (table 4). Initially, treatment 1 (control) stock was significantly taller and had larger buds and larger root collar diameters than stock from treatments 2 and 3 (table 1). In the first season after outplanting, treatment 1 stock grew significantly better than stock from treatments 2 and 3. Frozen stored stock grew more than spring lifted stock. By the end of the second season in the field, there were no significant differences in mean height growth between the treatments. Height growth, taken as a percent of initial size, was better for spring lifted root conditioned stock than control stock in both years.

In the first season after planting, treatment 1 stock maintained larger mean root collar

**Table 3**—*Morphological characteristics of root pruned and wrenched jack pine seedlings*

| Conditioning treatment | Height (cm) | | RCD (mm) | | RAI ($cm^2$) | TDW (g) | RDW (g) | T/R | BD (mm) |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Initial | Final | | | | | |
| 1. Control | 2.9 a | 18.7 a | 2.3 | 4.4 a | 32 | 3.5 a | 0.7 b | 5.2 a | 2.5 a |
| 2. 21 day | 2.7 ab | 15.1 b | 2.3 | 4.1 ab | 38 | 2.8 ab | 1.0 a | 2.9 b | 2.2 b |
| 3. Periodic | 2.6 b | 14.4 b | 2.1 | 3.8 b | 32 | 2.3 b | 0.7 b | 3.3 b | 2.2 b |

Values in the same column followed by different letters are significantly different at the 95% level of confidence. RCD = root collar diameter, RAI = root area index, TDW = total dry weight, RDW = root dry weight, T/R = top-root ratio, BD = bud weight.

diameters than stock from treatments 2 and 3 (table 4). There were no significant differences in mean root collar diameter increment between the root conditioning treatments in the first or second season after outplanting.

Supplementary potassium fertilization had no significant effect on the survival or growth of the white spruce transplants after outplanting.

*Black* spruce. Survival was high in both years with treatment 2 stock that had been frozen stored having significantly better survival than control stock. Treatment 1 (control) stock was taller than stock from treatments 2 and 3 at the time of planting (table 5). There were no significant differences in height growth between the root conditioning treatments after the first or second season in the field. Overwinter frozen stored stock grew significantly better than spring lifted stock during the first season after outplanting. The mean root collar diameter of control stock remained larger than that of root conditioned stock in both years.

Supplementary potassium fertilization had no effect on the survival or growth of the black spruce transplants after outplanting.

*Jack pine*. Survival after outplanting was very high in both years. Treatment 1 (control) stock was taller than treatment 2 and 3 stock at the time of planting. There were no significant differences in mean height growth, root collar diameter, or survival between any of the treatments after the first and second growing seasons (table 6). Height growth was better in the second season after outplanting, indicating stock had become established and recovered from outplanting shock.

**Table 4**—*Height and root collar diameter measurements for root conditioned white spruce transplants in the first and second season after outplanting*

| Conditioning treatment | Survival (%) | | Height growth (cm) | | | RCD (mm) | | |
|---|---|---|---|---|---|---|---|---|
| | 1986 | 1987 | Initial | 1986 | 1987 | Initial | 1986 | 1987 |
| Frozen stored | | | | | | | | |
| 1. Control | 98.0 | 98.0 | 25.3 a | 8.6 a | 6.3 | 6.3 a | 7.6 b | 7.7 a |
| 2. 21 day | 99.0 | 97.5 | 21.0 b | 6.9 b | 5.0 | 5.6 b | 6.5 c | 7.0 b |
| 3. Periodic | 98.0 | 96.0 | 23.3 b | 7.2 b | 6.2 | 5.8 b | 7.1 bc | 7.2 b |
| Spring lifted | | | | | | | | |
| 1. Control | 97.5 | 95.0 | 27.5 a | 7.6 a | 5.6 | 6.5 a | 8.2 a | 8.0 a |
| 2. 21 day | 99.5 | 99.5 | 23.8 b | 6.4 b | 5.7 | 5.9 b | 7.6 b | 7.7 a |
| 3. Periodic | 99.0 | 98.5 | 22.9 b | 6.2 b | 5.6 | 6.0 b | 7.2 b | 7.5 ab |

Values in columns followed by different letters are significantly different at the 95% level of confidence. RCD = root collar diameter.

**Table 5**—*Morphological characteristics of root pruned and wrenched black spruce transplants in the first and second season after outplanting*

| Conditioning treatment | Survival (%) | | Height growth (cm) | | | RCD (mm) | |
|---|---|---|---|---|---|---|---|
| | 1986 | 1987 | Initial | 1986 | 1987 | 1986 | 1987 |
| Frozen stored | | | | | | | |
| 1. Control | 81.0 c | 75.5 c | 21.2 a | 14.5 a | 7.6 | 5.7 a | 8.0 a |
| 2. 21 day | 91.5 ab | 89.0 ab | 18.2 b | 13.5 a | 7.5 | 5.4 b | 7.5 b |
| 3. Late | 83.0 bc | 83.0 bc | 19.9 b | 13.9 a | 8.7 | 5.3 b | 7.4 b |
| Spring lifted | | | | | | | |
| 1. Control | 92.0 ab | 87.5 ab | 20.9 a | 10.7 b | 9.0 | 5.7 a | 7.6 b |
| 2. 21 day | 97.0 a | 94.0 a | 16.3 b | 10.5 b | 8.9 | 5.0 b | 6.5 c |
| 3. Late | 85.5 bc | 83.5 bc | 19.3 b | 10.0 b | 8.5 | 5.3 b | 7.2 b |

Values in the same column followed by different letters are significantly different at the 95% level of confidence. RCD = root collar diameter.

**Table 6**—*Morphological characteristics of root pruned and wrenched jack pine seedlings in the first and second season after outplanting*

| Root conditioning treatment | Survival (%) | | Height growth (cm) | | | RCD (mm) | |
|---|---|---|---|---|---|---|---|
| | 1986 | 1987 | Initial | 1986 | 1987 | 1986 | 1987 |
| 1. Control | 98.0 | 98.0 | 16.4 a | 16.4 | 23.3 | 5.4 | 8.9 |
| 2. 21-Day | 98.5 | 97.5 | 14.6 b | 17.4 | 24.1 | 5.5 | 9.2 |
| 3. Periodic | 99.5 | 98.5 | 13.5 b | 15.6 | 23.8 | 5.1 | 8.6 |

*Values in the same column followed by different letters are significantly different at the 95% level of confidence. RCD = root collar diameter.*

Supplementary potassium fertilizer had no significant effect on the survival of jack pine seedlings after outplanting. Fertilized seedlings grew 11% more than unfertilized in the first season after outplanting. By the end of the second season in the field fertilized seedlings were only 7% taller than unfertilized stock.

## Discussion

Root pruning and wrenching treatments decreased the height, root collar diameter, top dry weight, top-root ratio and bud size of white and black spruce transplants and jack pine seedlings in the nursery. As the treatments increased or had no effect on root dry weight and root area index, they increased root system size relative to top size.

A major problem with overwinter frozen spruce is reduced survival after outplanting. Root pruning and wrenching treatments appear to have improved the survival of overwinter frozen stored black spruce but had no effect on the survival of stored white spruce stock.

The major problem with jack pine bareroot stock in northern Ontario is excessive height growth in the second year in the nursery. The optimum top-root ratio for jack pine is 3:1 (16). In this study, control stock had a mean top-root ratio greater than 5:1, indicating that the tops were too large relative to root system size. Root conditioning improved the morphology of 2 + 0 jack pine by decreasing the top-root ratio to 3:1.

The season in which the root conditioning treatments were carried out at the nursery was unusually wet (precipitation was 120% of normal) (10). Unusual wetness may be the reason for the small size of the control stock and may also have reduced the degree of stress after pruning and wrenching, so that there was little difference in physiological condition, and therefore the outplanting performance, between the three treatments.

Supplemental potassium fertilizer reduced the root growth of black spruce in the nursery but had no effect on white spruce or jack pine root growth. Excess potassium has been shown to cause root damage in previous studies (8). Supplementary potassium did not improve the outplanting performance of white or black spruce transplants but appeared to improve the growth of jack pine seedlings after outplanting. No previous studies have reported growth increases as a result of potassium fertilizer. It is possible that the potassium fertilizer made the seedlings less susceptible to water stress (11). This would allow them to grow when the unfertilized stock could not.

## Conclusions

Root pruning and wrenching can be used as a cultural tool in the nursery to improve the morphology of 2 + 2 white spruce, 1½ + 1½ black spruce and 2 + 0 jack pine stock by decreasing height and increasing root system size.

The effects of these treatments on outplanting success are not yet clear, but the treatments appear to have improved the survival of overwinter stored black spruce transplants. Although root pruning and wrenching treatments have increased survival and growth after outplanting in New Zealand and the Pacific Northwest, in this study they did not significantly

improve the performance of white and black spruce trans plants or jack pine seedlings after outplanting in northern Ontario (5).

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