Comparing Large Bareroot and Container Stock: Water Stress as Influenced by Peat and Soil Water Availability

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Abstract

To evaluate the effect of the rooting media on seedling planting shock in black spruce [*Picea mariana* (Mill.) BSP], we planted three large seedling stock types (containerized, containerized with washed root system, and bareroot) in pans filled with sand and created two contrasting watering regimes (well-watered and limited water). We measured shoot xylem water potential (ψx) weekly on seedlings from all treatment combinations during a 10-wk period. Over the entire sampling period, and independent of the watering regime, containerized seedlings with washed-root systems showed similar water potentials to bareroot seedlings. Both types presented more negative values than intact containerized seedlings. Differences in the water status of newly outplanted large containerized and bareroot seedlings seem to result mainly from the effect of the peat-based growing medium on water availability in the rooting zone.

Introduction

In the province of Québec (Canada), vegetation control with herbicide is no longer an operational option on public forest lands (Ministère des Ressources Naturelles du Québec 1994). Alternative strategies to herbicides include planting seedlings the year following final harvest, when competing vegetation is still relatively undeveloped. Another element of this regeneration strategy includes the use of large conifer stock that can overcome competition by noncrop species (Jobidon and others 1998, 2003). However, there is still a need to evaluate the conditions for successful establishment of bareroot and containerized large transplants, as influenced by silviculture and nursery cultural practices.

Recent field experiments indicate that large container-grown seedlings of black spruce [*Picea mariana* (Mill.) BSP] experience more pronounced water stress than do bareroot seedlings during their first growing season on harsh-competition sites of eastern Québec (Thiffault and others 2003). The generally observed poor first-year root-soil contact for containerized seedlings (Burdett 1990) was hypothesized to be responsible for the results observed. Örlander and Due (1986a, b) report that the most important resistance to water flow in the soil–plant pathway for seedlings of containerized Scots pine (*Pinus sylvestris* L.) is in the peat soil surrounding the roots. Low soil hydraulic conductivity of peat-based growing medium under low soil water content conditions and its subsequent effect on containerized seedling water stress are also reported by Bernier (1992) and Bernier and others (1995). No study, however, has investigated, under a semicontrolled environment, the water relations of the different types of large stock seedling actually outplanted in Québec in order to understand how different soil water availability conditions may affect their capacity to absorb water.

We designed this study to test the following hypotheses: (1) the peat-based growing medium is responsible for the differences in water stress experienced by newly planted large containerized and bareroot seedlings; (2) significant differences in the water status of large containerized and bareroot stock are more important under low soil water content than when soil water is readily available.

Material and Methods

Seedling description. We obtained large containerized (initial height = 35 to 45 cm, 13.8 inches to 17.7 in) and bareroot (initial height = 40 to 60 cm, 15.7 to 23.6 in) black spruce seedlings from the Saint-Modeste governmental nursery (Québec) in late fall of 1998. Large containerized seedlings (CO) were produced over 2 yr (2+0) in 350–cc, 25-cavity airslit containers developed by the Ministère des Ressources naturelles du Québec (Gingras and Richard 1999). Bareroot seedlings (BR) were grown outside over 4 yr (2+2). We ovendried a sub-sample of each stock type at 65±2 °C for 48 h to determine initial dry biomass. We produced a third stock type, "washed container" (WCO), by randomly selecting half of the containerized seedlings, immersing their root systems in water, and gently washing. The objective of this operation was to remove all of the growing medium (peat–vermiculite, 3:1 v:v), while minimizing disturbance to the root system.

Experimental design and measurements. We filled plastic pans of 90 dm^3 with fine sand and grouped them 2 × 2 to form four experimental blocks that were distributed in a greenhouse at Université Laval (46°46'51" N., 71°16'46" W.). We planted two seedlings of each stock type (BR, CO, and WCO) side by side in each of the eight pans, the stock type position being randomized at the pan level. To induce bud break and favor root growth, we watered all pans every 2 d for 1 mo. Seedlings received a water-soluble fertilizer (20N–20P–20K, 1 g L^{-1}, 5 L pan^{-1}) 2 wk after plantation. Meanwhile, we gradually increased photoperiod (from 8 h to 16 h), day-time air temperature (15 to 25°C), and night-time air temperature (10 to 18°C). Air relative humidity was not controlled and varied from 25 to 45 percent. Thirty days after planting, each pan within each experimental block was randomly assigned to receive one of the following qualitative watering treatments: (1) well-watered conditions (WR1) or (2) limiting soil water (WR2). We created the WR1 treatment by abundant watering of the pan every 2 d. We induced the WR2 treatment) by abundant watering every 4 wk.

As soon as watering treatments commenced, we evaluated seedling shoot xylem water potential (ψx) between 11 a.m. and 1 p.m. weekly for 10 consecutive wk. We preferred midday to predawn measurements because they more closely reflect acclimation of newly planted seedlings to site condition (Bernier 1993). At each sampling period, we measured 24 seedlings (3 stock types × 2 watering regimes × 4 blocks) with a portable pressure chamber (PMS Instruments, Corvallis, OR), following the recommendations of Ritchie and Hinckley (1975). The experimental design was a split-split-plot in time, with the watering regime treatment (WR) applied to the main plot, stock type (ST) considered as the subplot unit, and time (T) as the sub-sub-plot level.

Statistical analysis. We determined the significance of the effects of watering regime, stock type, time, and all possible interactions on ψx by analysis of variance for repeated measurements (ANOVAR), using the MIXED procedure of the SAS 8.01 software (SAS Institute Inc., Cary, NC). In the case of a significant p-value ($p \leq 0.05$) for the treatment or interaction, we used a Fisher's protected LSD test (Steel and others 1997) to separate treatment means. Before analysis, we square-root transformed all data to satisfy the normality and homoscedasticity postulates. For clarity and convenience, we present back-transformed means.

Results and Discussion

The qualitative watering regime treatments were effective in creating contrasting soil conditions, as shown by the significant WR × T effect on seedling ψx (table 1). Detailed analysis of this interaction revealed that seedlings in the low water availability treatment took 4 wk to present significantly lower ψx than seedlings under well-watered conditions (figure 1). After having been rehydrated at the fourth week, the WR2 seedlings recovered a similar water status to the WR1 seedlings for 1 wk, and then presented more negative ψx values until week 9.

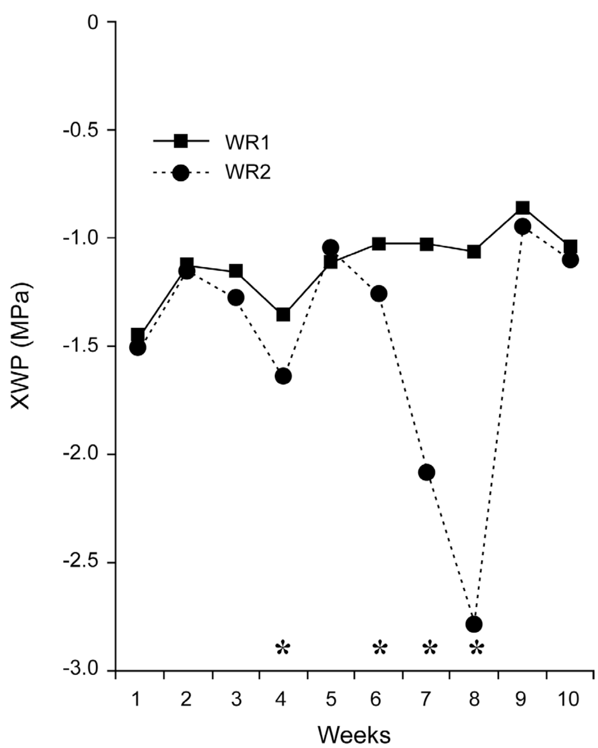

Figure 1. Effect of the watering regime on the weekly φx of black spruce seedlings. WR1: well-watered condition (watered every 2 d); WR2: limiting soil water(watered immediately after the φx measurements of week 4 and 8). A significant watering regime effect on x for a particular week (p≤0.05) is indicated with an asterisk. Standard error of the mean for the plotted data is ± 0.07 MPa.

Stock type had a statistically significant effect on shoot ψx, and this effect was independent from the watering regime or sampling date (table 1). Lack of a significant interaction between stock type and the watering regime negates the second research hypothesis; the difference between the stock types must be interpreted independently from soil water availability. Multiple comparisons of treatment means showed that WCO and BR seedlings had similar x, and that both stock types experienced a slightly more pronounced water stress (more negative ψx value) than CO seedlings (table 2).

Nursery managers can do little to regulate air temperature and humidity above the nursery seedbeds (Lavender 1984). During production, bareroot seedlings are exposed to more demanding climatic conditions than are containerized seedlings produced in tunnels. The water potential below which stomatal conductance falls steeply varies in relation to the environmental and physiological history of the shoots (Beadle and others 1978). Thus, the cultural regime under which a seedling is produced can influence seedling capacity to control water loss once outplanted on a forest site. In the present experiment, WCO seedlings behaved like BR in terms of water potential (table 2). It can be concluded that both stock types (CO and BR) presented similar stomatal control of water loss, since the sole elimination of the peat barrier to water flow resulted in a similar water status. This result is different from those of Blake and Sutton (1987), who report that black spruce bareroot seedlings have greater responsiveness of stomatal conductance to xylem water potential than containerized seedlings. Seedlings used in their study, however, were much smaller that those used in this experiment, with average total dry weight of 7 g and 1 g for the bareroot and the container stock, respectively. Seedlings produced under different cultural regimes can be expected to differ in their physiological status at time of planting (Grossnickle 2000). Thus, comparison between studies may be precarious.

Table 1. Source of variation (fixed), degrees of freedom (d_f), and p-values for xylem water potential of the three stock types of black spruce seedlings, submitted to two watering regimes during 10 wk.

Source of variation (fixed)	d_f	p
Watering Regime (WR)	1	0.003
Stock Type (ST)	2	0.016
WR × ST	2	0.198
Time (T)	9	<0.001
WR × T	9	<0.001
ST × T	18	0.445
WR × ST × T	18	0.323

Table 2. Effect of stock type on the xylem water potential (ψx) of large black spruce seedlings.

Stock type	**ψx (-MPa)**
Containerized 350 cc (CO)	1.21a
Containerized 350 cc with washed root system (WCO)	1.30b
Bareroot (BR)	1.31b
Analysis was performed on square-root transformed data, but back-transformed means are presented for clarity and convenience. Means followed by the same letter are not significantly different according to the Fisher's protected LSD test (p > 0.05).	

The containerized and bareroot seedlings we used presented morphologically different root systems with similar initial shoot:root biomass ratios (table 3). Thus, our results support the previous observation that initial size of the root system does not relate well to its capacity to conduct water after planting (Krasowski and Owens 2000). Instead, quality of the root system, in terms of vigor and fibrosity, may be of crucial importance (Lamhamedi and others 1998) to positively influence the feedback loop relating seedling root growth, water status, gas exchange, and photosynthesis (Burdett 1990).

It can be concluded from our greenhouse experiment that (1) differences between large containerized and bareroot black spruce seedling water status were induced by the peat surrounding the root system of the container-grown seedling; and (2) peat growing medium effect on containerized seedling water status was independent from soil water availability.

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Table 3. Initial dry biomass (g) of large containerized and bareroot seedlings.

	Bareroot	**Containerized 350 cc**
Shoot dry biomass (g)	32.0±7.5a	7.0±0.5b
Root dry biomass (g)	10.5±1.6a	3.1±0.7b
Shoot:Root Biomass Ratio	3.0±0.3a	2.4±0.8a
Data are expressed as mean±sd. For each variable, stock type means followed by the same letter are not significantly different at p=0.05.		

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