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Hydraulic Conductance of Roots Present at the Time of Lifting and Newly Regenerated Roots of 2 + 0 Eastern White Pine Seedlings

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Root hydraulic conductivity was measured on eastern white pine (Pinus strobus *L.) seedlings with varying proportions of newly regenerated roots. The surface areas of the tap root, old lateral roots, and newly regenerated roots were measured, and hydraulic conductance per seedling was calculated. Hydraulic conductance was significantly affected by the percent of the root system composed of newly regenerated roots as well as the temperature of the water used in the testing system. An increase from 0 to 25% new root surface is estimated to result in a 123% increase in hydraulic conductance.* Tree Planters' Notes 39(3): 5-8 ; 1988.

Root growth potential (RGP), the ability of a bareroot seedling to grow new roots when placed in a favorable environment, has been often correlated with high survival and increased growth (1, 2), making it a reliable physiological indicator of seedling vigor.

RGP is a good predictor of outplanting success for a number of reasons. First, a seedling with high RGP quickly grows new roots and establishes contact with the soil. Secondly, a seedling with high RGP is a vigorous one that has generally high overall growth potential. A third probable reason is that a seedling with high RGP quickly grows new roots, which may be much more efficient at water and nutrient uptake than the roots present at the time of lifting.

Root hydraulic conductance is a measure of the ability of a root to take up water. Root hydraulic conductance is typically measured by severing the top of a seedling, inserting the root system in a liquid-filled pressure chamber set at a standard pressure, and measuring the amount of liquid that is forced through the severed end of the stem in a standard time interval.

Hydraulic conductance is calculated by dividing the volume of measured liquid by the time interval used, the surface area or weight of the root system, and the pressure units. Roots with high hydraulic conductance provide less resistance to water flow and allow more water to move to the stem than roots with low hydraulic conductance.

It is still not clear if newly regenerated roots are more efficient at water uptake than roots present at the time of lifting (which typically are suberized) and if so, how much more. Chung and Kramer (3) demonstrated that removal of unsuberized roots from root systems on 1-year-old loblolly pine decreased hydraulic conductance but to a degree lower than the proportion of the root system removed. Sands et al. (4) showed that unsuberized roots have substantially higher hydraulic conductance than older roots.

This study was undertaken to determine the relative difference in hydraulic conductivity of roots present at the time of lifting (January) compared with newly regenerated roots. This information will be useful in assessing the relative importance of old versus new roots in seedling establishment after outplanting.

Materials and Methods

Two-year-old white pine seedlings were hand lifted from four locations (blocks) within the Virginia Department of Forestry Augusta State Nursery (Waynesboro, VA) on January 21, 1987. The seedlings were root pruned at 12 cm below the root collar and then placed in a hydroponic system as described by DeWald et al. (5). The blocks were maintained as from the nursery.

Testing of root hydraulic conductivity of the white pine root systems began on February 9, 1987, after the seedlings had time to initiate new roots. Tests were performed at 3- or 4-day intervals to obtain a range in the proportion of new white roots.

On each test date, the root system of one seedling from each of the four original nursery locations was tested for hydraulic conductance. In order to remove potentially confounding age effects, at least one seedling that had no newly regenerated roots was tested on each test date. This resulted in a total sample size of 30.

The top of each seedling was severed 4 cm above the junction of the highest lateral root. The stem surface was covered with high-vacuum grease and then inserted into a piece of rubber tubing. The tubing and stem were then inserted into the lid of a pressure chamber and a pipette was inserted into the tubing. Each root system was then placed in a plastic cylinder filled with tap water located in a pressure chamber.

After chamber pressure was raised to 5 bars, the volume of water flowing through the root systems was measured with the attached graduated pipette. Measurements were recorded at 10-minute intervals until the change in volume over the time interval remained constant for a minimum of four readings, indicating that the system had reached equilibrium. The change in volume at equilibrium was used for calculating hydraulic conductance. The temperature of the water in each chamber was also recorded.

Root surface area was estimated using a LICOR 3000 portable area meter. Surface area was estimated separately for the tap root, the old lateral roots (roots present at the time of lifting), and any newly regenerated lateral roots. Dry weights of the above categories of roots were measured to the nearest 0.001 g after the roots were dried to a constant moisture content at 60 °C.

Linear regression techniques were used in analyses, with root hydraulic conductance as the dependent variable. Independent variables used in the analysis were the percentage of the root system composed of new roots, tap root, and old lateral roots, water temperature at the time of testing, duration of time each seedling remained in the hydroponic system, and nursery block location. Root system proportions were analyzed on both a surface area and dry weight basis.

Results

Hydraulic conductance was significantly affected by both the percentage of the root system composed of newly regenerated roots and the water temperature during testing. The ratio of tap root to old lateral root, duration in the hydroponic system, and nursery block location were all nonsignificant predictors.

Because analyses using root dry weights provided comparable results, all further discussion will refer to analyses using root system surface area.

The best model resulting from linear regression analyses is:

$$\text{Hydraulic conductance } (\times 10^{6}) = -1.252 + 0.109\ (H_2O\ \text{temp.}) + 0.036\ (\%\ \text{new roots})$$

Water temperature and percentage new roots are both highly significant ($P < 0.01$). Observed data and the regression line, using the mean water temperature (18.15 °C) from all test dates, are shown in figure **1.**

Discussion

Results indicate that newly regenerated roots are more efficient in water absorption than the root system present on the seedling at the time of lifting in late January. Using the regression model and the average temperature (18.15 °C) for all tests, a seedling with no newly regenerated roots is estimated to have a hydraulic conductance of 0.73×10^{-6} cm sec^{-1} bar^{-1}, while a seedling with 25% of the root system comprised of newly regenerated roots is estimated to have a hydraulic conductance of 1.63×10^{-6} cm sec^{-1} bar^{-1}. An increase from 0 to 25% new root surface area, therefore, results in

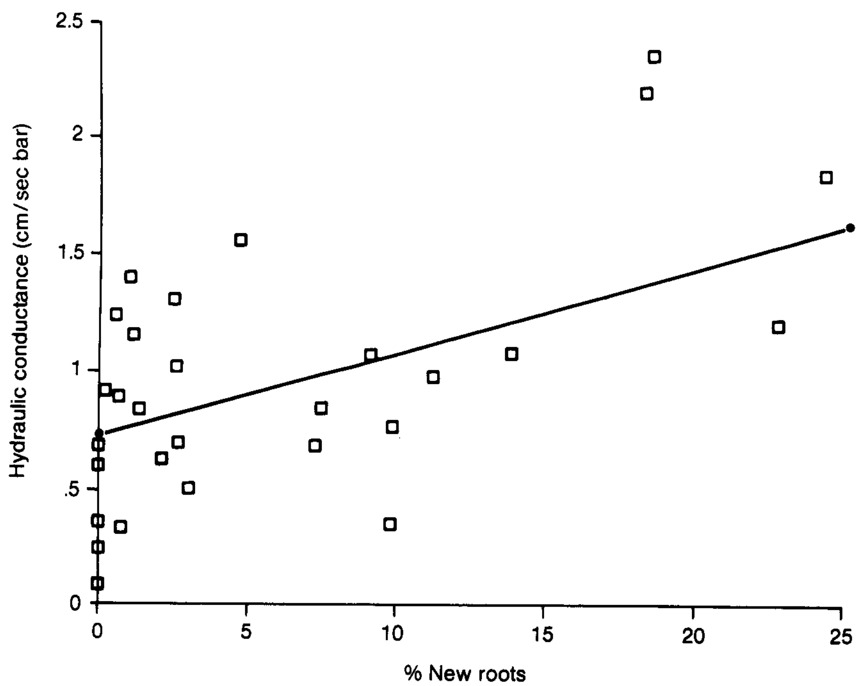

Figure 1—*Relationship of the percentage of the root system comprised of newly regenerated roots on hydraulic conductance of 2+0 eastern white pine. Regression line drawn using mean H_2O temp. of 18.15 °C with model: hydraulic conductance ($\times 10^6$) = $-1.252 + 0.109$ (H_2O temp.) + 0.036 (percentage new roots); $N = 30$, $r^2 = 0.56$.*

a 123% increase in hydraulic conductance. Extrapolation was used to calculate an estimate of the hydraulic conductivity of newly regenerated roots. A root system composed of all new white roots is estimated to have a hydraulic conductance of 4.35 x 10^{-6} cm sec^{-1} bar^{-1}. This would be a 493% increase in efficiency in water absorption in newly regenerated versus old roots. These estimates are comparable to those made by Sands et al. (4) and Chung and Kramer (3) using loblolly pine.

Water temperature of the testing system was a highly significant factor affecting root hydraulic conductance, and this confounds the plot of hydraulic conductance x the percentage new roots (shown in figure 1). This relationship has previously been shown by Sands et al. (4). Kramer (6) also demonstrated that root hydraulic conductance of eastern white pine was highly influenced by temperature and that the range of approximately 15 to 21 °C had the greatest effect. In this temperature range the relationship was approximately linear. The range of temperatures in this study was from 14 to 21.5 °C.

It should be understood that this study was not undertaken to examine the difference in hydraulic conductance between unsuberized and suberized roots, per se, but instead between root systems present at the time of lifting and newly regenerated roots. Newly regenerated roots were largely unsuberized, but the extent of suberization was dependent on length and age. Differences between suberized and unsuberized roots would be expected to be larger than differences estimated between new and old roots in this study.

Furthermore, hydraulic conductance has been shown to be greatly influenced by growing media (3). Because seedlings in this study were maintained in an artificial hydroponic system, estimates of hydraulic conductance may not be comparable to levels occurring in outplanted seedlings. Exact estimates are considered less important than the relative differences between old and new roots.

Root growth potential (RGP), the ability of a bareroot seedling to grow new roots when placed in a favorable environment, has been found to be a useful predictor of field performance in several species in the Pinaceae (1, 2, 7, 8). Results of this study point to the importance of new root growth in increasing the capacity of a eastern white pine seedling to uptake water and thus points to the value of high RGP. Johnsen et al. (9) demonstrated that RGP was a useful predictor of first-year field performance, but that consistency in a seedling lot's ability to grow new roots was more important than average new root production. This relationship was stronger on non-irrigated than on irrigated sites.

Estimates obtained from this study indicate that new root growth does increase hydraulic conductivity but also indicate that roots present on the seedling at the time of lifting can conduct water. In fact, at early planting dates when soil temperatures are not yet conducive to new root growth, old roots must provide all water absorptive surface area. This may also be concurrent with times of lower transpirational demand. As environmental temperatures increase, transpiration increases, old root hydraulic conductivity increases, and more efficient new roots are produced. The relative importance of new and old roots may be dependent on soil temperature, soil moisture levels, degree of contact between old roots and soil, and vapor pressure deficits between needles and the atmosphere.

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