Interrelationship of Seedling Dormancy Status and Media Temperature in Determining New Root Growth Capacity of Northern California Conifer Species

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Objectives: This study was designed to examine how potential for new seedling root growth (i.e., extension of current roots and formation of new roots) is affected by both media temperature and changes in seedling phenology as seedlings transition through the dormancy cycle. Though it has been established that root growth of many conifer species is maximized around 20°C, few studies have examined how media temperature may interact with changes in seedling dormancy status during the period from dormancy induction in fall through dormancy release in spring. Additionally, no studies have examined either of these trends specific to seed sources in northern California. This information will be useful to help match seedling physiological status with site environmental conditions to optimize new root growth immediately following planting.

Procedures: Seedling shipments were received from Cal Forest Nursery (Etna, CA) on 8-14-2004, 9-17-2004, and 11-12-2004. Species included Douglas-fir (single seed source from 1676 m elevation, but with or without nursery blackout treatment), ponderosa pine (seed sources from elevation of 1067 and 1524 m), and California red fir (single seed source, 1676 m elevation). On each date, seedlings of each species/source (5 treatments, 600 seedlings total) were measured for initial root volume, height, and root collar diameter. A subsample of seedlings was evaluated for numbers of new white roots. After initial measurements, seedlings were placed into a hydroponic growing system (Figure 1) to evaluate growth potential over a four-week period. The system is set up as a randomized complete block design with three blocks serving as replications. Each block contains four growing tanks (45.7 cm x 45.7 cm x 30.5 cm), with each tank corresponding to a controlled root zone temperature (10, 15, 20, and 25 °C). Each tank in a block supports ten seedlings per species/source. Water in each tank is pumped through a thermoelectric chiller/heater with set points at each of the four temperatures. Pumping of water from the tank and through the chiller/heater is achieved through the use of small magnetic drive centrifugal pumps connected to polyethylene tubing. Preliminary measurements indicated that water temperature throughout the initial four-week period was within ± 2 °C of each set point. To avoid potential for experimental confounding, supplemental nutrition was not added to the water. The system is set up in a controlled environment growth room, with a 16-hour photoperiod, a constant air temperature of 23.3 °C, and light intensity of 120 $\mu mol/m^2/sec$. Also on each date, dormancy status and cold hardiness for each seed source/treatment were determined by the electrolyte leakage method. Thirty-six seedlings from each seed source/treatment, not used for the growth trial, were used for this procedure. For each treatment, approximately five needles were removed from each seedling and cut into segments 1 cm in length. These were divided into four equal groups. Segments from each group were placed in nine vials containing de-ionized water, with ten segments per vial. The nine vials corresponded to nine test temperatures [2 (control), -3, -7, -11, -15, -19, -24, -29, -34, and -40 °C]. Measurements of conductivity in each vial were made after freezing and autoclaving, allowing calculation of an index of injury at each temperature. Preliminary data from August 2004 showed how the species, seed sources, and blackout treatments differed in dormancy status (Figure 2). This data suggests that 1) high elevation ponderosa pine was more cold hardy than low elevation ponderosa pine, 2) nursery black out treatments increased cold hardiness of Douglas-fir, and 3) California red-fir was slightly more cold hardy than Douglas-fir without blackout.

Obstacles: The exploratory nature and complexity of the experimental procedure presented some problems initially. Foliage of seedlings placed in the system on 8-14-2004 and 9-17-2004 began to turn brown within 3-10 days. Root systems also exhibited high mortality. Seedlings in high root zone temperatures (20, 25 °C) exhibited symptoms faster than those in colder temperatures (10, 15 °C), leading us to hypothesize that aeration was insufficient. Supplemental aeration had not been added for two reasons: 1) water in the tanks was under constant flow through the pumps and thermoelectric system, and 2) fresh water had to be added periodically to keep levels in the tank high. This was apparently inadequate, as indicated by supplemental measurements of dissolved oxygen in non-aerated tanks compared to those in aerated tanks. Dissolved oxygen in non-aerated low temperatures was also higher than non-aerated high temperatures. For seedlings placed in tanks on 11-12-2004, we added a supplemental aeration system consisting of six dual-valve aquarium/hydroponic air pumps connected to the tanks (one line per tank). At the end of each pump line is an aquarium air stone. The air stones release small bubbles of air into the water. This not only brings bottom water to the surface, but releases oxygen directly into the water. Three weeks into the current sampling, we have determined that this modification was successful for both California red fir and ponderosa pine, which appear healthy. However, some of the Douglas-fir seedlings again exhibited foliar symptoms within several days of transplant, and about 60-80 % have been removed from the sampling. Remaining seedlings of all species are exhibiting new root formation and elongation, particularly at higher root zone temperatures. There is also noticeable new root production at lower root zone temperatures, although there has been little root elongation. Growth parameters from this sample will be quantified at the end of the four-week period.

Future Plans: Despite the successes of the most recent round of measurements, adjustments to the current system are being considered. Although California red fir and ponderosa pine do not seem to be negatively affected with our current system, Douglas-fir seedlings still show high mortality, even with supplemental aeration. As noted previously, this occurred fastest in the warmer root zones, indicating a possible deficiency in dissolved oxygen. Plans are underway to mitigate any limitations associated with aeration deficiency. One proposed method is potting seedlings into sealed cylindrical tubes and suspending the tubes in the temperature-controlled water. Root zone temperature would be controlled and oxygen levels consistent across all treatments. However, irrigation presents a logistical obstacle to this method. An individual irrigation regime may need to be developed for each seed source in each root zone temperature to ensure a consistent moisture level in the media. Another option is to use a modified version of our current system to increase aeration. This can possibly be accomplished by using one dual-valve air pump, containing two air stones, in each tank to increase the amount of dissolved oxygen and decreasing the number of seedlings placed in each tank. Alternatively, it may prove most logistical to maintain our current system, which has proven effective for California red fir and ponderosa pine, and emphasize these two species for the remainder of the current experiment. As our system is further refined, we will proceed with original proposal objectives, including 1) making final morphological measurements at the end of each four-week test period, 2) assessment of new root and shoot biomass production, 3) evaluation of dormancy status using the electrolyte leakage procedure and monitoring days to budbreak, and 4) examining photosynthetic efficiency (e.g., rate of photosynthesis and chlorophyll fluorescence) throughout the growing cycle.

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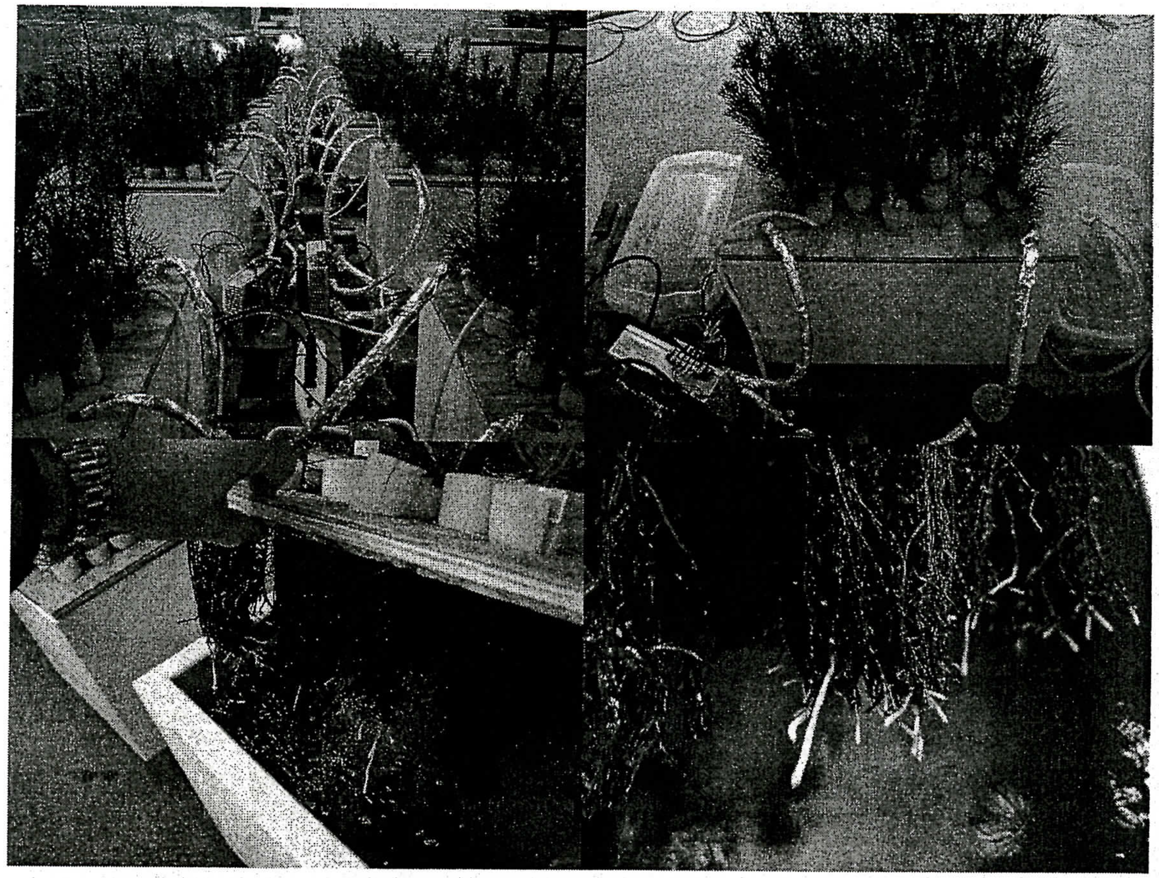

Figure 1. Experimental setup to examine capacity for new seedling root growth as affected by media temperature.

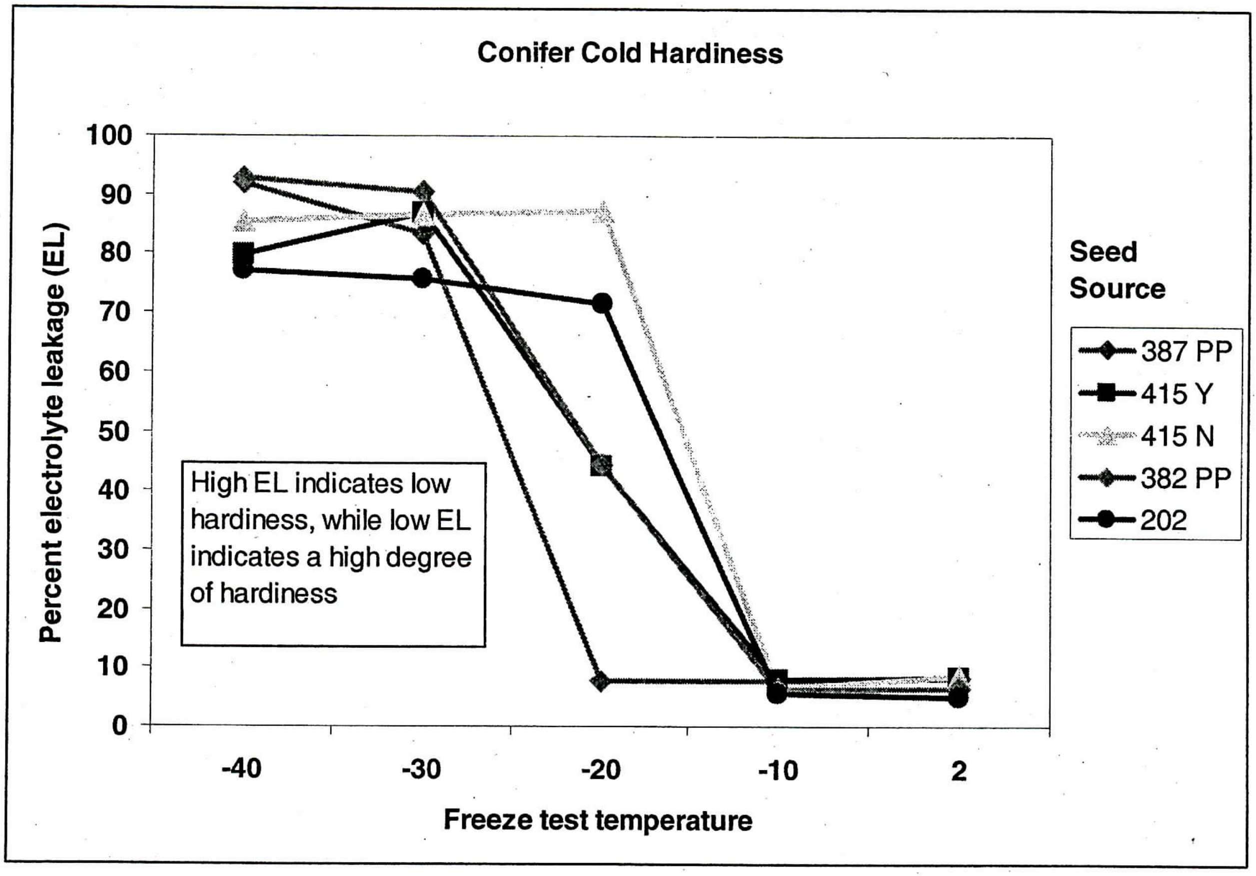

Figure 2. Variation in electrolyte leakage (EL) by species and seed sources as sampled in August 2004. Seed source designations are 387 PP – 1524 m elevation, 382 PP – 1067 m elevation, 415 Y – Douglas-fir (1067 m elevation) with blackout, 415 N – Douglas-fir (1067 m elevation) without blackout, and 202 – Red fir (1676 m. elevation).