Root Regeneration of Fall-Lifted White Spruce Nursery Stock in Relation to Soil Moisture Content

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Abstract

The root regenerating potential of fall-lifted 2+0 white spruce nursery stock is described after transplanting into soil-maintained at 8, 10 and 15% soil moisture content (SMC) in glass fronted root boxes. At 15% SMC (0.1 bar soil moisture tension), which is close to field capacity, root regeneration began 10 days after transplanting and root elongation continued at a high rate for the remainder of a 40-day study period. At 10% SMC (0.6 bar SMT) root regeneration was delayed until 20 days after transplanting and root elongation was at a slower rate. At 8% SMC (1.5 bars) root regeneration and elongation was negligible. Plant moisture stress measured at 40 days was least when root regeneration was most and vice versa. The results suggest that field planting of white spruce in soils with moisture tensions of over 0.6 bar will be hazardous.

Résumé

L'auteur discute de la rhizogénèse des semis de 2 ans d'épinette blanche extraits de la pépinière à l'automne et repiquée sur sol dont la teneur en humidité était maintenue à 8, 10 et 15% dans des boîtes à couvercle de verre. Au niveau de 15% (0.1 bar), ce qui se rapproche de la capacité au champ, la rhizogénèse a débuté quelque 10 jours suivant le repiquage, et l'élongation racinaire s'est maintenue à un taux élevé durant les 40 jours que dura la période d'observation. Au niveau de 10% d'humidité, (0.6 bar), la rhizogénèse était retardée pendant plus de 20 jours suivant la transplantation, et l'élongation racinaire s'est manifestée à un taux plus lent. Finalement, au taux de 8% d'humidité (1.5 bars), la rhizogénèse de même que l'élongation racinaire étaient négligeables. Le stress hydrique de la plante, enregistrée à 40 jours étaient moindre lorsque la rhizogénèse était maximale, et vice-versa. Ces résultats suggèrent que la plantation d'épinette blanche sur sols à tension d'humidité supérieure à 0.6 bar est risquée.

Introduction

Plantation failure in the immediate period after planting is often attributed to soil drought or to a combination of soil drought, low root regeneration potential and plant moisture stress when the seedlings lack functional roots (Cleary 1968; Stone and Jenkinson 1970). Unless transplanted seedlings can rapidly elongate new roots in order to increase water supply and thus lower plant moisture stress the probability of survival is low. Stone and Jenkinson (1970) showed that the root regenerating potential of ponderosa pine (*Pinus ponderosa* Laws.) is very low in soils with moisture tensions of approximately 15 bars, wilting coefficient, but is adequate in soils with moisture tensions of 2.5 bars or less. Root regeneration studies with northern conifers showed that root regeneration was severely curtailed in soils at less than 1.0 bar soil moisture tension.

The objective of this study was to measure the root regeneration potential (RRP) of fall-lifted 2+0 white spruce (*Picea glauca* (Moench) Voss.) nursery stock planted in sandy loam soils maintained at relatively high levels of soil moisture content (SMC) and low levels of soil moisture tension (SMT). Thus the study provided a means of evaluating the effect of variation in SMC and SMT on the RRP and survival of white spruce. A secondary objective of the study was to measure the plant moisture stress (PMS) of the white spruce seedlings at the end of the 40-day post-planting growth period and to relate it to the RRP that had taken place during the previous 40 days. In this study root regeneration potential was measured by determining the change in the surface area of the root system over a 40-day period in square centimeters of root area index (RAI) in a 'Rhizometer' (Morrison and Armson 1968). RRP was also determined by periodically measuring total root elongation in centimeters on the glass front of a narrow root growth box angled at 45°.

The white spruce seedlings were transplanted into sandy loam soil at three relatively high levels of SMC (15, 10 and 8%) and low levels of SMT (0.1, 0.6 and 1.5 bars) because SMTs of 0.5 bar or more have been shown to sharply reduce the growth of well rooted conifer seedlings (Sands and Rutter 1959). It is important to note that the highest SMT level maintained in this study, 1.5 bars, was a tenth of that normally associated with reduction in growth of white spruce by some (Glerum and Pierpoint 1968).

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Methods

Two hundred and fifty 2+0 white spruce seedlings were lifted in November on the Thunder Bay Forest Station and maintained in frozen storage at -4°C (25°F) until January. Twenty-four of these seedlings with well developed root systems of similar size were selected for study. The RAI of each seedling was determined on the Rhizometer and recorded. Eight seedlings were then planted in each of three sets of eight root boxes that contained sandy loam soil adjusted to 15, 10 and 8% SMC. Calibration of the soil at these levels of SMT in a ceramic plate apparatus indicated they would exert 0.1, 0.6 and 1.5 bars SMT (Fig. 1). After planting, the SMT values at 0.1 and 0.6 bar were checked with a tensiometer probe and were found to be within 5% of the desired values. (SMT values of 1.5 bars could not be checked because they exceeded the range of the tensiometer.)

The seedlings were planted in the root boxes so that their roots were within 5 mm of the glass to ensure that their roots were as visible as possible. The root boxes were $30.5 \times 15.25 \times 2.54$ cm ($12 \times 6 \times 1$ in.) in internal dimensions and were fitted with 30.5×15.25 cm glass fronts; there were 16 equally spaced 2 mm irrigation holes in the back. After planting the trees the exposed surface of the soil was covered with aluminium foil. The root boxes were then placed in a growth chamber at an angle of 45° with the glass front down so that the length of new roots could be traced on the glass. The growth chamber was programmed to provide 14 hour days at 24°C (74°F), 2 hours of dawn and dusk, 6 hours of night at 15.5°C (60°F) and a minimum of 60% relative humidity. Every 2 days each root box was weighed to determine the amount of water used. This amount was then replaced by the injection of 16 equal quantities through the back of the box. By this method the mean SMC of the soil in each root box could be maintained at the desired level $\pm 0.5\%$ for the 40-day period of the experiment.

Newly developed roots and the extension of old roots were traced on the glass at 4 to 6-day intervals. At the end of the 40-day growth period the seedlings were carefully removed from the root boxes one at a time and the PMS of both the tops and the roots immediately measured with a 'pressure bomb' (Scholander 1965; Pierpoint 1967). The RAI of each seedling root system was then remeasured and compared with the initial RAI measurement to obtain the increment or decrement that had occurred over the 40-day period.

Analysis of covariance was used to determine the significance of the differences between the RAI increments or decrements. Analysis of variance was used to determine the significance of difference between lengths of root elongation and PMS over the 40-day period.

Results

The soil moisture content of the sandy loam

Figure 1. The relationship between per cent moisture content and tension in the sandy loam.

soil used in this study had a tremendous influence on the root regeneration of the 2+0 white spruce seedlings, even though the SMT was kept below 1.5 bars.

Figure 2 shows that the roots of the seedlings planted in soils maintained at 10 and 8% SMC (0.6 and 1.5 bars SMT) decreased in RAI by an average of 1.3 and 2.5 cm^2 , while those at 15% SMC (0.1 bar SMT) increased in RAI by an average of 3.0 cm^2 over the 40-day period after planting. Covariance analysis of initial and final RAIs showed that the difference between the RAIs at 8 and 10% SMC were non-significant, but that the differences between the RAIs at 8 or 10 and 15% SMC were highly significant.

Figures 3 and 4 show the mean daily and mean cumulative root elongation in centimetres of the seedlings grown at 8, 10 and 15% SMC during the 40-day period. Root elongation at 15% SMC (0.1 bar) started 10 days after planting and 10 days before root elongation began at 10% SMC (0.6 bar) (Fig. 4). Peak mean daily root elongation at 15% SMC was also 10 days earlier than at 10% SMC (Fig. 3). Root elongation at 8% SMC was negligible. Figure 5 illustrates the root elongation patterns of typical seedlings at each SMC level. Analysis of variance of cumulative root elongation at 24 days showed that the differences

Figure 2. Change in Root Area Index (RAI) over the 40-day study period.

Figure 3. Mean daily root elongation in mm of white spruce transplanted into soils at 8, 10 and 15% soil moisture content (SMC).

between 8 and 10% SMC treatments were non-significant, but that those between 8 or 10 and 15% SMC treatments were highly significant. Analysis of variance at 40 days showed that the differences in cumulative root elongation were all highly significant.

A regression between RAI increment or decrement and cumulative root elongation of the seedlings at 40 days was carried out to explore the relation between these two measures of RRP. These data were linear and fitted the equation $Y = -9.0 + 5.81X$, well, with $p = <0.0001$ and $r = 0.88$.

Table 1 shows the PMS of the roots and the tops after 40 days at 8, 10 and 15% SMC. PMS appears to be related to the SMC maintained during the 40-day period as both roots and tops increased in PMS with decreasing SMC. Analysis of variance showed that the differences in PMS between the roots and between the tops of the seedlings grown at the three levels of SMC were all significant.

Discussion

This study clearly shows that fall-lifted 2+0 white spruce seedlings planted in soils maintained at 1.5 bars SMT are not able to regenerate roots even though root regeneration potential is high at that season. It is surprising that white

Figure 4. Cumulative mean root elongation in cm of white spruce transplanted into soils at 8, 10 and 15% soil moisture content (SMC).

Figure 5. Mean periodic root elongation of white spruce seedlings after transplanting in soils at 8, 10 and 15% soil moisture content.

Table 1. The mean plant moisture stress (PMS) in bars of the tops and roots of white spruce seedlings 40 days after transplanting into soil maintained at 8, 10 and 15 per cent soil moisture content (SMC).

Part of seedling	Moisture content of the soil		
	8%	10%	15%
Tops.....	26.9	(PMS in bars) ** 19.2 **	9.9
Roots.....	27.1	* 23.4 *	15.3

Note: * and ** indicate differences were significant at 0.05 and 0.01 probability.

spruce planted into soils at a tenth of the SMT associated with wilting is unable to regenerate roots and therefore is predisposed to die. It is even more surprising that white spruce seedlings transplanted into soils at 0.6 bar SMT remained inactive for almost 2 weeks before root elongation began. Had these seedlings been planted in the field during dry weather, rather than in a favorable controlled environment, it is probable that their slow root regeneration response would have predisposed them to die.

It appears that the root systems of white spruce seedlings that are unable to regenerate new roots decline in RAI owing to attrition and decomposition in the soil after planting. In the post-planting period there appears to be a relationship between the maintenance of PMS and RRP. Thus if roots are regenerated water is absorbed and turgor remains high enough for further root regeneration and seedling establishment. If roots are not regenerated and intimate contact with the soil is not achieved, the PMS rises and root regeneration and extension becomes impossible.

The results of this preliminary study of RRP

in relation to SMC suggest that the land to be planted with white spruce should be close to field capacity and must not exceed about 0.5 bar SMT if plantation establishment is to be successful.

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