Does root pruning containerized stock alter growth rate and development of planted forest seedlings?

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ALRF seed grant report – May 9, 2005

Objectives:

- To evaluate the treatment effect of mechanical root pruning containerized PSB stock using three species and five soil conditions.

- To determine if an optimum range of root pruning exists by comparing growth characteristics including biomass after one growing season against chemical root pruned and uncut styroblock stock.

Summary of Rationale:

Rooting success of a planted seedling is determined by the ability to survive during the vulnerable establishment period as well as to optimize the performance of future growth in varying microenvironments. Root growth performance of a seedling is characterized by excellence in nutrient absorption, carbohydrate storage, and structural support, all of which is governed by the architecture of developing roots. Root systems are, however, strongly modified by the cultural practices of the nursery, the method in which they are planted and the environmental factors of the planted microsite.

Regional and contemporary research recognizes growth and architectural differences with stock types and microsite selection in the initial establishment period. Balisky and Burton (1997) observed reduced lateral root abundance during the first year's growth of pine and spruce stock types. Growth further decreased due to cold soil temperatures associated with microsite in high elevation cuts blocks of interior BC. The MSc thesis of Heineman (1991) compared two years biomass growth of containerized 4-15 spruce stock on a subhygric site with different microsite types. She observed differences in root growth morphology and performance across a microsite treatment array similar to Delong et al. 1997. Both height and root growth increased for lodgepole pine (Krasowski 2003) and interior spruce (Krasowski and Owens, 2000) using box pruned plugs in forest soils. Also noted were morphological rooting differences in the stock type. Unfortunately, benefits of box pruned root systems are at present unused by the industry as a consequence of their prohibitive cost. I propose an experiment that considers the consequence of mechanically root pruning conventional containerized styroblock plugs (415-B).

Root growth of conventional plugs tends to develop towards and converge at the bottom of the plug (Balisky et al. 1995). This growth can best be described as a showerhead spray of root egress orientated with poor lateral development. Such architecture is more prevalent in lodgepole pine as they are generally less able to form adventitious roots; those being roots that emerge from differentiated parenchyma cells in the cambium of root pericyle (Sutton, 1980). Another problem inherent with containerized stock comes from roots twisting and kinking as they are deflected down the ribbed wall of the container. Deformities may reduce the hydraulic flow with disrupted tracheids in the xylem. Impedance in the translocation of sugars within the sieve cells of the phloem found in root deformities promote blockages and subsequent growth to exaggerate around a constriction (Hay and Woods, 1978). Root deformation is also exacerbated by improper tree planting technique where the plug is compressed or deflected a vertical orientation.

In the central interior, root plug is often planted such that the bottom is located deep within mineral soil where environmental conditions are often cold, wet, and dense. Surface soils, however rich in aerobic activity and nutrients are also more abundant in root competition and have a higher likelihood of drying out in the summer. Thus, rooting egress that balances lateral and bottom root growth with a minimum of root deformation in a vertical and radial symmetry pattern is considered optimum.

I hypothesize that root pruning containerized seedling stock while reducing the total initial root length and total number of initial root tips within the plug will initiate greater lateral and surface root development. Also I aim to determine if an optimum level of root pruning exists. As levels of pruning increase, I expect to observe reduction in tree survival, top growth, and total rooting abundance.

Indeed soil conditions vary and an interaction of pruning with soil condition may be found such that warm and well draining areas may have a different optimum than cold wet ones. At best, a practical silvicultural treatment of mechanical root pruning may exist that does not compromise top growth losses yet enhances rooting performance for a given soil type. Thus I aim to understand how root development is altered over a range of soil conditions in order to substantiate best treatment practices specific forest operations.

Method:

(Two experiments are proposed for this thesis but this report will be limited to the first of the two objectives. The second objective will begin May 2005)

Containerized styroblock 4-15B tree seedlings of three species – Douglas Fir (Fd- *Pseudotsuga menziesii* var *glauca*, Hybrid Spruce (Sx-*Picea glauca* Voss. *x engelmanii* Perry) and Lodgepole Pine (Pli- *Pinus contorta* Dougl. var. *latifolia* Engelm.) were collected from PRT nursery Red Rock on May 18th 2004. Trees were sorted to reduce variation using the mid range for height and diameter. Growth abnormalities were culled. Two pruning treatments were conducted on the 14.9 cm long, 3.5 cm diameter plug (volume 93 ml): Rp1- bottom 2 cm cut , Rp2- bottom 2 cm cut and two perpendicular insertions of a 1.5 cm wide knife 3 cm apart (roughly at 4 and 7 cm from top), C- uncut control. Criteria for root pruning were two fold: plug must remain intact capable of tree handling, and that knife insertions were blind to the root system and operational in standard. Experimental design of this field trial acknowledged initial stock type differences by isolating and matching replicates with similar height and diameter. As a replicate group (three individuals) was established, they were randomly allocated to pruning treatments (C, Rp1, Rp2), then colour coded with straps around the stem, collectively wrapped in a moistened paper towel and returned to their box where they were stored at two degrees until time of planting.

Table1. Stock type details and initial seedling measurements from soil surface just after planting.

Species	Stock Type	Seed Lot	Number (measured)	Height (mean ± sd)	Diameter (mean ± sd)
Fd	PSB 415b	00861	188	23.1± 3.2	3.3 ± 0.56
Pli	PSB 415b	14910	261	15.6 ± 3.4	2.9 ± 0.58
Sx	PSB 415b	61147	407	24.0 ± 2.8	3.5 ± 0.48

A soil treatment array was established as plots on Block 1 at the Aleza Lake Research Forest that followed a toposequence along a gradual slope. Plots were laid to capture contrasting soil moisture and nutrient regimes. The treatment array developed as such: deactivated sandy skid trail (ROAD), sandy slash burn piles (BURN), rotten logs of decay class 4 and 5 (WOOD), moderately drained upland silty forest floor (UPFLOOR), and poorly drained lowland clay forest floor (LOWFLOOR). Prior to planting, a pig tail marker was used to triangulate the centre of three selected microsites for each replicate group. Microsites established were roughly 1 meter apart. This effort was made to minimize possible error associated with microsite differences within each treatment group.

On May 21, 2004, trees were planted according to duff planting guidelines such that slash and thick non decomposed litter was removed. Trees were planted by myself eliminating inconsistency of planting method. No special sensitivities were given to the planting method such that trees were planted with the vigour found in an operational setting. Consideration to planting shovel was consistently inserted in an east to west orientation such that soil compaction associated with opening the hole and the possibility of rooting restriction caused by the shovel could be examined. Trees were planted systematically for species and randomly for treatment groups. Random planting of the treatment group involved blindly grabbing a treatment group (C, Rp1, Rp2) wrapped in a moistened paper towel from the planting bags and placing it on the ground and blindly extracting one per microsite. Twenty replicate groups per specie were established on the ROAD and BURN soil types while thirty six replicates were used for UPFLOOR, LOWFLOOR and WOOD, respectively.

Non-destructive root windows were installed for spruce C and RP2 seedlings replicated three times per soil type for a total of 36 windows. This involved pounding into the soil a metal plate with a sharpened end at a rough distance of 10-12cm from planted tree such that the observation plane would face north. Carefully this was removed and replaced inserting a plexiglass window 50cmX35cm. Then, to observe, the window, soil is excavated leaving a portion of the plexiglass retained by the soil. Thus a viewing area of 45X30cm is achieved. Chronosequences of rooting have occurred using digital photography and by tracing roots on colorless film.

As summer progressed vegetative competition accelerated and it was decided to brush a 50 cm radius by hand pulling (uprooting) and clipping using shears. This was carried out on July 28, 2004 such that ingress of competing vegetation would not dampen top growth, affect winter survival via snow press, and maintain a more uniform vegetative level across replicates within a soil type. Vegetative competition rank was established and a survey of vegetation was conducted prior to the brushing. Because of the varied shrub and herb types a rank system was devised to assess the tree's status with respect to competition such that all trees could be compared. For example thick herb (100% vegetation cover) would be analogous in rank to 60% shading of shrub.

Table 2. Vegetation rank class (0 – 5) within a 50 cm radius

Rank	Description
0	- up to 5% vegetation cover, no canopy interaction with tree
1	- up to 30% vegetation cover, or 20% shading effect on tree
2	- up to 60% vegetation cover, or 40% shading effect on tree
3	- up to 100% vegetation cover, or 60% shading effect.
4	- 80% shading effect. Tree is still competitive.
5	- overtopped with 100% shading. Growth likely suppressed and deformed (multiple leaders, stem curvature, and reduced branching).

Tree survival was surveyed at mid summer and again in October where survival was part of the seedling vigour assessment after a series of hard early frosts.

Table 3. Tree vigour assessment.

Rank	Description
Good	- Lamas growth, multiple leaders, some previous year needle loss
OK	- Frosted or reddened needle tips, crown yellowing, slight frost damage, abundant needle loss of previous year.
Poor	- Heavy frost damage, yellow or reddened needles, little growth, stepped on (by moose), extruded plug, heavy needle loss of current year
Dead	- Yup.

Trees were measured for first year's top growth characteristics of leader, height, diameter, and average mid-leader needle length before the onset of spring growth (April 12^{th} to 15^{th} 2005). Growth characteristics were analyzed using SYSTAT (version 10.2) testing across species, treatment and soil. Relative Growth Rate, a conventional variable in plant sciences, was analyzed for each species across treatment and soils. Relative growth rate (RGR) was determined for height, diameter, and height to diameter ratio for all of the sample population. For example RGR for height after the first year was calculated as: RGR H = (ln(final height) - ln(initial height))/1 year.

Soils are also being characterized according to plot. Soil temperatures are being logged with three prong thermocouples using Campbell Scientific Data logger measured at -5, -12 and -30 cm depth as well as +30 cm air temperature. Instantaneous temperature surveys on a mid-sunny summer day will identify variability within plots. Soil moisture is being measured gravimetrically at upper third (0-10 cm) and lower third (20-30cm) using a narrow 30cm soil core. Sampling of composites is being employed one per stratified quadrant per soil type consisting of 4 cores. Thus, seasonal moisture is calculated from 16 cores per soil plot. Composite soils are weighed in tins then oven dried at 70°C and reweighed. The difference is the loss of soil water.

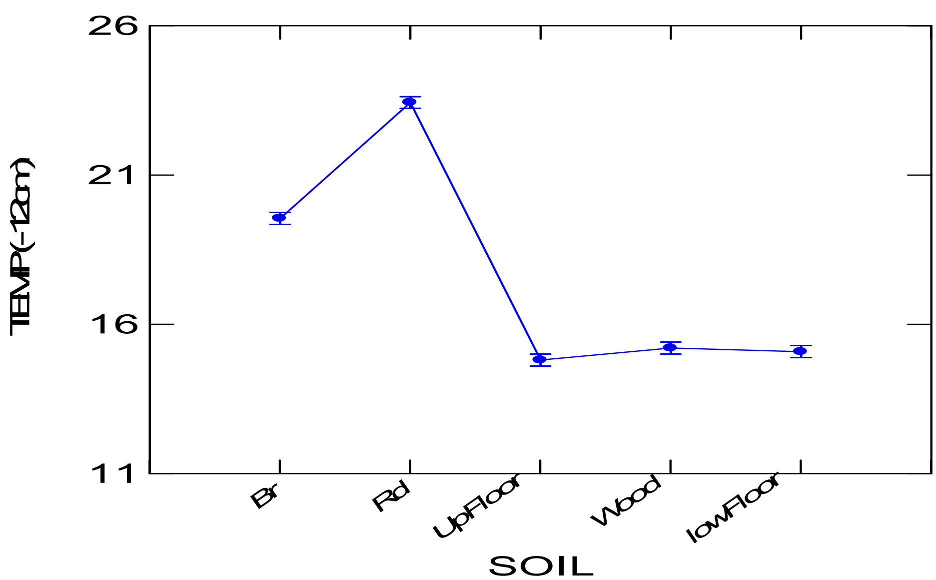
Gravimetric results, percent mass of soil water per unit mass of soil, are obscure without understanding soil density. Thus, they will be calibrated according to average bulk densities observed from 7 replicates within each soil type layer (upper 10cm, and lower 20-30 cm). Bulk density is measured by core method in 0-10cm, 10-20cm, and 20-30cm depths. Thus moisture content can be calibrated to volumetric moisture content by multiplying average bulk density with corresponding moisture content. In this way a soil conditions are analyzed for temperature, moisture and density to 30cm. This represents a significant portion of a seedlings rooting depth. Other soil measurements to be undertaken include soil nutrients and texture, average top soil thickness (forest floor humus form, decayed wood, or ash), as well as a general soil profile including humus form description per soil type.

Results and Discussion:

- Instantaneous soil temperatures

Results showed statistical differences ($p < 0.05$) across soil types when a temperature probe (Thermor ps100) was inserted next to each spruce replicate per soil type N=228, on a hot and sunny afternoon in June 24, 2004 (14:00-15:00). Air temperature was observed to be 28.5 °C.

Figure 1. Mean and standard error of instantaneous soil temperatures measured at -12 cm



Interestingly, the ash layer in the burn soil acted to dampen soil temperature of the subsoil, similar to that found in the Road. Its light grey colour causes a higher albedo than the sandy road resulting in slightly reduced top soil temperatures (-5cm) (data from temperature loggers not shown here). Indeed surface ash and the loose aerated charcoal layer just below it have a lower heat capacity and conductivity than sand alone. Organic matter in the forest floor and well decomposed wood show that they act well to dampen and insulate subsoil regardless of texture as shown with no differences in these treatments.

- Gravimetric soil moisture

Surface soils (0-10cm) generally had low levels of moisture fluctuation even though 2004 was considered a dry year. Surface wood and burn soils showed greater range of moisture loss. Lower burn subsoil also has restricted replenishment of rain water with the reduced conductivity of the ash and mineral surface. Thus, rain moisture tended to perch in the ash without percolating sub soil as noted in the summer and fall measurements. Thus Burn subsoil was most prone to dry out followed by Road. Upland silt showed that it can perch water and is generally quite wet. Lowland soils are saturated at a shallow depth throughout the year. In the lowland, the April measurement had deep puddles of standing water within the plot. Decayed wood showed that is has a very high moisture retention capacity. Table 4 shows percent mass of soil water to mass of oven dry soil (70°C) for upper and lower soil layers measured at different times of year, attempting to capture the range of moisture conditions: summer (dry), fall (wet), and spring (wet). August was indeed the driest time observed in 2004.

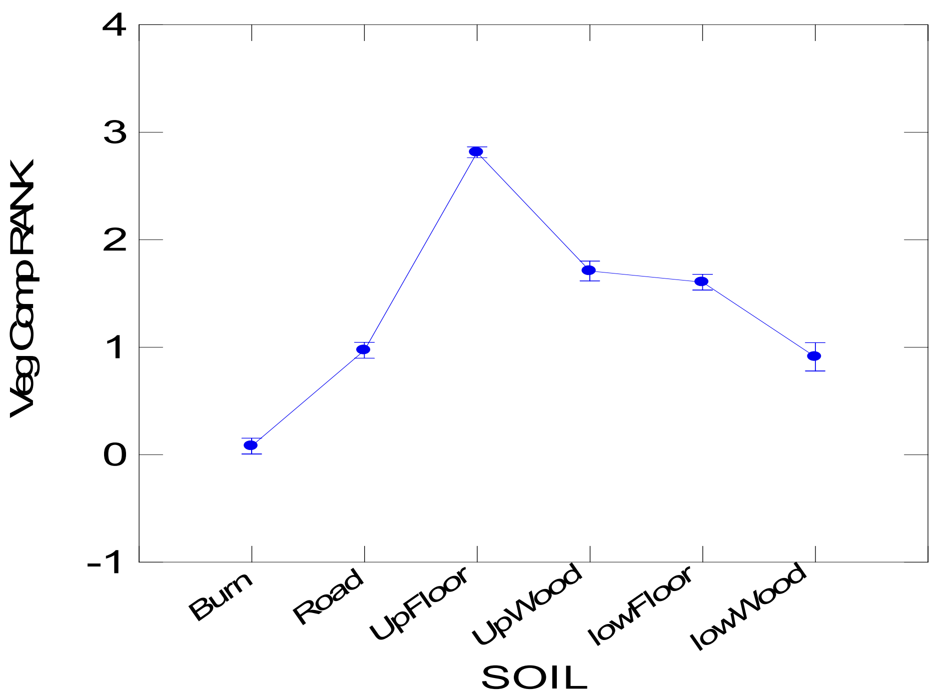
Table 4. Percent mass fraction of soil water measured at four time periods

Soil Type		Aug 18	Aug 28	7-Oct	27-Apr
Road	Upper	8	9	12	12
	Lower	10	8	16	17
Burn	Upper	8	9	21	15
	Lower	13	12	13	14
UplandFloor	Upper	34	31	49	45
	Lower	30	29	34	36
UplandWood	Upper	128	181	269	243
	Lower	31	36	34	45
LowlandWood	Upper	133	169	172	293
	Lower	28	31	38	35
LowlandFloor	Upper	49	40	57	58
	Lower	30	32	33	36

- Vegetative Competition

Vegetative competition showed statistical differences across treatments ($P < 0.05$). Indeed upland forest floor was the most competitive among tested soil types while the burn soil was the least. Decayed wood microsites showed much lower vegetative competition and prove to be favoured to forest floor. Lowland forest floor due to its wet water regime, had more sporadic and herbaceous cover. Road competition was similar in species to upland but less abundant.

Figure 2. Mean vegetative competition rank and Standard Error across soil types N= 875



- Survival

During vegetative competition survey, of July 28/2004, three of 1025 trees had died. No further analysis was made owing to the small number of deaths. Mercury plummeted on August 21, 2004 registering - 4 °C on the data loggers. In an October survey of the fall frost damage, no obvious additional mortalities were observed; the stocks, however, did suffer. Doug fir showed 27% of the sample population to be ranked in poor condition, while spruce showed only 1% and pine 2%. Mortality of many of these individuals is expected by spring flush of the 2005 year.

Doug fir stock showed several variations and combination of damage to the buds, needles, and stems. Figure 3 shows frost damage of an individual's stems but not needles. Figure 4 shows frost damaging needles but not stems. Interesting too was that much of the other shrub and herbaceous vegetation showed the signs of early summer frost damage; geraniums, ferns, and devils club leaves were dead black. Thimbleberry, Mountain ash, Douglas maple, and Vibernum shrubs were also hard hit. In sharp contrast, twinberry, rose, raspberry, birch seedlings, and Cornus showed no ill effect of the frost. Frost must be a strong agent in the transformation of forest species from sheltered forests to open clear cuts.


Fig 3 & 4. Fd showing contrasting effect of the August 21 frost damage to top growth of Doug Fir (pictures taken on October 12th, 2004)

- Root windows

Root windows were confounded by separation from the sandy soil profiles, air pockets and soil horizon disruptions. However, root window investigation proved worth while despite that windows restrict and distort the orientation of growing roots. Also any air pocket along the glass changes the nature of the root morphology from its inherent pattern dictated by the soil. Indeed, rooting was markedly different according to soil type. As early as in August, individuals in the sandy road had explored the entire window, while roots have yet to be observed in the lowland forest floor. By October, much of the soil was wet and water table was perching in the upland at about 30-50 cm depth and lowland plots at about 7-20cm depth. Note the blackened and likely dead root in the upland window picture (figure 9). Also note that mild fall conditions had root tips still growing albeit at a lower rate than observed in

August as seen in figure 4. By October 12, 2004, the activity of growing white root tips was greatly reduced which, when excavated this spring, windows showed roots to be dark and dormant right to the root tip. This spring, root burst occurred with a warm front that brought soils at -12 cm depth to be above 9°C. While surface soils were warmer and root growth seemed accelerated at the surface, this did not limit growth of tips buried deeper in the profile. The following are demonstrative pictures of the soil types.

Figure 5. Root window in slash burn soils. Note ash layer and absence of vegetative competition

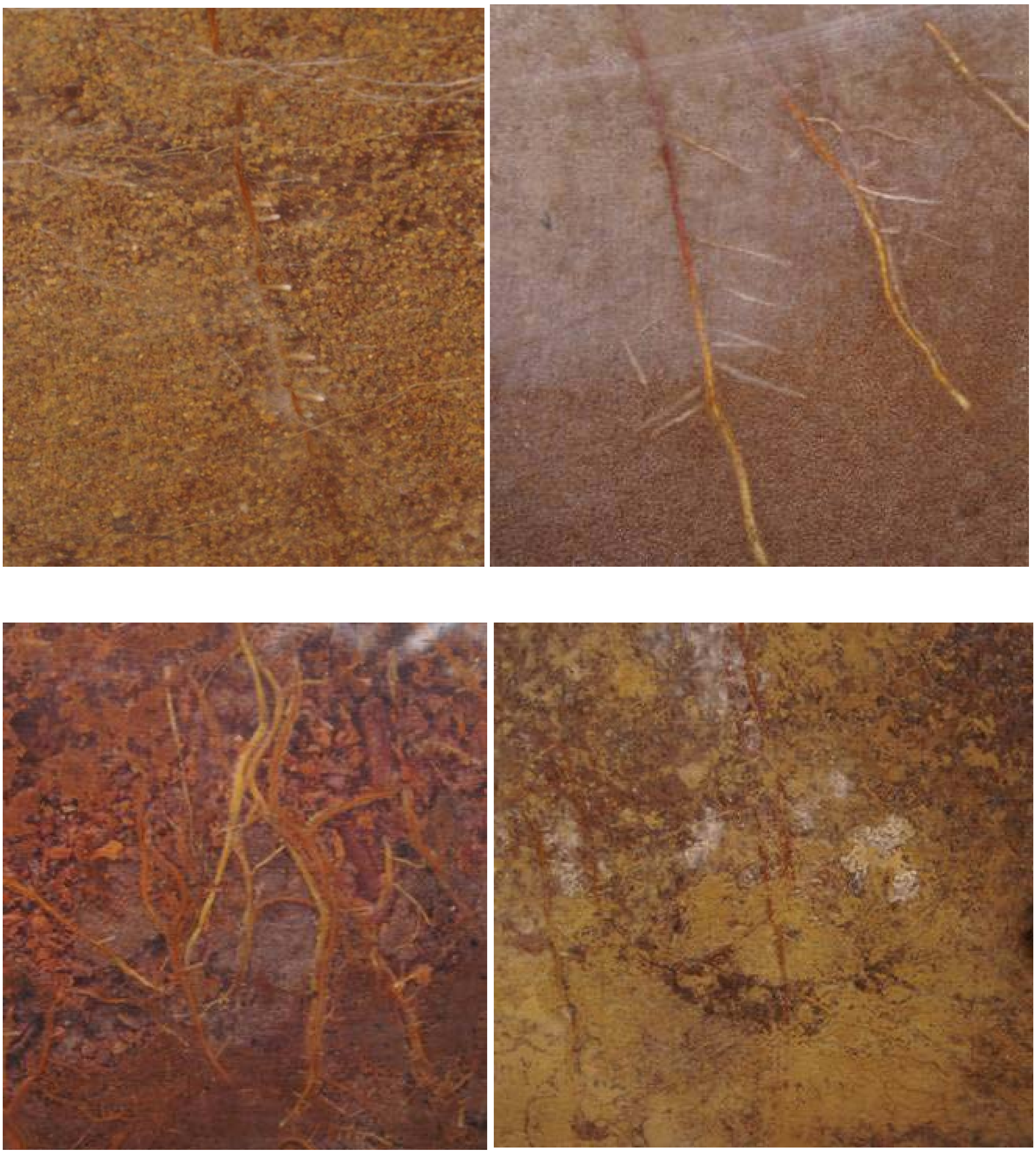
Figures 6 & 7. Burn spruce control (rep1) Left - Aug. 10, Right- Oct.12

Figures 8 & 9. Root windows of Oct 12, 2004. Left – Road; Right – Upland Floor

Figures 10&11 (Below), Root window picture of Oct. 12, 2004. Left- Wood, Right- Lowland Floor (no roots observed yet).

Branching pattern differences was well observed across soil type as seen in the figures 12-15. Wood rooting is intensive and branchy in the nutrient poor substrate while roots in the sandy road are well spread out and far reaching, covering lots of ground to extract limited supplies of water and nutrients. The burn with a similar water regime to the sandy road has a higher nutrient regime. The high nutrient availability is what appears to modify the spruce roots to elongate their feeding branches. In the abundance of both nutrient and moisture as in the upland forest floors, roots are much slower to develop with fewer roots exploring the windows.

Figures 12, 13, 14,& 15. Spruce root development patterns across the varied soil types tested (clock wise from upper left): sandy road, sandy slash burn, upland forest floor (over silt), upland decayed wood (over silt).



- Tree measurements: First year's growth.

Although replicate treatment groups wrapped in a paper towel were blindly picked from planting bags, SYSTAT detected a statistical difference in the initial height and diameters across the soil types for both pine and spruce. This being noted, a taller or larger initial tree size is likely to grow more than a smaller one regardless of treatment. For this reason relative growth rates of height (RGR H), diameter (RGR D), and height to diameter ratio (RGR H/D) are used. For height, as an example, this value represents per centimetre growth relative to its initial per cm height over the year. This is a more conservative analysis than leader height differences.

Statistical analyses of RGR Height separately for each species, across pruning treatment and soils showed varied results. Even when statistical differences were found ($P < 0.05$) mean value differences are small. Indeed second year results may broaden these apparent differences. For RGR Height, Doug Fir showed soil related differences, while pine showed no differences and spruce showed significant differences across treatment and soil. In the case of RGR Diameter, Doug fir and pine showed soil differences while spruce showed pruning treatment and soil differences. Finally, RGR Height to Diameter ratio showed similar results to RGR Diameter. The general trend for pruning treatment in spruce was that height growth was taller for Rp1 than C and Rp2, while C to have greater growth in diameter. Thus, height to diameter growth had lower C and Rp2 values to Rp1. Soil differences showed stronger trends than the treatment.

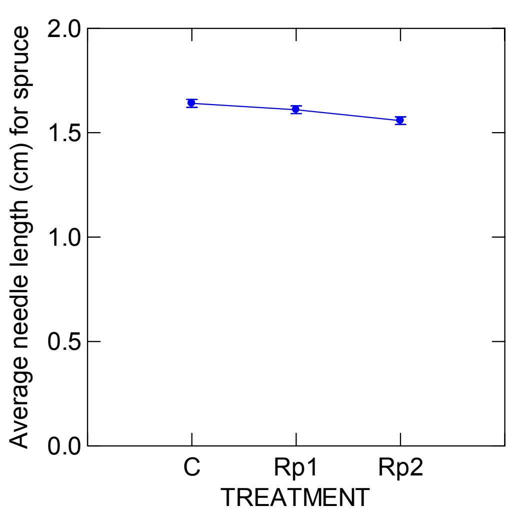
Soil trends were diverse and growth interacted with species preferences. A treatment X soil interaction proved significant when testing a three way ANOVA with treatment, soil and species. Doug fir grew tallest in the burn and poorest on the road. Upland forest floors were very close to road but intermediate between the two in the three soils tested. This does not come as a surprise as burns have a high base saturation and higher pH than typical forest soils (Arocena and Sanborn 1999). Doug fir has been shown to be sensitive to low pH and poor nutrient regime.

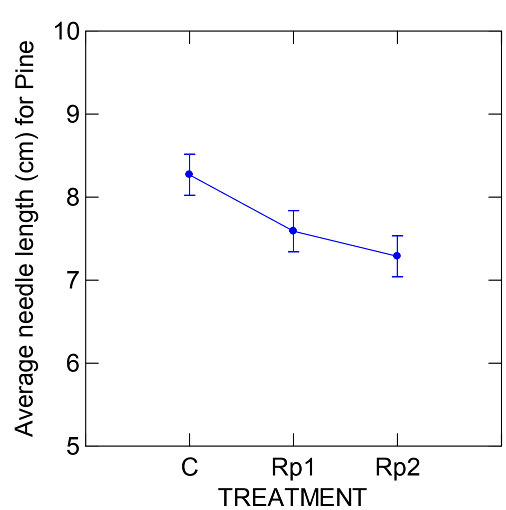
In contrast, pine showed no strong differences in height in the four soils tested. However, diameter was enhanced in the lowland forest floor, followed by burn, then road and upland forest floor. Thus, height to diameter ratios showed road and upland forest floor to have the greatest relative height to diameter growth. A high height to diameter means taller and or skinnier. Indeed the upland forest floor microsites in the presence of cooler soils and high shading effects of vegetative competition are likely the causes of altered morphology to tall and skinny. Spruce showed slight but significant differences in relative height growth. In the six soils tested, height followed the order upland forest floor = decayed wood > burn > road >> lowland forest floor. The lowland forest floor trees look yellow and poor due to the anaerobic subsoil conditions. In diameter growth, seedlings in burn soils were fattest; the seedlings also have the highest height to diameter ratio. Thus, burn soil followed a similar trend for all species as being one that shows reduced height growth (in pine and spruce but not fir) and favours greater diameter growth. This makes strong differences when coupled as height to diameter ratio.

An interaction between species and microsites showed that in lowland forest floors, pine is more vigorous than spruce. Operationally, I suggest planting pine in lowland forest floors and spruce on elevated microsites, like decayed wood where they appear much more vigorous. It is important however that the tree planter recognizes the difference between decay classes. Decayed wood microsites were very suitable microsites for spruce at Aleza Lake where climate is moist enough throughout the summer to evade these elevated microsites from drying out. Neither pine nor Doug fir were tested in decayed wood.

- Average mid-leader needle length

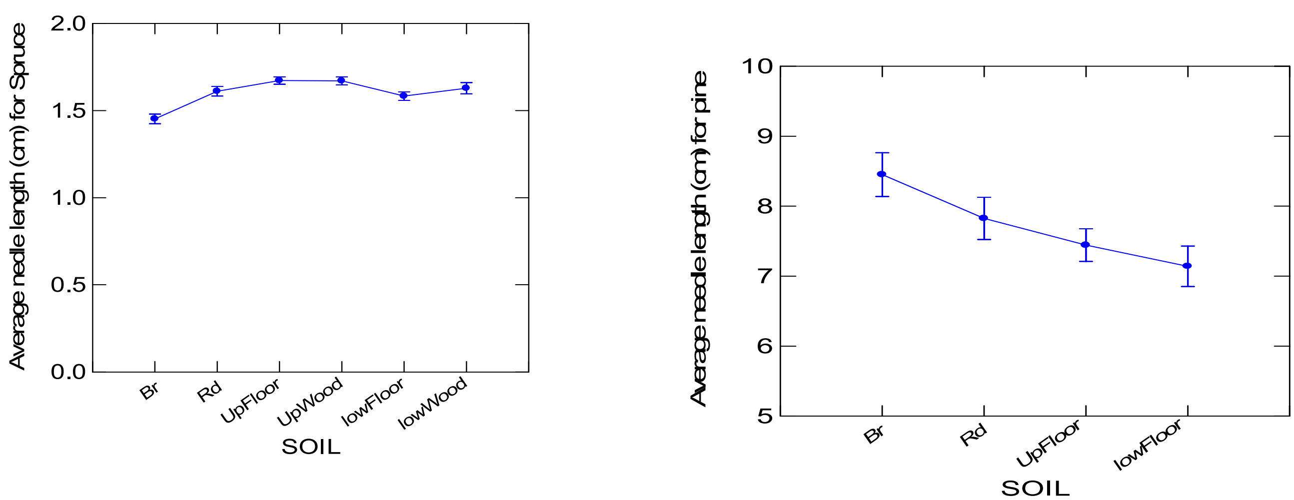
Figures 16 & 17. Average Mid-leader needle length and Standard Error of the mean for pine (N=277) and spruce (N=431) against treatment types.





Needle length is partly controlled by the tree's water relations at the time of cell elongation in the early part of spring. A significant difference for both pine and spruce was detected and the difference was consistent across the two species measured. The Doug fir was too badly damaged by frost to be measured. What the above suggests is that root pruning advanced initial water stress in the plants across all soil types. Indeed soils also proved to show significant differences with needle length as shown in the figures below. Note the species and soil interaction differences in needle length below. Here the trees species acted in opposite of each other.

Figures 18 & 19. Average Mid-leader needle length and Standard Error of the mean for pine (N=277) and spruce (N=431) against soil types tested.



Concluding remarks

Rooting variables of total abundance, symmetry, and thickness of emergent roots partitioned by rooting zone will be examined to determine if pruning alters rooting pattern and morphology root egress across treatment, species and soil type. Expected rooting differences across pruning treatments are to show greater abundance of roots emerging out of the upper plug as compared to uncut control. I expect also that soil treatments to strongly modify root development pattern acting as the master variable to root development and growth. Pruning treatment and species may be nested within these soil differences. Indeed root branching pattern is likely to have interactions with soils and species pattern and may help explain which soils each species is best adapted to. Lodgepole pine, hybrid (interior) spruce, and Douglas fir are the species under investigation. However, as a result late August frost, the Douglas fir stock was badly damaged, and will be investigated early this spring rather than wait for the final investigation in August. This may prove to be a blessing in disguise, as this broadens out the sampling period and allows for alteration in method of analysis for the other two species.

Having dug up a reasonable amount of the pruned stock I see positive differences with the treatment but they still look rather bunched before busting out. I feel I can enhance better lateral root growth and further reduce root deformities with alternative pruning techniques to the ones tested here. This concludes this report. In closing, I would be very grateful for any funding opportunities that exist or comments regarding this research work. I can be reached at the University of Northern British Columbia at tel. 960-5673, of by email: devakhurana@yahoo.com .

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