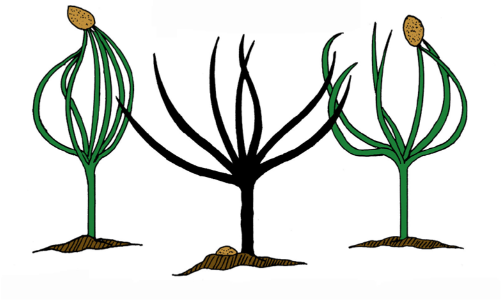
Center for Forest Nursery and Seedling Research

Annual Report 2018



Editors:
Lauren Goss & Lori Mackey

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Annual Report No. 1
University of Idaho

University of Idaho
Center for Forest Nursery
and Seedling Research

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Table of Contents

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Effects of Site Preparation on the Long-term Growth of Interior Douglas-fir and Western White Pine

Jonathan R. Cherico and Andrew S. Nelson

Introduction

Inland Northwest forests are frequently regenerated with tree planting to meet state mandates, promote desired tree species composition, and ensure prompt reforestation. In 2014 across the state of Idaho, more than 4.9 million tree seedlings were grown and 3,625 ha of land were planted with trees (Hernández et al. 2015). Competition with hardwood, shrub, grass, and forb natural regeneration limit resource availability for artificially planted conifer seedlings, potentially reducing survival and growth (Löf et al. 2016; Oester and Fitzgerald 2016). Silvicultural treatments prior to planting or during the early stages of stand establishment can be applied to improve individual tree and stand productivity throughout the rotation. Site preparation, which removes competing vegetation and establishes more favorable soil conditions at the seedling microsite, is often implemented to inhibit planted tree resource competition. (Lowery and Gjerstad 1990).

This project used stem analysis to recreate trends in height and diameter growth in response to different site preparation treatments. Stem analysis is often performed when a record of past tree growth is desired and temporal height and diameter data is not available for individual trees (Kershaw et al. 2017).The objectives of this study were to (1) examine temporal trends in stem growth for western white pine (Pinus monticola Dougl. Ex. D. Don) and interior Douglas-fir (Pseudotsuga menziesii var. glauca), (2) to determine the growth response of these two tree species to different site preparation treatments throughout a 35-year period, and (3) to understand the impact of neighboring tree competition on present growth trends.

Methods

Site Description and Experimental Design

In 1982, two study sites were established 21 km northeast of Priest River, Idaho on the USFS Priest River Experimental Forest. The low elevation “Fire Weather” site lies on a flat alluvial bench at 715 m in elevation. This site is characterized by a Tsuga heterophylla/Clintonia uniflora habitat type, and is representative of less favorable growing locations within the moist forests of the Northern Rocky Mountains (Harvey et al. 1997). The mid-elevation site, “Observatory Point”, was clearcut in 1981, with all harvesting debris being piled and burned in 1982. The Observatory Point site is located at elevation of 1456 meters, with slopes ranging from 10-35% (Page 1985). The habitat type is also represented by Tsuga heterophylla/Clintonia uniflora, but is subject to less extremes in temperature, and is representative of higher productivity forests of the Northern Rocky Mountain region (Cooper et al. 1991).

A restricted randomized design at Fire Weather, and a randomized complete block design at Observatory Point were installed in 1982. Three site preparation treatments and an untreated control were applied in 30 m planting rows. The low elevation site consisted of four blocks planted continuously as one plot, whereas the mid-elevation site consisted of three isolated but nearby replications, each having similar slope, habitat type, soil, and aspect (Page-Dumroese et al. 1997). Treatments applied include: (1) scalping, in which the uppermost 10 cm of organic material and mineral topsoil were removed with a tractor crawler, (2) soil bedding without chemical competition control, (3) soil bedding with chemical vegetation control, and (4) an untreated control in which minimal soil disturbance was applied. Each treatment row is 1.5 meters wide, with beds approximately 46 cm high. The chemical vegetation control treatment consisted of band application of glyphosate to non-coniferous vegetation in the second and third years of the study at a rate of 1.68 kg per hectare, and manual competition removal in the planting year. Scalped organic material and mineral topsoil were used to create the raised beds (Page 1985).

In April 1983, 1-0 container stock seedlings of western white pine and interior Douglas-fir were planted at both sites. Each replicate treatment had seedlings planted on 31 x 46 cm spacing, or 218 seedlings per treatment row.

Field data collection

Prior to destructive sampling, both sites were inventoried to determine the number of remaining trees in each treatment replication. Diameter at breast height (DBH), treatment row, and tree count within row were recorded for all trees. Site inventories in 2017 identified 360 study trees, with 219 trees present at Fire Weather and 141 trees at Observatory Point. Trees were grouped into DBH quartiles by site, species, and treatment. One to two trees from each site, species and treatment diameter quartile were randomly selected for destructive sampling.

Each subject tree selected for destructive sampling next had a series of neighboring tree measurements recorded in order to formulate an index of neighboring tree competition. The eight closest neighboring trees in each cardinal direction were selected for these neighborhood measurements. Neighboring tree measurements included distance between neighbor tree and subject tree, neighbor tree crown radius towards and away from the subject tree, neighbor tree height to base of live crown and total height, and cardinal location of the neighbor tree relative to the subject tree.

After all neighboring tree measurements were recorded at a site, trees were destructively sampled for stem analysis. Each subject tree was felled. Once the subject tree was successfully felled total tree height and height at the base of the live crown were then recorded using the measuring tape. Stem disks were harvested at 0.15, 0.76, and 1.372 meters up the stem, followed by disks at every 0.914 m after breast height, as well as at the base of each live crown section.

Laboratory sample processing and analysis

Disks were sanded to expose tree rings. Once all disk samples from a subject tree had been processed, disks were scanned with WinDendro™ (Regent Instruments Inc., Quebec CA) software at 1200 or 1600 dpi. Radial increment was recorded at two paths per disk, either at a 90° angle or at both the largest and smallest radii in order to account for variability in stem growth. XLStem (Regent Instruments Inc., Quebec CA), generated temporal stem growth data, including cumulative height, diameter at breast height (DBH), and stem volume, in addition to height, DBH, and stem volume annual increment.

Results

Age, species, site, and treatment all had a significant effect on cumulative height, DBH, and volume growth (Table 1).

Table 1. Analysis of variance for age, site, species, and treatment effects on temporal trends of height, DBH, and volume cumulative growth

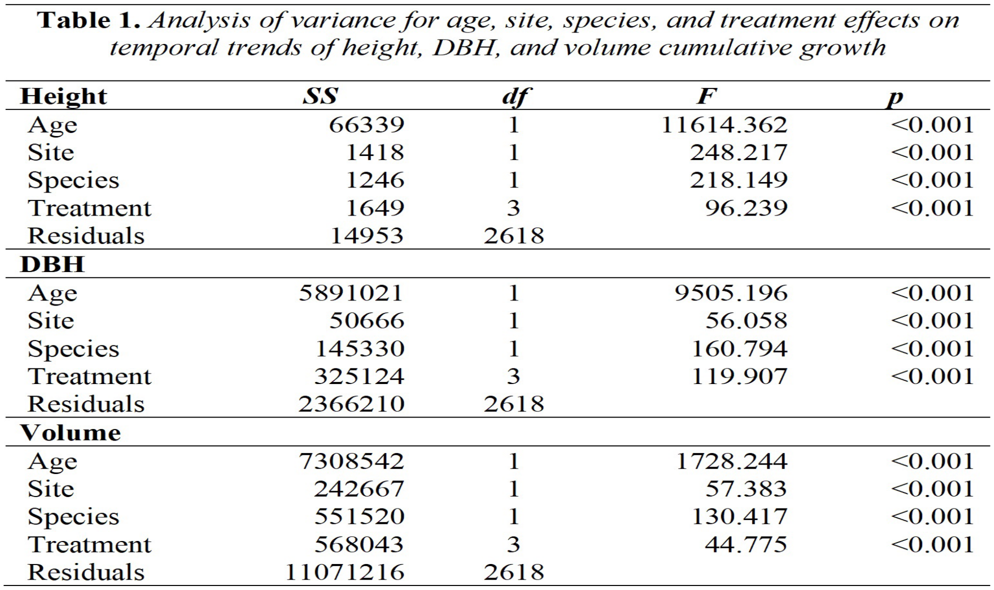

Table 1. *Analysis of variance for age, site, species, and treatment effects on temporal trends of height, DBH, and volume cumulative growth*

Height	*SS*	*df*	*F*	*p*
Age	66339	1	11614.362	<0.001
Site	1418	1	248.217	<0.001
Species	1246	1	218.149	<0.001
Treatment	1649	3	96.239	<0.001
Residuals	14953	2618		
DBH				
Age	5891021	1	9505.196	<0.001
Site	50666	1	56.058	<0.001
Species	145330	1	160.794	<0.001
Treatment	325124	3	119.907	<0.001
Residuals	2366210	2618		
Volume				
Age	7308542	1	1728.244	<0.001
Site	242667	1	57.383	<0.001
Species	551520	1	130.417	<0.001
Treatment	568043	3	44.775	<0.001
Residuals	11071216	2618		

The only treatment that produced substantial gains in height growth was the herbicide plus bedding treatment (Figure 1). All other treatments showed minimal gains over the untreated control. The trend in treatment differences was similar between sites and most noticeable for Douglas-fir. Western white pine's response was more site specific, where the scalping treatment had a deleterious effect on height growth at Fire Weather and herbicide+bedding produced substantial gains at Observatory Point.

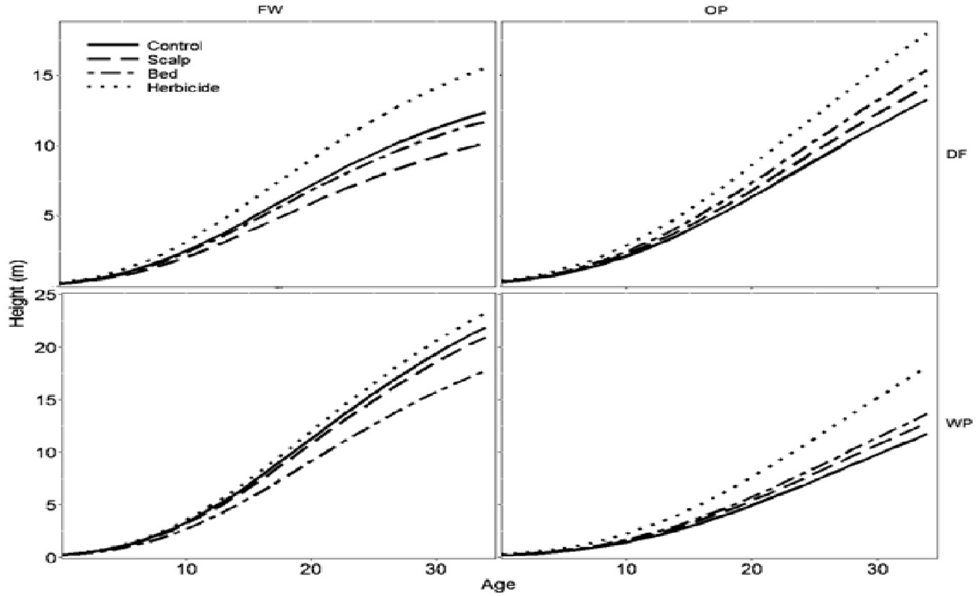

Figure 1 Predicted temporal height growth by site, treatment, and species

A similar response was found in diameter growth over time between the two species (Figure 2). The major difference was the minimal difference among treatments for Douglas-fir at Observatory Point. Based on the growth response of all trees at that site it is possible that the site had suitable conditions for the species that did not require intensive site preparation. Comparatively, western white pine diameter exhibited a positive response to site preparation. These results help in the application of precision silviculture to tailor specific treatment to particular site conditions to maximize growth.

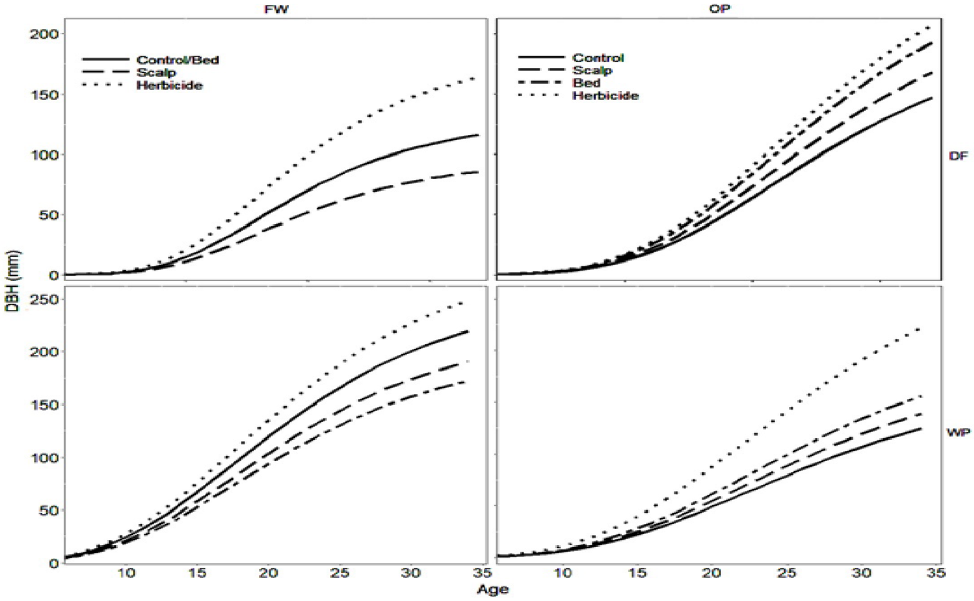

Figure 2 Predicted temporal DBH growth by site, treatment, and species

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Biomass Allocation of Inland Northwest Conifer Seedlings in Response to Root Growth Potential and Site Characteristics

Jacob A. Reely and Andrew S. Nelson

Introduction

Plants acquire water and nutrients from the soil via the root system, and structural carbon is created in the shoot of the plant via photosynthesis. The Optimal Partitioning Theory (OPT) states that a plant will allocate biomass to whichever organ acquires the most limiting resource because there is an evolutionary tradeoff between allocation of biomass to above- and belowground structures. Global patterns of biomass partitioning and intraspecific variation in biomass partitioning patterns of plants have been shown to be consistent with the OPT (Gedroc et al. 1996; McCarthy and Enquist 2007). According to the OPT if water or nutrients are limiting resources then plants will allocate more biomass to the root system. However, if light is the limiting resource then the allocation of biomass will favor shoot growth. Therefore, the relative allocation of biomass towards component structures (e.g. foliage, roots, stem) provide information as to how a plant is responding to the environment.

Seedling quality is generally described in terms of growth and survival on a particular planting site (Duryea 1985). Wakeley (1954) identified that any seedling quality assessment should be based on morphological and physiological characteristics of seedlings. Accurate assessment of seedling quality includes measures of morphological and physiological characteristics of seedlings, and the seedlings' response to a given planting environment (Ritchie 1984). Physiological metrics of seedling quality include root growth potential (RGP), cold hardiness, and leaf gas exchange, among others. RGP evaluates a seedling's ability to grow roots in a favorable environment, such as a mist chamber or potted in a greenhouse. While RGP does not account for the range of environmental conditions a seedling is exposed to when planted, RGP testing provides results that help nurseries and landowners rapidly screen seedlots that may exhibit poor field performance. Additionally, seedlings that are able to quickly grow new roots when planted in a new environment will overcome the stress of transplanting more quickly than a seedling with reduced root growth, as it is more quickly "coupled" with the new environment (Grossnickle 2005).

The influence of seedling allometry, RGP, and site characteristics on seedling survival have been explored, often by isolating a single factor. However, little research has been conducted to quantify the relative contribution of these factors on the field performance of planted conifer seedlings. Using western larch, interior Douglas-fir, and grand fir as study species, the specific objectives of my overall thesis were to: (1) develop species-specific seedling allometric models; (2) investigate the temporal effects of soil moisture, soil temperature, and RGP on morphology and biomass partitioning; and (3) investigate how the early seedling survival on different sites was influenced by biomass partitioning, environmental conditions, and RGP. This report present results on the modeling of biomass partitioning, and effects of RGP and site characteristics on seedling height-to-diameter ratio and root-to-shoot ratio.

Methods

Various Douglas-fir, grand fir, and western larch seedlots were tested for RGP in aeroponic mist chambers at the University of Idaho Center for Forest Nursery and Seedling Research Lab in spring 2016. Seedlots were grown at various nurseries across northwestern U.S. and western Canada. All seedlings were grown in Beaver Plastics 8L Styroblock containers (Stuewe & Sons Inc., Tangent, OR). Seedlings were stored in a freezer with temperature of -2°C until the time of RGP testing.

The study was installed on PotlatchDeltic Corp. land ~4.72 km east of Bovill, Idaho (elev. ~975 m) (Figure 1). The site was a western redcedar habitat type (Cooper et al. 1991). The stand was clearcut harvested in 2013 with no additional management until seedlings were planted.

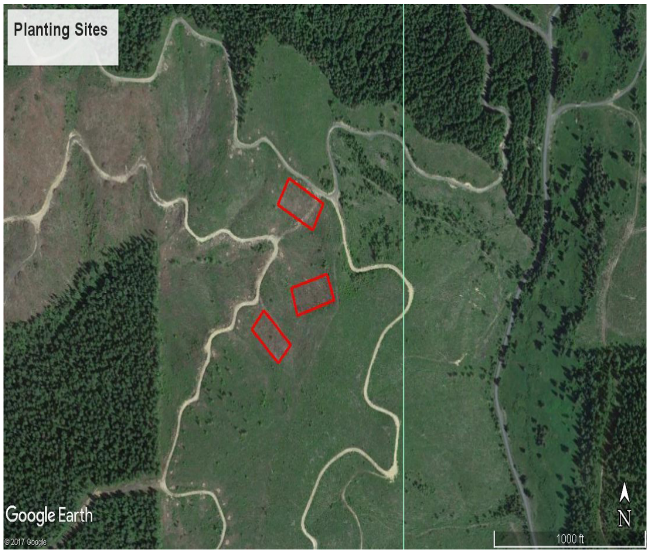

Figure 1. Aerial photo of planting sites.

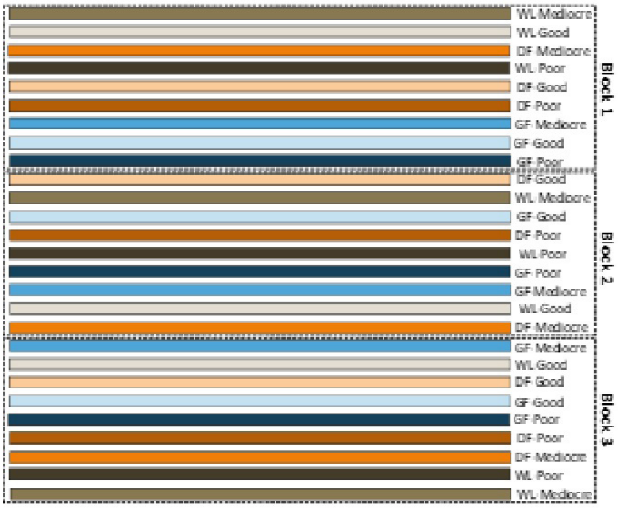

Figure 2. Experimental design at the North Aspect site. Each row contained 60 seedlings (30 for each of two seedlots) from three RGP ratings (Poor, Mediocre, and Good) for three species

The experiment was installed on three sites with hypothesized differences in moisture and temperature regimes: (1) north aspect, (2) north aspect with supplemental watering, and (3) south aspect. Seedlings of each species were planted in a completely randomized block, split-plot design with three blocks (Figure 2). Seedlots were the split-plot factor, while RGP rating was the whole-plot factor. Each species x RGP rating combination was replicated three times at each site. Species x RGP combinations were randomly assigned to one row within a block (3 blocks/site); blocks were based on slope position (upper, middle, lower slope). For each row 30 seedlings of a single seedlot were planted along the contour of the slope, spaced 1.22 m x 1.22 m; in the same row, another 30 seedlings of the paired seedlot were planted along the same contour creating a split-plot factor of seedlot-within-block.

Site Treatments

One week before planting, a broadcast application of glyphosate herbicide was applied to all three sites to control existing vegetation. The treatment applied glyphosate at a rate of 2.8 kg. active ingredient (a.i.) per hectare mixed with 2% (v/v) nonionic surfactant in water using a CO2 powered backpack sprayer (Bell-spray Inc. Model 4F). Standing woody vegetation was hand-cut and moved off-site. On July 12, 2016 a 5% concentration direct application of glyphosate was applied to the south-aspect site using Birchmeier Iris® backpack sprayers due to high abundance of bracken fern. Some seedlings were incidentally damaged by herbicide and were removed from the analysis. On September 6, 2016, the north-aspect site with the supplemental watering treatment received 3,406 l of supplemental water. *Data Collection and Analysis*

Soil moisture and temperature were measured within each block for two growing seasons using Em50 data loggers and 5TM soil moisture and temperature sensors (Meter Group, Pullman WA) (Figure 3). Sensor were installed at depths of 15 cm and 50 cm. Variability in logging debris was accounted for by inserting sensors in areas of high slash loading and low slash loading within each block.

Seedling height was measured from the ground line to the tip of the terminal leader and diameter was measured at ground line of field planted seedlings in June, August, and October of 2016. While measuring seedlings survival was also recorded along with animal damage.

Every-other seedling within a row was reserved for randomly-selected destructive harvesting during 2016. Seedlings were sampled in June, July, September, and November 2016. Before harvesting height and diameter were measured and then seedlings were excavated from a 0.13-m3 hole (0.30 m radius, depth of 0.46 m). Soil was removed from the seedling's roots then separated into aboveground and belowground components and dried to constant mass (65°C for ~72 hrs.). The aboveground and below ground biomass were weighed; aboveground biomass was separated into woody and foliar components and weighed separately.

Statistical Analyses

Species-specific non-linear allometric models were fit to biomass measurements of destructively sampled seedlings using the power function. Allometric models were developed using the nlme package (Pinheiro et al. 2016) in R, using seedlot-within-site as random-effects. Biomass models were used to predict component biomass and R:S of non-destructively sampled seedlings measured throughout the first growing season. Individual seedling changes in morphology and differences in component biomass partitioning across the first growing season were used as response variables in species-specific linear, mixed-effects, repeated measures regression models to examine the influence of RGP, soil temperature, and soil moisture. Analysis was performed using R package "nlme" (Pinheiro et al. 2014).

Figure 3. Soil moisture and temperature sesors were installed in each of the 9 blocks across the 3 sites
Photo Credit: Andrew S. Nelson

The probability of an individual seedling surviving to the end of the second growing season after planting were used to examine the influence of RGP, average 2016 and 2017 growing season soil temperature and soil moisture, and seedling R:S at the end of the first growing season. Significance was assessed at the $\alpha=0.05$ level.

Results

Woody stem biomass, foliar biomass, and root biomass were all positively correlated with stem diameter for each species, while height was only correlated with western larch root and woody stem biomass (Table 1). Parameter estimates for a given biomass component differed substantially among species. For example, for a 3 mm diameter seedling, the models predicted foliage biomass of 1.1 g, 2.2 g, and 2.6 g. for western larch, Douglas-fir, and grand fir, respectively. Including seedlot-within-site as a random effect improved the fit of all models and reduced model error except for the models of western larch foliar biomass and grand fir root biomass. In general, models were strongest for western larch explaining over 80% of the variance, while the poorest fitting models were Douglas-fir and grand fir foliar biomass.

Table 1. Power coefficients for predicting biomass components (BC) from diameter (*D*, mm) and height (*H*, cm) for individual species.

	coefficients						
BC (g.)	a	b	c	R^2 fixed	R^2 random	RMSE fixed	RMSE random
WL_{RB}	0.007 (0.003)	1.293 (0.146)	0.900 (0.154)	0.84	0.88	0.502	0.432
WL_{FB}	0.114 (0.018)	1.841 (0.076)		0.81	0.81	0.822	0.822
WL_{WB}	0.004 (0.002)	1.443 (0.097)	1.155 (0.119)	0.92	0.94	0.876	0.785
DF_{RB}	0.272 (0.054)	1.328 (0.112)		0.60	0.65	0.608	0.585
DF_{FB}	0.932 (0.186)	0.797 (0.118)		0.32	0.58	1.007	0.795
DF_{WB}	0.159 (0.032)	1.816 (0.110)		0.73	0.75	0.817	0.788
GF_{RB}	0.215 (0.075)	1.655 (0.214)		0.49	0.49	0.762	0.762
GF_{FB}	0.818 (0.212)	1.049 (0.165)		0.36	0.53	0.931	0.799
GF_{WB}	0.168 (0.046)	1.847 (0.167)		0.65	0.70	0.630	0.580

** Model form is y = a * D b * H c or y = a * D b ; Species are indicated with two-letter code; western larch (WL), Douglas-fir (DF), grand fir (GF). Biomass components are indicated in subscripts; root biomass (RB), foliar biomass (FB), woody biomass (WB). Standard errors in parentheses.*

Seedling sturdiness, measured by H:D, and R:S showed somewhat consistent trends within a species, but the species differed in their response. H:D and R:S of western larch were negatively correlated with soil temperature and time, while only H:D was positively correlated with soil moisture (Tables 2-3). This compares with Douglas-fir, where soil temperature was not correlated with H:D and only weakly correlated with R:S. Interestingly, Douglas-fir H:D showed a strong positive correlation with soil moisture. Grand fir H:D was not correlated to either the main effect of soil moisture or the interaction of soil moisture and time. However grand fir R:S exhibited a strong negative correlation with the main effect of soil moisture and was also negatively correlated to temperature and the interaction of temperature and time.

Table 2. First growing season H:D (cm/mm) parameter estimates for western larch, Douglas-fir, and grand fir seedlings.

	western larch		Douglas-fir		grand fir	
Parameter	Value	Std.Error	Value	Std.Error	Value	Std.Error
(Intercept)	11.382	0.386	7.849	0.255	-	-
RGP	-	-	-	-	0.264	0.020
Temp.	-0.220	0.024	-	-	0.043	0.022
VWC	2.468	0.485	1.575	0.429	-	-
Time	-0.829	0.124	-0.488	0.222	-	-
RGP x Time	-0.014	0.006	-	-	-	-
Temp. x Time	-	-	-0.047	0.018	-0.041	0.003
VWC x Time	-	-	-	-	-	-

Table 3. First growing season R:S (g./g.) parameter estimates for western larch, Douglas-fir, and grand fir seedlings.

	western larch		Douglas-fir		grand fir	
Parameter	Value	Std.Error	Value	Std.Error	Value	Std.Error
(Intercept)	0.338	0.009	0.320	0.008	0.465	0.009
RGP	-	-	-	-	-	-
Temp	-0.003	0.001	0.003	0.000	-0.005	0.001
VWC	-	-	-	-	-0.073	0.009
Time	-0.037	0.007	-	-	0.082	0.007
RGP x Time	< 0.001	< 0.001	< 0.001	< 0.001	-	-
Temp x Time	0.002	0.001	-	-	-0.005	0.001
VWC x Time	0.024	0.006	-0.008	0.004	-	-

The odds of western larch seedlings further surviving to the end of the second growing season were negatively related to the average growing season soil temperature in the second year (Table 4), while the odds of a grand fir seedling surviving the second growing season was positively related to the average second growing season soil moisture content. The odds of Douglas-fir and grand fir seedlings further surviving the 2017 growing season were positively related to seedling R:S at the end of the first growing season.

Table 4. Second growing season survival parameter estimates for western larch, Douglas-fir, and grand fir seedlings

	western larch		Douglas-fir		grand fir	
Parameter	Value	Std.Error	Value	Std.Error	Value	Std.Error
(Intercept)	6.9936	2.0206	-	-	-7.759	2.472
2016 VWC	-	-	-	-	-	-
2017 VWC	-	-	-	-	10.144	5.047
2016 Temp.	-	-	-	-	-	-
2017 Temp.	-0.2562	0.1229	-	-	-	-
RGP	-	-	-	-	-	-
R:S	-	-	7.9944	0.4379	19.682	5.455

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Stand Structure and Understory Diversity of Western White Pine Plantations

Brooke Durnin and Andrew S. Nelson

Introduction

Western white pine (WWP), Pinus monticola, is found in the Cascade, Sierra and Interior Northern Rocky Mountains of the western USA. Before the 1860s these white pine type forests made up 25- 50 percent of the 2 million forested hectares in the Inland Northwest (Harvey et al. 2008), with the greatest abundance in the Inland Empire, that includes northern Idaho, eastern Washington, western Montana and southern interior British Columbia. The loss of WWP from white pine blister rust (Cronartium ribicola) and salvage harvesting during the 20th Century has altered historic stand dynamics and associated ecosystem processes. Without WWP, Harvey et al. (2008) claim that the forest ecosystem will be less productive and unstable, due to increased susceptibility to fire and insect damage, while also providing less watershed protection and carbon sequestration potential (Harvey et al. 2008). These late successional species are also more susceptible to root diseases, insects, and other disturbance such as drought, wind or fire (Neuenschwander et al. 1999).

A robust, well-funded blister-rust genetics program began in the 1960s that continues today. This began when Richard Bingham, from Spokane, Washington noticed healthy trees in blister rust-infected stands, suggesting natural resistance in WWP (Fins et al. 2001). Richard Bingham and other colleagues showed evidence of genetic blister rust control by crossing two disease–free trees. In 1957, Bingham crossed his more resistant seedlings together and started a breeding orchard on the campus of the University of Idaho. The resulting seedlings were the F2 generation and tests showed that after inoculating the seedlings with blister rust, 66 percent were still free of blister rust cankers after 2.5 years (Fins et al. 2001). This seed orchard has produced more than 200 million seeds since 1970 (Fins et al. 2001).

Reintroduction of disease-resistant WWP was widespread in the 1980s through the early 2000s on private, state, and federal lands. Most often, WWP was planted in monoculture plantations. Many of these plantations still exist yet we know very little about how WWP mortality and stand dynamics have influenced structure and composition of the trees and the understory floristic diversity. Therefore the objectives of this research are to (1) evaluate stand structure and tree composition of western white pine stands planted in the early 1990s across northern Idaho, and (2) examine understory floristic diversity of restored western white pine stands in relation to canopy characteristics and overstory species composition across northern Idaho.

Methods

Twenty-three stands were measured in summer 2018 on the Idaho Panhandle National Forests, Priest Lake and Coeur d'Alene Ranger Districts as well as private stands owned by PotlatchDeltic Corp. and Stimson Lumber Company (Figure 1). Stands were selected to meet the following conditions: 50% by WWP stem number, average stem diameter greater than 5-inches and reasonably accessible by road.

Plots were designed using a similar structure the to the USFS Forest Inventory and Analysis plot structure (FIA 2018). The first plot was located by entering the stand and randomly pacing 100 yards towards the stand center, throwing a stick/flagged pin to select exact plot center. The subsequent plots were located 120 feet away (slope distance) at azimuths of 0, 120 and 240, shown in Figure 2 (compass declination set to 14 degrees East). It was important to ensure all four plots were within the stand boundary and not in a drainage, old landing or skid trail. Each of the large tree plots were 1/20th acre (26.3-foot radius) where all trees greater than or equal to 5 inches DBH were measured. At each large tree plot the slope (%), aspect (degrees), and habitat type, if not already determined was recorded.

The species and DBH (diameter at breast height at 4.5 ft, to the nearest 0.1 inch) of each live tree (5-inch DBH and greater) was recorded. It was noted if WWP trees were pruned and presence of blister rust. Heights and crown heights were subsampled within the large tree plots. Starting at North and moving clockwise, the height of two trees of each species that were representative of the stand was chosen for height and crown height, measurement to the nearest foot.

To evaluate canopy openness, canopy cover was estimated using a tube densitometer. A cloth tape was laid across the plot North-South with another cloth tape across the plot East-West. Starting at 0 feet, canopy openness was recorded every 5 feet along the North-South tape. Along the East-West tape, starting at zero light presence was recorded, and then recorded at 5 feet to the North, repeated until 30 feet was reached. Then we switched to stepping South of the tape. Light presence was recorded at 30 feet, then 5 feet south of the 30-foot mark on the tape

A small tree (1/300th acre) plot was nested within the center of each large tree plot where all seedlings and saplings taller than 6 inches but 4.9 inches DBH and smaller were measured. The species and height class of all trees between 6 inches in height and 4.9 inches in diameter were recorded in the small tree plot.

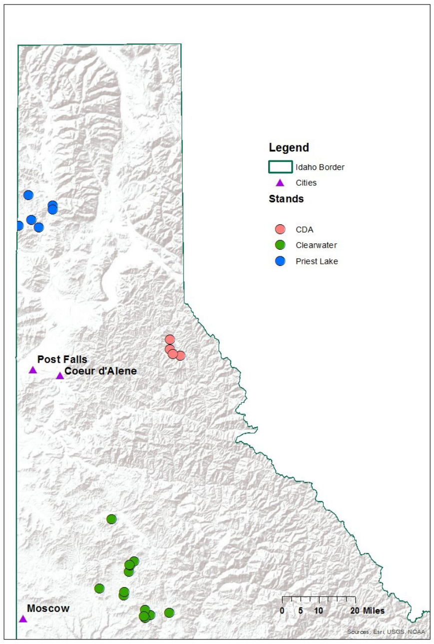

Figure 1. Location of the stands measured in 2018, by region: Pink (Coeur d’ Alene), green (Clearwater) and blue (Priest Lake).

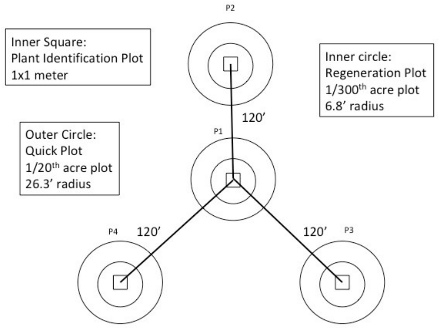

Figure 2. Nest plot layout used to measure stand structure and understory diversity in each stand.

A plant ID plot was established near the large-tree plot center. The corner of a 1x1 m plot was adjacent to the plot center, with a second corner facing North, resulting in the plot being in the northeast quadrat of the Small and Large Tree Plots. All species within the 1 x 1 m plot were identified to the species level except: Rosa spp., Viola spp., Epilobium spp. and grasses. The 1 x 1 m plot includes all species within the 1 x 1 m dimensions as well as 6 feet above the ground. Percent cover of the species was recorded to the nearest 5%; 1% indicating a trace. The average height of each shrub (to the nearest half foot) was recorded.

Results

Most stands had an average of 50% or greater western white pine (Figure 3). Data collection in 2019 will target stands with less than 50% western white pine so we can examine if understory diversity varies with less white pine in the stands.

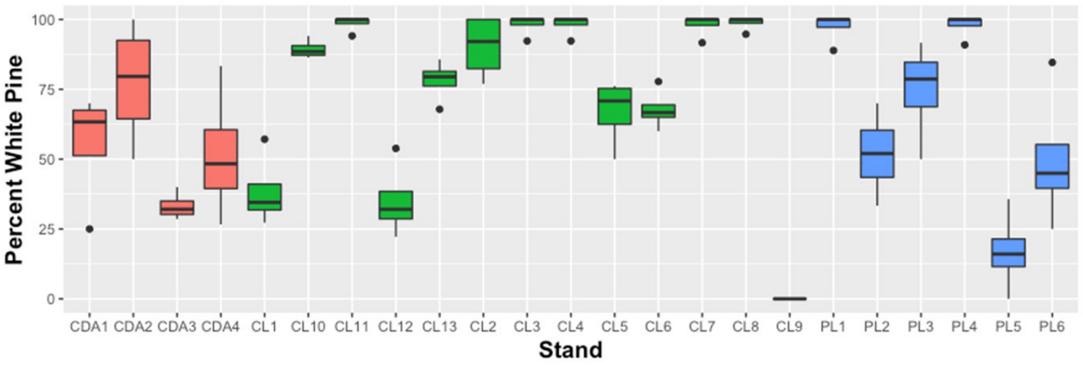

Figure 3. Percent of western white pine in each of the 23 stands measured in 2018.

Species richness (total number of species), and percent understory cover were positively correlated with the percent of western white pine in the overstory (Figure 4). Species richness and percent understory cover were negatively correlated with trees per acre and crown cover. The results show, that it is possible that the overstory stand characteristics of western white pine modifies the understory environment in a way that increases floristic diversity and understory cover. This may be due to an increased amount of light getting through the porous western white pine crown and reaching the forest floor. Canopy cover and total trees per acre within the western white pine stands lowers the percent understory cover and species richness. This is evident by the negative relationship (Figure 4). This is most likely due to lack of light reaching the forest floor, modifying the understory environment in a way that decreases floristic diversity and richness.

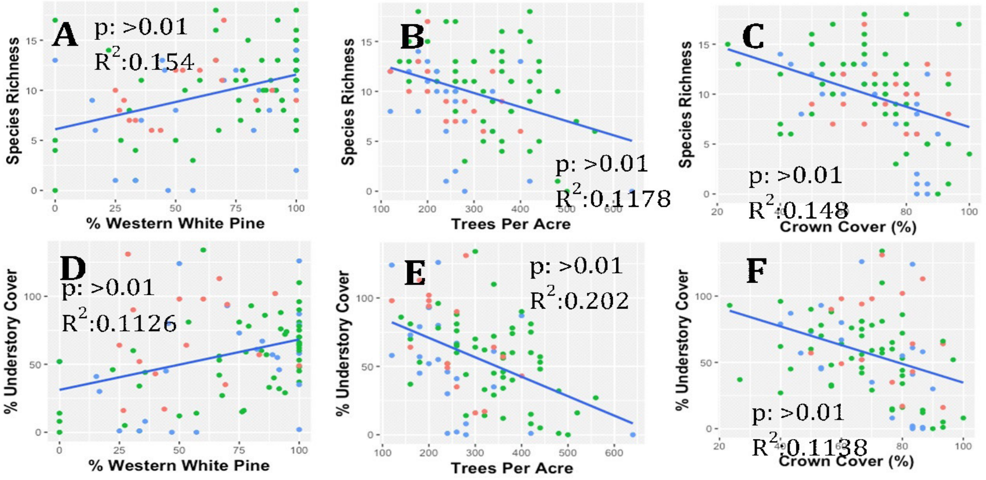

Figure 4. Linear regressions of species richness and percent WWP within the stand. Colors of dots follow the locations shown in Figure 1

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Response of Improved Western Larch Seedlings to Dought Stress and Site Quality

Kelsie M. Grover

Abstract: Improved western larch (Larix occidentalis) seedlings from seven half-sibling families and one bulk orchard lot were planted across three sites located throughout the Idaho panhandle and tested against varying site qualities. Plots were set up in a completely randomized block design with three replicates within each site, with seedlings planted operationally to mirror realistic commercial scales. Environmental data was collected throughout the growing season, including volumetric soil moisture, soil chemistry, and soil bulk density. Biological data was also collected on competing vegetation group types and competing vegetation at the seedling level. Significant effects of soil moisture, bulk density, and competing vegetation groups were found for average height growth, while no factors had significant effects on stem diameter growth. Family showed no significant effect on growth in the first year growing season following out-planting, despite there being significant family differences during first year nursery growth. Lack of family significance may be a result of first year establishment where seedlings are putting energy toward adapting to the environment. Ultimately, soil moisture, the presence of forbs, and competing vegetation directly next to seedlings were the most influential to performance. Seedlings showed larger heights at the drier site, but overall higher averages of growth at the wetter site because of consistent available moisture. Competition for resources with other vegetation, for water, nutrients, and light, had negative and positive effects on growth.

Response of Western Larch Genoypes to Simulated Outplanting Drought

Joshua Mullane[1] and Andrew S. Nelson

Introduction

Western larch (*Larix occidentalis*) is occurs exclusively in the inland northwestern United States, from the eastside of the Cascade Mountains to the Northern Rocky Mountains. Western larch is highly valued for commercial timber production, very fast growing, and one of the most fire resistant species in the region (Schmidt and Shearer 1990). Western larch is extremely intolerant of shaded conditions and exhibits indeterminate growth (Minore 1979). Root characteristics of western larch are equally unique among competing tree species, producing extensive fine roots and fewer large roots in contrast to Interior Douglas-fir (*Pseudotsuga menziesii var. glauca*) and grand fir (*Abies grandis*) (Reely 2018).

Temperatures across the western United States are expected to increase during the twenty-first century (Sillmann et al. 2013), while projected changes in precipitation are more uncertain (Kharin et al. 2013). Instead, spring runoff from snow is expected to occur earlier in the spring (Stewart et al. 2005) potentially reducing summer soil moisture and lead to increased dryness of vegetation (Gergel et al. 2017). Models suggest western larch will be sensitive to these changes in regional climate and will likely exhibit substantial restriction of suitable habitats through the twenty-first century (Rehfeldt and Jaquish 2010) It is still unclear how western larch responds to drought conditions in experimental conditions, or if different genotypes show unique responses to drought. If genotypes can be selected to better withstand projected drought, efforts can be strategically allocated towards increased production and deployment of drought-adapted genotypes to help ensure western larch remains a component of Inland Northwest forests. Therefore, the objective of this study is to examine how western larch genotypes selected across a range of mother-tree climates in the Inland Empire respond to simulated drought, both morphologically and physiologically.

Methods

Four clones were selected from the Inland Empire Tree Improvement Cooperative (IETIC) in Kalamaka, British Columbia, Canada for this study. The mother tree was known for each clone, but the male pollen came from other trees from within the improved orchard. Seed was processed by clone at the Tree Improvement Centre in British Columbia and was sent to the Franklin H. Pitkin Nursery at the University of Idaho in fall 2016. Seedlings were grown at the Pitkin Nursery in 415C Styroblock containers (Beaver Plastics), with each Styroblock containing a single family. Each block had 91 cells each with 130 ml cell volume. Seedlings were grown using the standard growing regime employed at the Pitkin Nursery (Dumroese and Wenny 1995). At the end of the nursery season, seedlings were removed from their containers in late December 2017 and January 2018 and placed in a freezer set to -2 °C.

Four clonal seed collections were selected for this study, hereafter referred to as 101, 106, 113, and 116. Climate metrics for each parent tree location are based on the model of Rehfeldt and Jaquish (2010), including mean maximum temperature in the warmest month (mmax) and the product of April-September precipitation and degree-days > 5 °C (gspdd5). Higher values of gspdd5 indicate warmer and wetter climates. Climate metrics for each of the four clones are shown in Table 1.

Table 1. Climate and elevation of the mother tree location for each of the improved larch seed sources. Mmax is the mean maximum temperature in the warmest month and Gspdd5 is the product of April-September precipitation(mm) and degree-days>5 °C divided by 1000.

Clone	Mmax (°C)	Gspdd5	Elevation
101	23.2	350.1	1265
106	28.1	460.7	792
113	24.5	346.4	1250
116	25.4	409.9	1036

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[1] Joshua was an undergraduate when this research was conducted. The project served as his undergraduate thesis. In January 2019, he started a Masters of Science program with Andrew Nelson.

We used a randomized complete block design for the study with 8 blocks, with blocking based on distance from the greenhouse wall. We randomized each combination of the four clones and three drought-treatments within each block for a total of 96 seedlings. Each seedling was potted into equal-sized 3.78-L pots. The soil medium was 80% high-grade peat moss and 20% vermiculite. Potting medium was wetted and 1300g of medium was added to each pot. . In addition, each pot received 11.4 g of Osmocote® Plus controlled-release fertilizer (15-9-12 + micronutrients; The Scotts Company).

The total weight of each pot was determined by adding the weight of the empty pot, the seedling, soil medium, fertilizer, and grit top-dressing. Pots were watered to field capacity and left to drain for 1 hour. Pots were then weighed to estimate the weight of water in each pot using the methods of Dumroese et al. (2015).

Three levels of drought treatment were tested in this study including 90% (Full Water), 70% (Moderate Drought), and 50% (Severe Drought) of field capacity based on the ratio of the desired amount of water in each pot divided by the weight of water at field capacity. Soil moisture for all seedlings was maintained at field capacity for the first 5 weeks. Dry-down treatments began in week 6 and continued through week 14 (26 February to 28 April 2018). Seedling weights were checked twice per week by weighing pots. If the weight of the pot exceeded the target moisture content no water was added. If the weight of the pot was below the target moisture percentage, water was added with the pot on a scale until the target weight was achieved. The amount of water (ml) needed to achieve the target was recorded for each seedling.

Seedlings were grown in a greenhouse at the Pitkin Nursery without supplemental light. Ambient temperature in the greenhouse was maintained at 20 °C throughout the study period.

Seedling height (cm) and diameter (mm; parallel to the lip of the pot) were measured every two weeks starting in week 1. A red circle was painted on the lip of each container to line up the calipers, so the diameter measurement occurred in the same location every two weeks. Height was measured to the tip of the terminal bud before seedlings started height growth and to the base of terminal needles once seedlings began to grow. Due to errors with the electronic calipers, measurements from week 7 were removed from the analysis.

Two random blocks were selected for more detailed measurements at weeks 6 (start of treatment), week 10, and week 14. A LI-6400 (LICOR Bioscience, Lincoln, NE) with a fluorometer head was used to measure instantaneous gas exchange. The chamber conditions were set to 1500 μmol m-2 s-1 light intensity, 25 °C block temperature, 400 ppm CO2. Seedlings were measured from 10 am until 2 pm. A side branch within the top 1/3 of the seedling was selected for measurement. Samples were left in the closed chambers for a minimum of 5 minutes until gas exchange measurement stabilized before taking a measurement. The foliage within the chamber was removed from the seedling to measure leaf area and adjust gas exchange measurements. The foliage samples were scanned on a flat bed scanner at 800 dpi and one-sided leaf area was measured using WinSeedle® software (Regent Instruments, Quebec, Canada). Foliage was then dried at 65 °C until constant mass and then weighed to the nearest tenth of a milligram.

Seedlings were then removed from the pots to estimate mass of roots, foliage, and the stem. Seedlings were cut at the root collar and the top of the seedling was placed in a paper bag for drying and weighing. Soil medium was carefully removed from the roots which were then dried and weighed. All components were dried at 65 °C until constant mass and then weighed to the nearest tenth of a milligram. Foliage weight from the leaf area scan was added to the final foliage weight of the seedling.

Results

Seedling Height and Diameter

Seedlings grew little in height for the first five weeks of the study, followed by a rapid increase through week 14 (Figure 1). Analysis of covariance (ANCOVA) was used to test for effects of clone, drought treatment, and week of the study plus their interactions as well as initial bud diameter (mm) as a covariate. All main effects were significant in the model ($p \leq 0.05$), but the following interactions were not significant and were thus dropped from the final model: interaction of clone and week ($p=0.194$), and interaction of clone, treatment, and week ($p=0.967$). Among the four clones, height at week 14 was lowest for clones 101 and 113—clones with mother trees from the highest elevations and lowest gspdd5. Height response to the drought treatments was clone-specific. The Full Water treatment and Moderate Drought treatment were not statistically different within clones except clone 116 ($p=0.013$).

Significant differences between the Full Water and Severe Drought treatments were found for clone 116 ($p<0.001$) and clone 106 ($p<0.001$) with origin climate of lower elevation and longer and more moist growing seasons. Even though the mean heights at week 1 were slightly different between treatments for clones 106 and 116, these differences were not significant ($p \geq 0.340$).

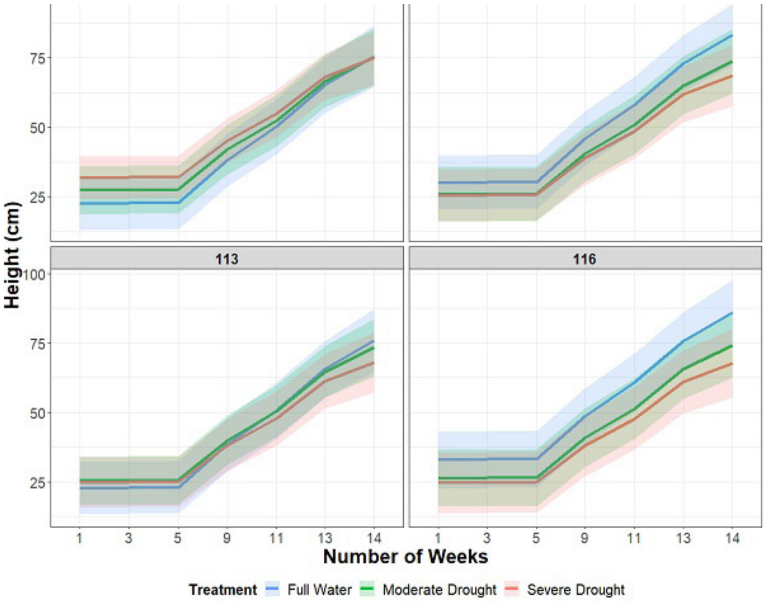

Figure 1. Change in seedling height (cm) from week 1 through week 14 by clone and drought treatment. Drought treatments began in week 6.

Seedling diameter showed a similar trend to seedling height, with minimal change through the first five weeks followed by a rapid increase (Figure 2). The final ANCOVA model for stem diameter only dropped the three-way interaction of clone, treatment, and week ($p=0.672$), while all other main effects and interactions were significant ($p\leq0.035$). Diameter responses to drought showed less consistent effect, where diameter at week 14 was greater in the Full Water compared to the Severe Drought treatments for all clones ($p \leq 0.011$). This indicates seedlings express drought responses more consistently in stem diameter than height, which seems to suggest a parent-tree climate effect.

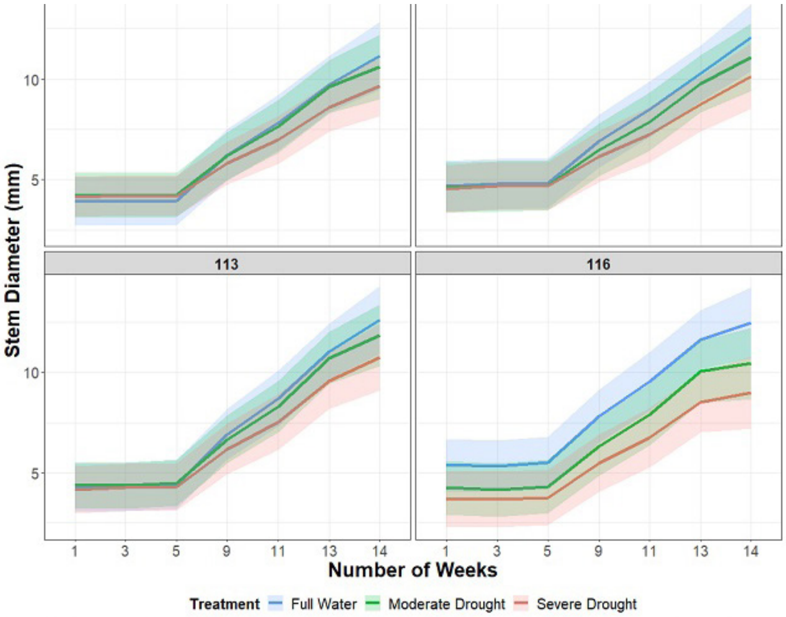

Figure 2. Change in seedling stem diameter (mm) from week 1 through week 14 by clone and drought treatment. Drought treatments began in week 6.

Seedling Mass

Compared to seedling dimensions, clone was not a significant factor in any of the seedling mass models (Figure 3). Among foliage, stem, and roots, mass was no different between the treatments at the start of the simulated drought that began in week 6. By week 14 foliage mass was 1.4396 g greater in the Full Water treatment compared to the Severe Drought treatment ($p=0.004$).

A similar effect was observed for stem mass, where mass was 4.8614 g greater than the Severe Drought treatment (p<0.001).). Belowground, root mass was not affected by the drought treatments, and by week 14 root mass in the Full Water treatment was only 0.7189 g greater than the Severe Drought treatment (p=0.567).

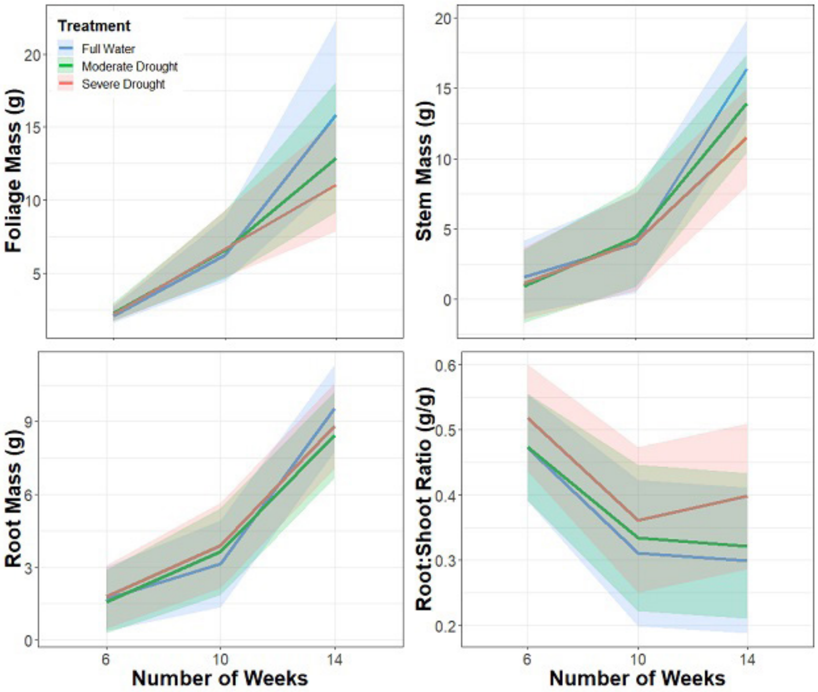

Figure 3. Change in seedling mass at the start of treatment in week 6 through week 14.

Seedling Gas Exchange

Seedling photosynthesis and leaf-level transpiration increased substantially between the start of drought treatments in week 6 and subsequent weeks (Figure 4). The large increase coincides with the rapid increases in height and diameter after week 5. Even though treatment effects between Full Water and Severe Drought on diameter were observed for all clones and for clones 116 and 106 for height, no treatment effects were found for photosynthesis. The difference between Full Water and Severe Drought was only 1.13 µmolCo2m-2s-1 (p=0.701). Comparatively transpiration, a metric of plant water use and movement, was 0.48 mmolH2Om-2s-1 greater in the Full Water treatment compared to the Severe Drought treatment at week 14. It is possible that the reduced amount of water in the soil medium of the Severe Drought treatment reduced the amount of water available to move through the plant thus reducing the overall diameter growth for all clones and height growth for clones 116 and 106.

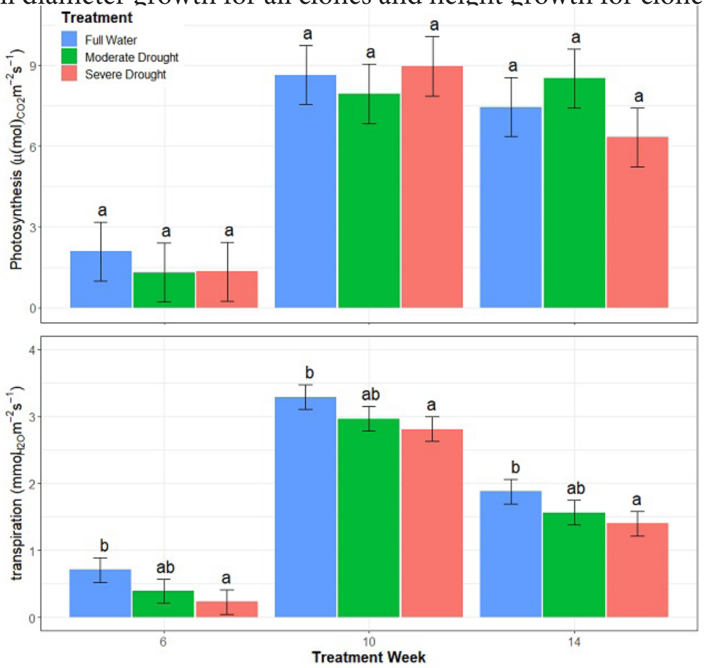

Figure 4. Change in seedling photosynthesis and transpiration from the start of treatment in week 6 through week 14.

Joshua Mullane watering western larch seedlings in the Pitkin Greenhouse.

Photo Credit: Andrew S. Nelson

Root mass after seperation of soil medium to be dried and weighed.

Photo Credit: Andrew S. Nelson

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Intermixing *Cola* and Nitrogen-fixing *Samanea* Outplanting in the Dry Tropical Forest Region of Togo

Gabrielle Harden[1] and Andrew S. Nelson

Introduction

Deforestation of tropical forests is a global problem threatening biodiversity, contributing to climate change, land erosion and desertification, and resulting in increased social conflict. Between 2000 and 2010, tropical forest area declined 7 million hectares per year, while the area of agricultural land increased by 6 million hectares per year (FAO 2016). The largest losses of forest during this time were tropical rain forests of South America, while tropical forests of West and Central Africa were third, with an annual loss of about 1.5 million hectares per year (FAO 2016). Efforts to combat deforestation have shown some success such as the Reducing Emissions from Deforestation and Degradation (REDD+) programs implemented around the world. REDD+ incentivizes countries to help reduce carbon emission to the atmosphere by providing financial support to protect forests from unsustainable harvesting and to restore forests in areas of over exploitation (Gullison et al. 2007). An added benefit of REDD+ programs is the conservation of biodiversity through the protection or restoration of forest cover and habitat (Harvey et al. 2009). In much of West Africa, tropical deforestation has devastated much of the historic forest cover, requiring active restoration of native forests to achieve REDD+ goals and increase biodiversity, yet little research is available to help develop best practices for restoring forests on lands that were formerly cleared for agriculture.

Figure 1. Map of West Africa showing location of Togo. Source: Google Earth

Togo, located in West Africa between Ghana and Benin (Figure 1), has one of the highest rates of deforestation in the world (5.1% between 2000 and 2010) (FCPF 2015). The total country area is 5.68 million hectares, yet only 3.6% is forest (FAO 2018). High deforestation in Togo is a result of the largely rural agrarian population (7.5 million people total, 60% of which are rural (FAO 2018)) that have cleared lands for agriculture and exploitative harvesting for timber. Native forests that remain are mostly in reserves managed by the federal government that exclude entry from the general population and some sacred forests (Kokou et al. 2008). Plantations are also present across the country, but the majority are non-native species, such as teak (*Tectonia grandis*) or Eucalyptus species. These plantations are mostly used for fuel wood and sometimes for timber. Numerous problems are associated with these non-native plantations, including changes in ecosystem processes, lack of structural heterogeneity for biodiversity, and inhibition of native flora used for human food and medicine. In addition, their short life span before harvesting limits their added benefit to carbon sequestration and climate regulation. Togo has started receiving funds to implement REDD+ programs as part of their National Development Plan. One of the overarching goals of the program is to restore lost and degraded forests through the Readiness and Rehabilitation of Forests in Togo REDD+ support program funded by the German government (BMZ 2015).

Even though Togo has begun to implement programs to monitor forest loss and gain and assess capacity to restore native forests, there is a lack of understanding of how to actively restore native forests. Forest science capacity in the country is very limited, and no studies have been conducted to date testing strategies for restoration. Togo lies within the Dahomey Gap, the climatically dry corridor separating the West African rain forest into the Upper and Lower Guinean forests (Poorter et al. 2004). The drier conditions historically consisted of a forest-savannah mosaic, which is much different than evergreen tropical rain forests that dominate much of West Africa (Jenik 1994). These environmental conditions combined with soil degradation through agricultural practices result in poor tree establishment and the need for better science on field-based strategies for improving seedling survival and growth.

In 2016, the Center for Forest Nursery and Seedling Research (CFNSR) at the University of Idaho partnered with the Institute for Community Partnership and Sustainable Development, a Togo-based NGO, to develop a forest nursery and improve restoration of forests in Togo. The nursery is researching ways to improve seedling quality of culturally and ecologically important tree species for the region.

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[1] Gabrielle is an undergraduate student in the College of Natural Resources. She was awarded an Adele Berklund Scholarship to pursue this project for her undergraduate thesis. Additional measurements will be collected in March 2019.

A local women's group grows the seedlings in the nursery using scientific principle of tree propagation. Periodic trips to Togo check on the nursery to ensure propagation protocols are being followed and test additional strategies to improve nursery production. The first crop was 5,000 seedling, of which 2,000 were planted as part of a restoration project intermixing nitrogen-fixing *Samanea saman* seedlings to improve soil fertility and increase survival and growth of native *Cola gigantea*. The field study uses a replacement series design (Rejmanek et al. 1989) that varied the proportion of each species across a gradient from 100% *Cola* to 100% *Samanea* and was replicated three times across a one hectare site. *Cola* has rapid growth (Figure 2) and is highly valued for food (fruit) and provides fuel for cooking. *Samanea* is also valued for fuel and can readily fix nitrogen in the soil through associations with nitrogen-fixing bacteria on root nodules (Figure 3).

Figure 2. One-year old Cola Seedling planted at nursery site

Photo Credit: Andrew S. Nelson

Figure 3. Nitrogen-fixing nodules on *Samanea* seedling

Photo Credit: Andrew S. Nelson

Research Objectives

We are examining the early performance of seedlings planted as part of the field study testing intermixing of nitrogen-fixing species to improve restoration of native forests. The study was planted in June 2017 and the high rates of tree growth in the region should provide ample time in the ground to detect effects of the different treatments when remeasured in October 2018 and February/March 2019. Our specific objective is to examine temporal changes in Cola and Samanea height and diameter growth and survival, as well as foliar stomatal conductance and chlorophyll content in relation to the varying composition of the two species at the end of the second rainy season (October 2018) and towards the end of the third dry season (February/March 2019).

Methods and Data Analysis

The region has a tropical savanna climate, with two rainy seasons. The first rainy season occurs between April and July, while the second takes place between September and October. During these rainy seasons, Togo receives 100 to 150 cm of precipitation. November through March is extremely hot and dry with temperatures generally exceeding 32˚C. July through September is considered to be the cold season, with average high temperatures rarely surpassing 28°C. (WWCI 2016).

The study site is located ~9 km west of Notsé, Togo. Row agriculture (primarily cotton and corn) was practiced for the last 25 years. In tropical regions, the soils are very old with very low nutrient reserves (Buol et al. 2011). The majority of nutrients are held within the plants growing on the site. When forests are harvested and biomass is burned, much of the nutrient reserves are removed from the site, resulting in harsh conditions for restoration. Therefore, we believe the site has low nutrient reserves due to the long history of agriculture, of which cotton and corn aggressively remove any remaining stores.The site was cleared of all vegetation by cutting and pulling by hand prior to planting (Figure 4). Plots boundaries and planting spots were installed with the assistance of local high school students and UI graduate students. Seedling, which were grown in the nursery as part of the larger project, were planted in early June 2017 over a three-day period after the rains began. Trees were planted by the local students with the assistance of a local reforestation advisor. Trees were transported to the site from the nursery in Notsé and protected from direct sunlight to reduce seedling stress.

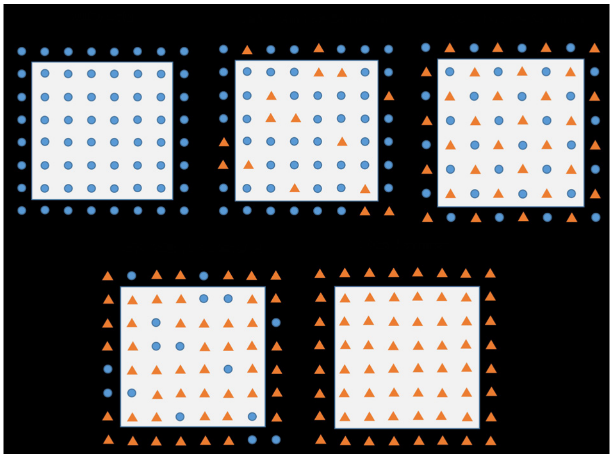

Figure 5. Seedling arrangement within each of the five treatments.

Figure 4. Planting site prior to planting in June 2017

Photo Credit: Andrew S. Nelson

The seedlings were planted in plots that had one of five different proportions of *Cola* and *Samanea* including 100% *Cola* – 0% *Samanea*, 75% *Cola* – 25% *Samanea*, 50% *Cola* – 50% *Samanea*, 25% *Cola* – 75% *Samanea*, 0% *Cola* – 100% *Samanea* (Figure 5). The 50%-50% treatments alternated every other tree with a different species, while the 75%-25% and 25%-75% treatments attempted to get an even distribution of the minority species dispersed across the plot, while also clumping individual species to create a diversity of immediate neighborhood conditions. These treatments were replicated three times at the site, totaling 15 plots. Each square plot has 64 trees (8 × 8 trees) with a 36 tree (6 × 6 trees) monitoring plot nested within the center. Trees were planted at a 3 × 3 m spacing.

Seedlings in the nested measurement plots were measured for height and diameter, and survival shortly after planting in June 2017 and at the end of the first rainy season in November 2017. Tree measurements were collected again in November 2018 at the end of the second rainy season. When trees were being measured, we also measured stomatal conductance using a SC-1 Leaf Porometer (Meter Group, Pullman, WA) and chlorophyll content using a CCM-300 Chlorophyll Content Meter (Opti-Sciences, Inc, Hudson, NH). We are in the process of analyzing the data from the November 2018 measurements along with the initial June 2017 measurements. We will remeasure the morphology and physiology of the trees in early March 2019, in the height of the dry-hot season, to examine seasonal changes.

Repeated-measures analysis of variance will be used to analyze trends in height and diameter growth, seedling survival, stomatal conductance, and chlorophyll content. Due to the unequal time periods between measurements, time will be represented in the models as months after planting. The *Cola* model will be used to help determine an optimal proportion of nitrogen-fixing *Samanea* to improve establishment and growth of the native *Cola*. This study aims to examine the benefit of the *Samanea* on *Cola* growth, so I expect to see a positive effect of *Samanea* on *Cola* at the 75% *Cola*-25% *Samanea* treatment and perhaps the 50-50% treatment, but the *Samanea* density in the 25% *Cola* -75% *Samanea* treatment may hinder *Cola* growth due to competition.

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Seedling Quality Lab

The Center for Forest Nursery and Seedling Research (CFNSR) provides third-party seedling quality testing services, including root growth potential, cold hardiness, and root electrolyte leakage.

Root Growth Potential Testing Procedures

We randomly select 15 (20 for western larch) seedlings from each seedlot, which are then thawed in a refrigerator (+2 °C). Soil medium is then carefully washed from roots so we can measure new roots that grow within the center of the plug plus root that grow on the surface of the plug. Seedlings are tested in the mist chambers for 16 days, except western larch which is tested for 20 days. Air temperature in the laboratory is maintained at 21 °C and LED lights are suspended above seedlings to provide 12 hours of supplemental light (~120 µmol m-2 s-1 PAR). The chambers are equipped with a recycling water mist system that uses a diaphragm pump and 3 misting nozzles (Fogg-it superfine: ½ gallon per minute). Seedling roots are misted for 5 seconds followed by 4 minutes and 55 seconds of no misting. Aquarium heaters heat the water in the bottom of the chambers to 21 °C. An airstone is also added to the water to increase oxygen concentration. Blackout curtains drape around the exterior of the chambers to insulate seedlings and maximize light availability from the supplemental LEDs.

At the end of the 16- or 20-day test period, seedlings are removed from the chambers and the number of new roots ≥ 1 cm long and the length of the longest new root segment are measured for each seedling.

Figure 1. The RGP mist chambers suspend seedlings over the top the chambers and are surrounded by blackout curtains.

Seedlings before entering Aeroponic chamber

Photo Credit: Lori Mackey

Seedlings at the end of testing, with new root development

Photo Credit: Lori Mackey

2018 RGP Outplanting

In 2018 we outplanted all the Inland Northwest seedlots tested for RGP to examine correlations between RGP and seedling survival and growth. We planted a total of 81 seedlots at three sites. One site was in the Blue Mountains, one site was in the Clearwater Mountains, and the third site was in the St. Joe Mountains. The experiment was a completely randomized design where each seedlot was randomly assigned to a row and each row contained 15 seedlings (Figure 2). Seedlings were planted in May 2018 followed by initial measurements of height and diameter. Seedlings were remeasured in September 2018 and checked for survival. We plan to remeasure these seedlings again in September 2019. Seedlings tested for RGP in 2019 will be planted at different sites to continue evaluation of the correlations between RGP and initial seedling performance. All of this data will go into a database to conduct robust, region-wide analysis of seedling quality and outplanting performance and used in the development of a regionwide early seedling performance model to increase reforestation success.

Seedling survival and growth were analyzed using generalized additive models with a loess smoother function applied to RGP measured as the number of new roots ≥ 1 cm long. Douglas-fir survival was high across all three sites and did not show a trend of greater survival with greater RGP (Figure 3). Western larch exhibited similarly high rates of survival across all three sites, with survival greater than 90%. The high survival of both species could be due to the mild early summer of 2018 with precipitation regularly through the end of June with moderate temperatures. Seedlings were also planted on high quality sites in the Inland Northwest. Height growth showed a stronger correlation with RGP than survival (Figure 4). Douglas-fir height growth was generally higher for seedlots with greater RGP across all three sites. Western larch height growth showed a pattern of peaking in height growth in the middle range of RGP, except at the Northeast Oregon site, where height growth peaked at moderately low and moderately high RGP values.

Figure 2. RGP outplanting site in the Blue Mountains of Northeastern Oregon.

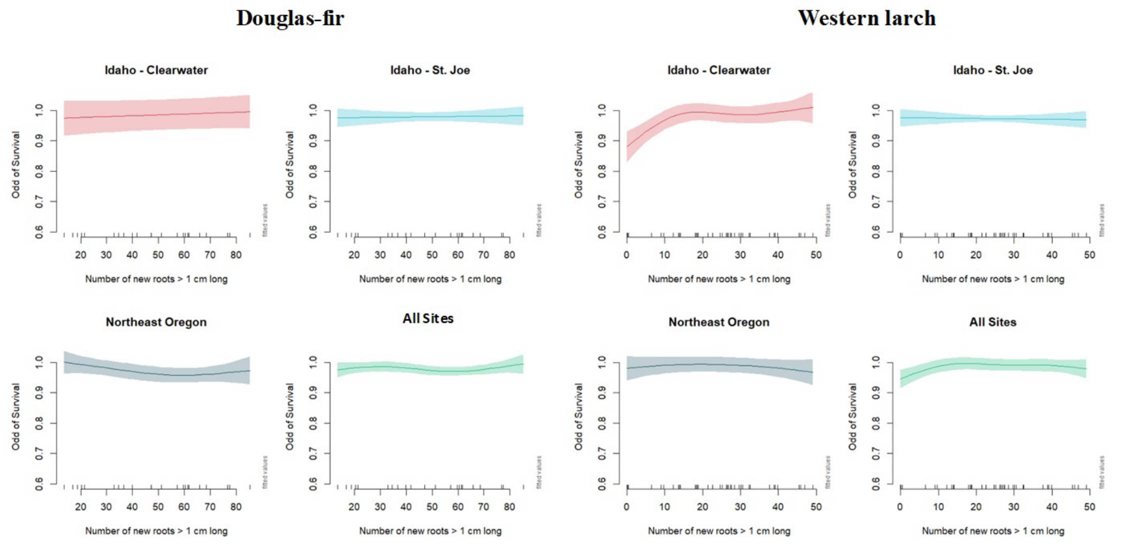

Figure 3. First year survival of Douglas-fir and western larch in relation to RGP

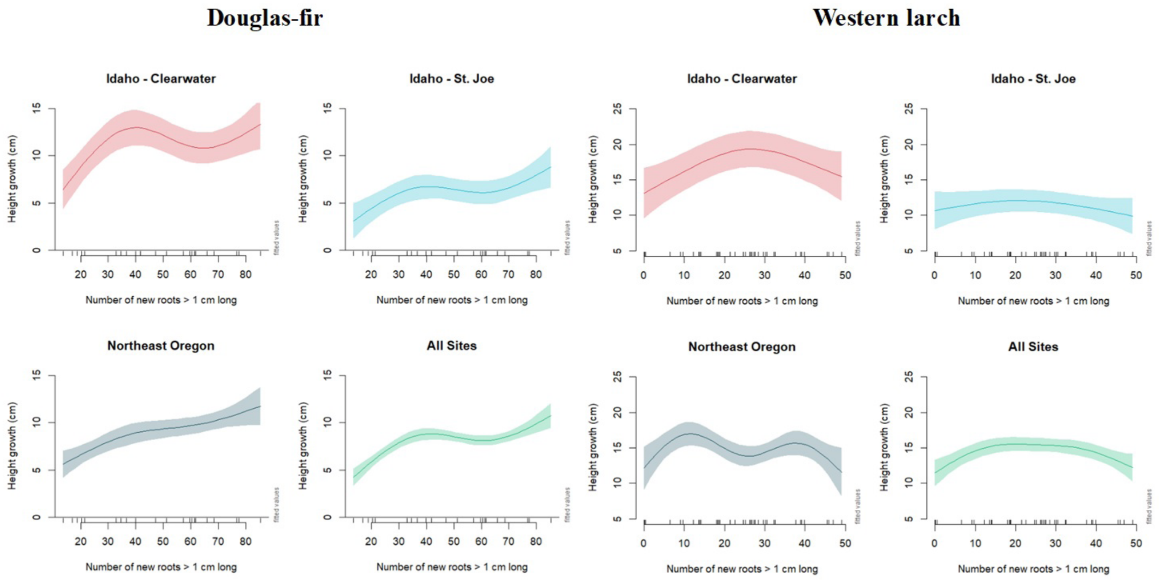

Figure 4. First year height growth of Douglas-fir and western larch in relation to RGP

Collaborative Research Activities

Marc Rust

Grafting for Inland Empire Tree Improvement Cooperative

In 2018, 1,285 Western Larch and 251 Western White Pine were grafted at the Pitkin Forest Nursery. These grafts were then outplanted onto a seed orchard.

Ross Applegren grafting a Douglas Fir seedling in the Pitkin greenhouses (photo from 2017 season)

Photo Credit: Marc Rust

Individuals with Research at CFNSR

Aaron Sparks
Raquel Partelli Feltrin
Wade Steady

Sub-irrigated ponderosa pine seedlings maintained by the CFNSR for collaborative research on sapling mortality responses to fire dose effects.

Photo Credit: Lauren Goss

2018 Publictions, Presentations and Grants

Peer-reviewed Journal Publications

Bose, A., Nelson, A.S., Kane, M., and Rigling, A. 2018. Density reduction in loblolly pine (Pinus taeda L.) stands to increase tree C assimilation: an approach with the dual δ13C and δ18O isotope signatures in needles. Annals of Forest Science. 75: 8. DOI: 10.1007/s13595-017-0687-1.

Collins, C.N., Brooks, R.H., Sturz, B.D., Nelson, A.S., and Keefe, R.F. 2018. Body composition changes of United States smokejumpers during the 2017 fire season. Fire. 1: 48. DOI: 10.3390/fire1030048.

Hernandez, G., Haase, D.L., Pike, C., Enebak, S., Mackey, L., Ma, Z., and Clarke, M. 2018. Forest Nursery Seedling Production in the United States-Fiscal Year 2017. Tree Planters Notes. 61(2) 18-22.

Hoffman, A., Bataineh, M., Adams, J., and Nelson, A.S. 2018. Partial harvesting effects on seedling growth and physiology of three hardwood species in mature Pinus-hardwood mixtures. Journal of the Torrey Botanical Society. 145(3): 237-249. DOI: 10.3159/TORREY-D-17-00031.

Lei, Y., Fu, L. Affleck, D.L.R., Nelson, A.S., Shen, C., Wang, M., Zheng, J., Ye, Q., and Yang, G. 2018. Additivity of nonlinear crown width models: Aggregated and disaggregated model structures using nonlinear simultaneous equations. Forest Ecology and Management. 427: 372-382. DOI: 10.1016/j.foreco.2018.06.013.

McDonough, T.C., Regan, D.J., and Nelson, A.S. 2018. Propagation protocol for blue elderberry (Sambucus nigra L. ssp. cerula (Raf.) R. Bolli). Native Plants Journal. 19(3): 254-259.

Shen, C. and Nelson, A.S. 2018. Natural conifer regeneration patterns in temperate forests across the Inland Northwest, USA. Annals of Forest Science. 75:54. DOI: 10.1007/s13595-018-0724-8.

Wagner, R.G., Gonzalez-Benecke, C., Nelson, A.S., and Jacobs, D.F. 2018. Forest regeneration in changing environments. New Forests. 49(6): 699-704. DOI: 10.1007/s11056-018-9687-8.

Williams, G.M. and Nelson, A.S. 2018. Spatial variation in specific leaf area and horizontal distribution of leaf area in juvenile western larch (Larix occidentalis Nutt.). Trees – Structure and Function. 32(6): 1621-1631. DOI: 10.1007/s00468-018-1738-4.

Williams, G.M., Nelson, A.S., and Affleck, D.L.R. 2018. Vertical distribution of foliar biomass in western larch (Larix occidentalis Nutt.). Canadian Journal of Forest Research. 48: 42-57. DOI: 10.1139/cjfr-2017-0299.

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Deal, R. (Editor) and 19 Associate Editors (Nelson, A.S.). 2018. The SAF Dictionary of Forestry, 2nd edition. The Society of American Foresters. Bethesda, MD. 208 p.

Conference Presentations

Durnin, B.A., Nelson, A.S., and Jain, T. B. 2018. Understory diversity in restored western white pine stands. Society of American Foresters Convention. Portland, OR. (poster)

Foard, M. B., Nelson, A.S., and Harley, G.L. 2018. Potential for streamflow reconstructions using species-, and site-specific tree ring models. 9th Annual Northwest Climate Conference. Boise, ID. (poster)

Grover, K. and Nelson, A.S. 2018. Response of improved western larch clones to site quality and climate. Society of American Foresters Convention. Portland, OR. (oral)

Nelson, A.S., Vore, S., Johnstone, R., and Johnson, G. 2018. Integrated vegetation management alternatives to promote vegetation diversity in Inland Northwest utility rights-of-way. Environmental Concerns in Rights-of-Way Management. 12th International Symposium. Denver, CO. (poster)

Grover, K., Nelson, A.S., Coleman, M., Rust, M., Kimsey, M., and Shaw, T. 2018. Response of superior western larch families to site quality. Center for Advanced Forestry Systems Annual Meeting. Burlington, VT. (oral)

Invited/Outreach Presentations

Cherico, J. and Nelson, A.S. 2018. The effects of site preparation on the long-term growth and productivity of interior Douglas-fir and western white pine. Intermountain Forestry Cooperative Technical Meeting. Moscow, ID. March 27.

Nelson, A.S. 2018. The importance of seedling quality for successful reforestation in the Inland Northwest. Setting Stands Up for Success—From Seed to PCT: Applied Early Stand Silviculture in the Inland Northwest. Spokane, WA. December 13.

Nelson, A.S. 2018. Rapid root growth potential testing of Inland conifers with aeroponic mist chambers. Eastside Seedling Characteristics and Quality for Optimum Performance. Joint meeting of the Western Forestry and Conservation Nursery Association and the Intermountain Container Seedling Growers' Association. Coeur d'Alene, ID. October 25-26.

Regan, D. and Nelson, A.S. 2018. Nursery production timelines: Tips for successful grower and buyer partnerships. Inland Empire Reforestation Council Meeting. Coeur d'Alene, ID. March 6.

Nelson, A.S. 2018. Togo nursery and restoration project. U.S. Embassy in Togo Office of Public Affairs. Notsé, Togo. February 21.

Nelson, A.S. 2018. Forest regeneration competition thresholds: Concepts and integration into reforestation plans. Wilbur-Ellis Professional Markets Technical Seminar. Spokane, WA. January 25.

Grants

University of Idaho Office of Research and Economic Development (co-PI)

ORED 2018 EIS Request: Gap analysis instrument for measuring leaf area of forest canopies (with M. Coleman (PI), D. Johnson, P. Goebel, M. Kimsey, T. Hudiburg) **$7,025**

Avista Utilities (PI)

Benefits of shrub competition when managing transmission line right-of-ways **$49,000**

PotlatchDeltic Corp (PI)

Competing vegetation effects on tree growth **$24,988**

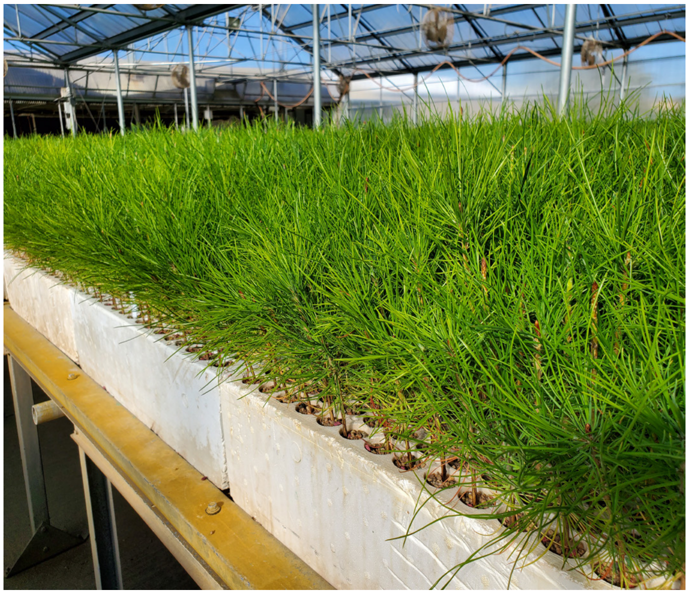
Collaboration with the University of Idaho's Experimental Forest

In 2017, the Pitkin Forest Nursery grew 58,250 seedlings consiting of 17,390 Westsern Larch, 2,700 Western White Pine, 8,500 Ponderosa Pine, 6,000 Western Red Cedar, 4,190 Engelmann Spruce, 11,250 Lodgepole Pine and 8,490 Douglas Fir for the Experimental Forest and were outplanted spring of 2018.

During the summer of 2018, Pitkin Forest Nursery student employees helped the experimental forest employees collect cones for seed collection that will be used to grow future crops for the experimental forest and the nursery stakeholders for years to come.

Engelmann spruce seedling crop for the Experimental Forest

Photo Credit: Lauren Goss



Ponderosa pine seedling crop for the Experimental Forest

Photo Credit: Lauren Goss

Western white pine seedling crop for the Experimental Forest

Photo Credit: Lauren Goss

Stakeholder Interactions and Program Impact

Sonny Perdue Visit *(July 2nd, 2018)*

The United States Secretary of Agriculture stopped by the University of Idaho on his "Back to our Roots" Tour. He came to our facility along with Idaho Govenor Butch Otter and Lieutenant Govenor Brad Little for a presentation in the Reveley building on the new Idaho Arena given by UI President Chuck Staben. The Idaho arena will be a wood products building, much like our own Reveley building.

Idaho State Deptt. of Agriculture Director Celia Gould, Idaho Gov. C.L. Butch Otter, Secretary of Agricultre Sonny Perdue, Idaho Lt. Gov. Brad Little and UI President Chuck Staben

Photo Credit: Lauren Goss

The nursery aims to interact with a variety of stakeholders over the course of the fiscal year. We were fortunate enough to the have United States Secretary of Agriculture stop by to see our facility and learn about what we do as well as the new Idaho Arena project. We also interacted with a number of other stakeholders throughout the year in addition to our annual customers.

Private Landowners Assisted	1,570
Seedlding Industry Research Projects	5
Research Projects	10
Teaching Projects	6
Service Projects	10

Special Programs-Forest Utilization Research Performance Report 2018

Student Engagement and Community Outreach

Lewiston High School Field Trip *Novemeber 5th, 2018*

Jamie Morton brought her science class to learn about the process of growing seedlings in a nursery. They toured our facility and did interactive forestry activities such as learning how to bore a tree and created match stick forests to learn how fire moves through a forest and different management techniques.

Lewiston High School Students learning how to bore a tree at the Pitkin Nursery
Photo Credit: Lauren Goss

Lewiston High School students burning match stick forests on the Reveley building deck
Photo Credit: Lauren Goss

HOIST Student Interns *June 11th, 2018 - June 26th, 2018*

We participated in the HOIST Program (Helping Orient Indian Students and Teachers into STEM) again this year. Our interns were 9th Grader Josie Rose Thomas from Owyhee, NV and 10th grader Desmond Hanchor from Owyhee, NV.

Vandal Sync *August 18th, 2018*

This year we had a number of University of Idaho freshman come out and volunteer as part of their freshman orientation. They helped with a number of tasks including watering trees and weeding the crop.

Freshman Vandal Sync volunteers and Vandal SYNC leader Sarah Page outside the Reveley Building after volunteering.

Photo Credit: Lauren Goss

Arbor Day

Every year for Arbor Day the nursery has a sale which is the only time of year that we sell 1 gallon pots. This event is a community favorite and as always we had people waiting at the door for us to open. Despite having a rainy saturday, we still successfully sold all of our 1 gallon pots and as well as a quanity of seedling plugs from our crop. This was the first year that the entire Arbor Day sale was in the Reveley Building. We had the seedling plugs inside and the pots outside. We had a number of students helping throughout the day answering questions for our 300+ customers that came out.

Shrubs and Hardwoods in 1 gallon pots growing in Bay 5 to be sold at Arbor Day

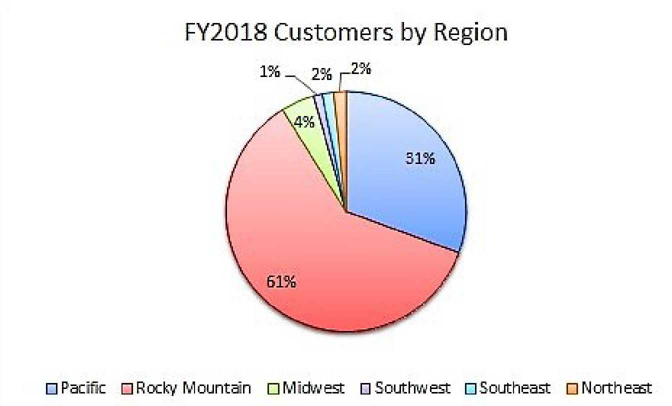
Photo Credit: Lauren Goss

Conifers in 1 gallon pots growing in Bay 5 to be sold at Arbor Day

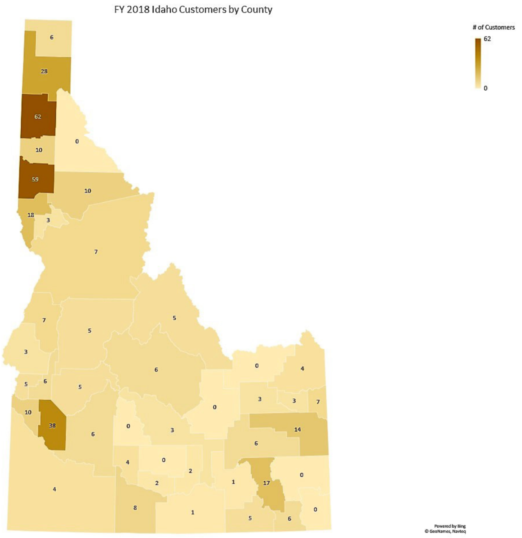
Photo Credit: Lauren Goss

Seedling Sales

During the 2018 Fiscal Year we had over 1,100 customers and produced around 470,000 seedlings. In addition, during our Arbor Day Celebration we had over 300 vistors over two days.



Fiscal Year 2018 Pitkin Forest Nursery Customers by Region in the United States



Fiscal Year 2018 Idaho Pitkin Forest Nursery Customers by County

FY 2018 Species

Conifers

Cedar, Incense
Cedar, Western Red
Fir, Canaan
Fir, Concolor
Fir, Corkbark
Fir, Fraser
Fir, Grand
Fir, Subalpine
Hemlock, Western
Juniper, Rocky Mountain
Larch, Western
Pine, Austrian
Pine, Bristlecone
Pine, Limber
Pine, Lodgepole
Pine, Pinyon
Pine, Ponderosa
Pine, Scotch
Pine, Western White
Spruce, Blue
Spruce, Engelmann
Spruce, Norway

Shrubs

Alder, Thinleaf
Ash, Native Mountain
Bayberry, Northern
Bitterbrush, Antelope
Boxwood , Mountain
Ceanothus, Redstem
Cherry, Choke
Cinquefoil, Shrubby
Currant, Golden
Currant, Red-Flowering
Dogwood, Redoiser
Elderberry, Blue
Hawthorn, Black
Huckleberry, Mountian
Lilac, Purple
Ninebark, Common
Oceanspray
Plum, American
Rose, Rugosa
Rose, Woods
Serviceberry
Snowberry
Sumac, Oakleaf
Syringa, Lewis
Willow, Arctic Blue
Willow, Coyote
Willow, Drummond

Deciduous Trees

Apple, Common Wild
Aspen, Quaking
Birch, Western Paper
Birch, Water
Cherry, Black
Chestnut, American
Cottonwood, Black
Maple, Sugar
Oak, Bur
Oak, Bur-Gambel
Poplar, Idaho-Hybrid
Walnut, Black

Goundcovers

Kinnikinnick
Horizontal Juniper

Milkweed

Milkweed, Showy

Camas

Camas, Common
Camas, Death
Camas, Great
Lily, Chocolate

University of Idaho
Center for Forest Nursery
and Seedling Research